

# DEPARTMENTS

## Emerging Technologies

### LINK: A Land Conservation Decision Support Tool

#### Introduction

Public and private land managers are in need of tools that ably incorporate landscape, species, and habitat relations into their conservation planning processes. A variety of geographic information system (GIS) applications facilitating the spatial aspects of land management are currently available and growing in number (e.g., Mladenoff et al. 1996, Andelman et al. 1999, Pattison et al. 2004, Carr and Zwick 2005, Fitzhugh 2005). Conservation agencies are increasingly taking advantage of these GIS capabilities by incorporating them into their operations (Bettinger 1999, Green 2001, Jansen et al. 2002). Despite these developments, there are few spatial decision support systems providing a link between a broad array of species and their habitat (Nelson et al. 2005), constraining integrated regional species management to a series of inchoate processes. The Upper Midwest Environmental Sciences Center has a long history of developing decision support tools that add rigor to environmental management (DeHaan et al. 2000, Fox et al. 2003, Nelson et al. 2005); *LINK* is the latest product in this history of software development.

#### Geographic information system tool linking species to habitat

*LINK* is a set of ArcGIS tools from the Environmental Systems Research Institute (ESRI, Redlands, California, USA) designed to map species–habitat patterns across a landscape. Any species that can be scored against land cover can be modeled with this tool, including birds, herpetiles, and mammals. Similar to previous tools developed at the Upper Midwest Environmental Sciences

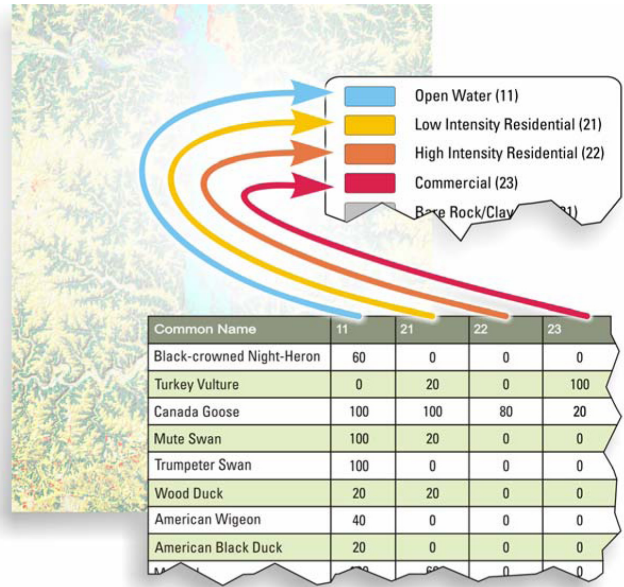


Fig. 1. *LINK* combines a species–habitat matrix with a raster source layer to provide mean potential species occurrence (PSO) and potential species richness (PSR) for the entire mapped spatial extent. Source layer (e.g., land cover) diversity is also provided (SDI). The metrics of occurrence and richness can be summarized based upon a zonal layer and restricted based upon species range maps.

Center (Fox et al. 2003), *LINK* uses species–habitat matrices to model potential species habitat and habitat diversity. These species–habitat matrices are user-contributed, and typically are created through expert opinion regarding species–habitat associations. What sets *LINK* apart from its predecessors, such as the Comprehensive Conservation Planning GIS Tool ([http://www.umesc.usgs.gov/management/dss/gis\\_tools\\_for\\_conservation\\_planning.html](http://www.umesc.usgs.gov/management/dss/gis_tools_for_conservation_planning.html)) is that it relates these user-contributed spe-

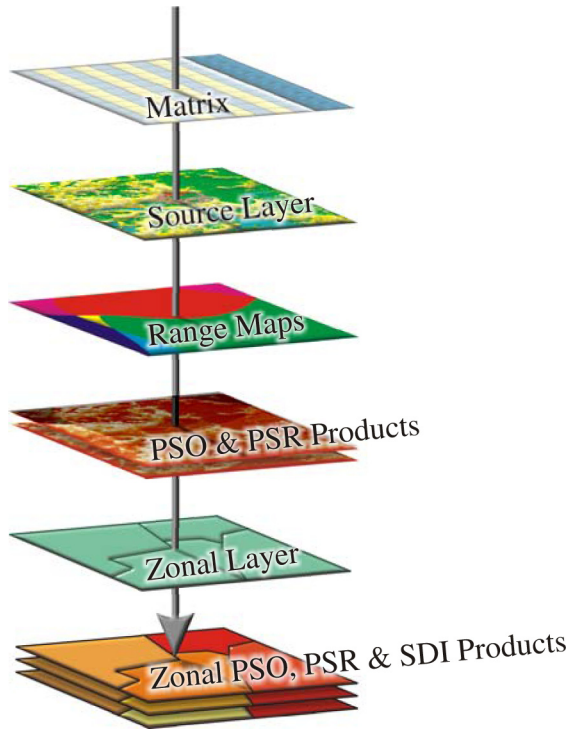


Fig. 2. A species  $\times$  habitat matrix represents the association of species to habitat. In this example the source layer habitat is based upon a land cover classification.

cies–habitat matrices to raster data sources such as land cover. Raster data allows *LINK* to model habitat associations over a much larger spatial extent (e.g., counties, states/provinces, regions) than its vector-based antecedents.

*LINK*'s main purpose is to make comparisons of conservation potential between management units and the surrounding landscape. It does this by summarizing potential species richness, mean potential species occurrence, and habitat diversity for any combination of taxa identified by the user. Three main data sources are needed to run a *LINK* query: a species–habitat matrix, source layers, and (optionally) zonal layers (Fig. 1).

A species–habitat matrix relates, for each habitat type within the raster source layer, a score representing species–habitat suitability (Fig. 2). Species–habitat suitability ranges from 0 (little to no value as habitat)

to 100 (prime habitat). A Relationship Manager allows the user to create an association between matrices and source layers, and between source layers and zonal layers.

The source layer is a raster spatial data layer containing landscape information for species listed in the matrix. The source layer must be an integer ESRI Grid (e.g., National Land Cover Dataset 1992 <<http://landcover.usgs.gov/natl/landcover.asp>>, Land Cover of Canada 1995 <[http://ccrs.nrcan.gc.ca/optic/coarse/boreal/land\\_e.php](http://ccrs.nrcan.gc.ca/optic/coarse/boreal/land_e.php)>, CORINE Land Cover Database <<http://terrestrial.eionet.eu.int/CLC2000>>). A zonal layer is a vector (polygonal) spatial data layer used to divide the landscape into units of comparison and must be in an ESRI Shapefile format. Bird Conservation Regions, counties or townships within a state or province, or management units within a refuge or conservation area, are examples of appropriate zonal layers.

### Queries

*LINK* relates values contained in the species–habitat matrix to the source layer, allowing the generation of several indices of potential habitat (Table 1). These indices include mean potential species occurrence and potential species richness, and may be calculated for an individual species or a group of species. If the user chooses, the program can summarize these indices for each zone within a zonal layer. A zonal layer is not required to run a *LINK* query, but summarizing habitat information by zone helps to illustrate the distribution of habitats across a region; the use of a zonal layer provides a unit-by-unit evaluation of potential habitat within the area of interest.

### Limiting avian species predictions to range boundaries

Due to interest within the Fish and Wildlife Service Migratory Birds Program, we developed an extension to the *LINK* tool that incorporates bird species ranges into models of habitat suitability (Fig. 3); in this way, avian species are modeled only for those areas in their

Table 1. Examples of tabular, charted, and mapped output available from *LINK*.

Output measure	Description
Number of species queried	Number of species queried using the <i>LINK</i> Query dialog.
Potential species richness (PSR)	Number of queried species having a matrix score >0 for the source grid class. The possible range of values is 0 to <i>n</i> , the number of species queried.
Mean potential species occurrence (PSO)	Mean matrix score of queried species for the grid class. The possible range of values is 0–100.
Sum of potential species occurrence	Sum of the matrix scores for the source grid class. The possible range of values is 0 to <i>n</i> , the number of species queried × 100.
Area-weighted mean PSO Score	Summary for each queried species for extent of the source layer. Values can range from 0 to 100.
PSR by zone	Summary statistics of potential species richness for each zone of the zonal layer.
PSO by zone	Summary statistics of potential species occurrence for each zone of the zonal layer.
SDI by zone	Simpson's diversity index of source layer classes possessing a mean PSO > 0. Values range from 0–1; higher values indicate greater diversity of habitat. Nonhabitat is excluded.

range in which they are believed to occur. This range limitation emphasizes that the *LINK* tool models potential rather than occupied habitat. As part of this extension, we incorporated ranges for all birds in the Western Hemisphere, as provided in the collection of digital distribution maps by NatureServe (Ridgely et al. 2003) and the Breeding Bird Survey (Sauer 2004). The NatureServe ranges act as a 0/1 binary mask of the predictions, allowing predicted habitat to show only for areas within the range of the species, whereas the Breeding Bird Survey ranges act as weights to the predictions, weighing predicted species occurrence by the scaled species predicted abundance.

### An example implementation of *LINK*: priority birds in Minnesota

Currently, the tool is loaded with source layers (National Land Cover Dataset 1992), various zonal layers, and a species–habitat matrix developed for birds of the Prairie–Hardwood Transition Bird Conservation Region. It is easy, however, for users to insert their own species–habitat matrices, source layers, and zonal layers into *LINK* using the import tool developed for such a purpose.

As an example of how *LINK* may be used, we cal-



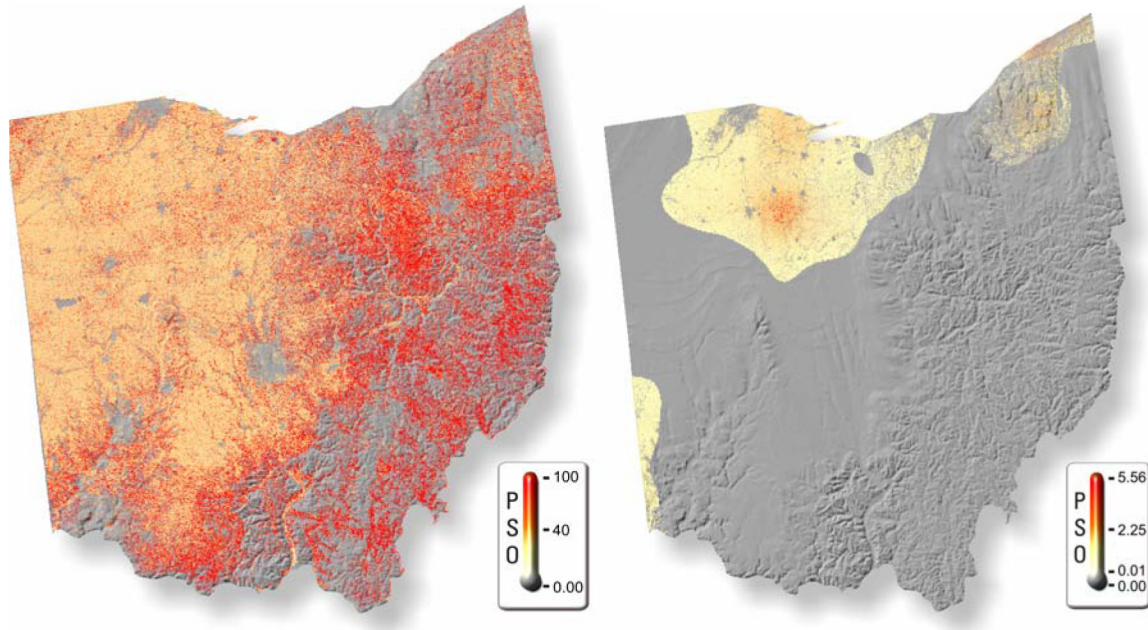


Fig. 3. An extension to *LINK* limits predictions of suitable avian habitat to those areas in which species are known to range. The image on the left is a prediction of Upland Sandpiper occurrence for Ohio, whereas the image on the right is the same prediction after limiting the prediction to the area within the species range, weighted by the Breeding Bird Survey's predicted abundance. The northeastern population has high predicted occurrence, but low observed abundance according to the Breeding Bird Survey, and therefore the area, after limiting by range, receives a reduced predicted occurrence.

culated mean potential species occurrence and potential species richness for all regularly breeding United States Fish and Wildlife Service Priority 1 bird species in Minnesota (Table 2), summarized the results by county (zonal layer), and weighted the summary by the Breeding Bird Survey range maps (Fig. 4).

This summary, which took approximately 10 minutes of processing time, suggests that the priority birds as a whole in Minnesota are concentrated in a band in the north-central portion of the state. This area consists of a transition between the boreal hardwood and prairie-hardwood ecoregions, a zone possessing the mix of habitats that these ecologically disparate species require. Inferences for individual species suggest Black-billed Cuckoo, Upland Sandpiper, Golden-winged Warbler, and Wood Thrush exhibit the greatest potential occurrence within the state and are predicted to occur over a fifth of the area. Conversely, Acadian

Flycatcher and Peregrine Falcon are expected to occur on <1% of the area of the state. With this information, management authorities may now devote their conservation efforts to a particular subset of counties as opposed to the entire set of counties within the state, concentrating scarce conservation funds on focused areas.

### Summary

*LINK* is a spatial decision support system allowing natural resource managers to draw inferences regarding the combined distribution of species over large areas. *LINK* is designed to operate within the ESRI ArcGIS 9.X platform with the Spatial Analyst extension, uses raster-based source layers, is most applicable to relatively large geographic areas (e.g., states, counties, regions), and produces output depicting mean potential species occurrence and potential species richness

Table 2. Mean predicted species occurrence (area-weighted mean PSO) of regularly breeding Minnesota birds identified as Priority 1 species for the upper midwestern United States. Occurrence values vary between 0 and 100. Black-billed Cuckoo is predicted to occur across one-quarter of the state, whereas the Blue-winged Warbler is predicted to occur in one-tenth of the state. Peregrine Falcons are predicted to occur on <1% of the area of the state.

Common name	Species	Area-weighted mean PSO
Black-billed Cuckoo	<i>Coccyzus erythrophthalmus</i>	25.68
Upland Sandpiper	<i>Bartramia longicauda</i>	24.63
Golden-winged Warbler	<i>Vermivora chrysoptera</i>	24.61
Wood Thrush	<i>Hylocichla mustelina</i>	22.64
Dickcissel	<i>Spiza americana</i>	15.79
Sedge Wren	<i>Cistothorus platensis</i>	15.28
Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>	15.24
Bobolink	<i>Dolichonyx oryzivorus</i>	12.78
Cerulean Warbler	<i>Dendroica cerulea</i>	12.03
Blue-winged Warbler	<i>Vermivora pinus</i>	10.25
Black Tern	<i>Chlidonias niger</i>	9.54
Marbled Godwit	<i>Limosa fedoa</i>	9.51
Loggerhead Shrike	<i>Lanius ludovicianus</i>	6.37
Short-eared Owl	<i>Asio flammeus</i>	5.93
Henslow's Sparrow	<i>Ammodramus henslowii</i>	2.70
Common Tern	<i>Sterna hirundo</i>	1.65
Wilson's Phalarope	<i>Phalaropus tricolor</i>	1.28
Acadian Flycatcher	<i>Empidonax virescens</i>	0.75
Peregrine Falcon	<i>Falco peregrinus</i>	0.23

for each grid cell within the mapped extent, or summarized per zone or management unit. Any species that can be scored against habitat can be modeled with this tool. The software comes with an extensive help section.

*LINK* is most useful as a tool to generate and test quickly hypotheses regarding the potential conservation value of particular habitats or particular zones within a broader geospatial extent. It may be especially useful in a workshop setting attended by a group of planners, biologists, and decision makers, as the speed of the tool makes it amenable to answering questions of potential focus areas on-the-fly. It is not meant to be a sub-

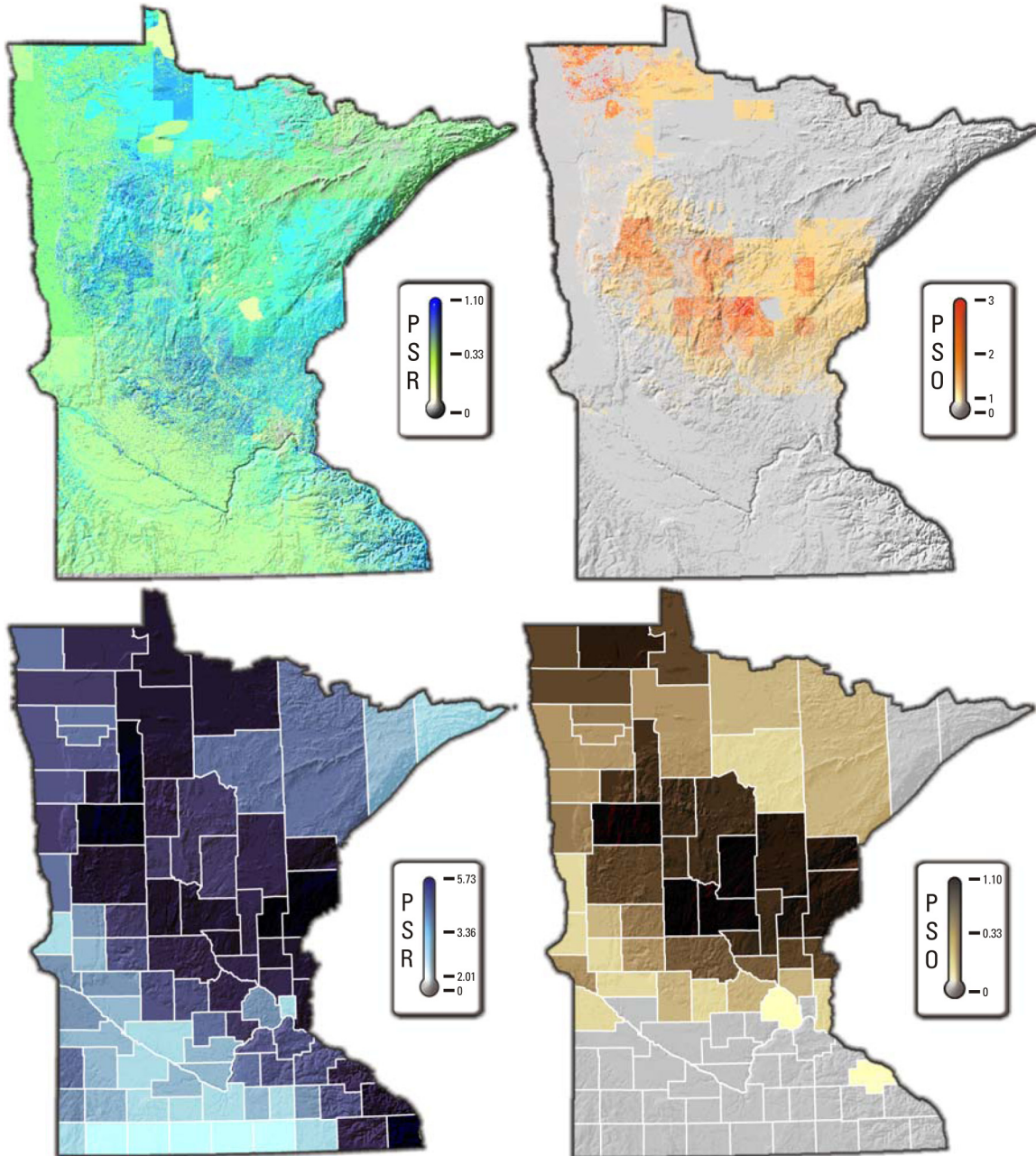


Fig. 4. Potential Species Richness (PSR), Mean Potential Species Occurrence (PSO), and PSR and PSO summarized by the zonal layer County. The assemblage of Priority 1 species for the upper midwestern United States is most rich in a band running from north to south, whereas species occurrence is greatest in the central portion of the state; this area demarcates the Boreal Hardwood north from the Prairie–Hardwood Transition in the south.



stitute for complex statistical single-species models, especially those designed to evaluate habitat quality or predict the effect of specific management practices.

Users should understand that the validity of the *LINK* products are directly constrained by (1) the accuracy, resolution, and classification categories of the geospatial data set (land cover), and (2) the quality and validity of the user-supplied habitat-association matrix. Given those constraints, however, *LINK* is potentially a useful tool filling the void between geospatial prioritizing guesswork and expensive modeling processes that may or may not produce more accurate results. It is also very useful in the way it can be used to summarize habitat value across multiple species, priority species, or other focus groups. Because it weights the potential value of habitats for each species in the species-habitat matrix, *LINK* is more informative than simple presence/absence models applied to broad habitat categories, such as those represented by the National Land Cover Dataset.

Interested parties may download this tool, along with demonstration data and a user's help manual, from the Internet at [http://www.umesc.usgs.gov/management/dss/bird\\_conservation\\_tools\\_link.html](http://www.umesc.usgs.gov/management/dss/bird_conservation_tools_link.html) or by sending an e-mail to [tfox@usgs.gov](mailto:tfox@usgs.gov), with your shipping address and the versions of ArcGIS (8.x or 9.x) and Windows operating system that you are using.

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## Literature cited

Andelman, S., I. Ball, F. Davis, and D. Stoms. 1999. SITES V 1.0: an analytical toolbox for designing ecoregional conservation portfolios. The Nature

Conservancy, Alexandria, Virginia, USA.

Bettinger, P. 1999. Distributing GIS capabilities to forestry field offices. *Journal of Forestry* 97:22-26.

Carr, M., and P. Zwick. 2005. Using GIS suitability analysis to identify future land use conflicts in North Central Florida. *Journal of Conservation Planning* 1. <http://www.journalconsplanning.org/2005/volume1/issue1/carr/manuscript.pdf>

DeHaan, H. C., T. J. Fox, C. E. Korschgen, C. H. Theiling, and J. J. Rohweder. 2000. Habitat needs assessment GIS query tool for the upper Mississippi River system: user's manual. Prepared for U.S. Army Corps of Engineers, St. Louis, Missouri, USA.

FitzHugh, T. W. 2005. GIS tools for freshwater biodiversity conservation planning. *Transactions in GIS* 9:247-263.

Fox, T. J., J. J. Rohweder, K. P. Kenow, C. E. Korschgen, and H. C. DeHaan. 2003. Geographic information system tools for conservation planning: user's manual. U.S. Geological Survey, Biological Resources Discipline Information and Technology Report USGS/BRD/ITR-2003-0005.

Green, D. S. 2001. GIS Strategic Plan for managing Geographic Information Systems (GIS) and spatial data in the U. S. Fish and Wildlife Service, with the focus on FY2001-2004. U.S. Fish and Wildlife Service, Arlington, Virginia, USA. [http://www.fws.gov/data/gisplan\\_fws.html](http://www.fws.gov/data/gisplan_fws.html)

Jansen, M., M. Judas, and J. Saborowski, editors. 2002. *Spatial modelling in forest ecology and management: a case study*. Springer Verlag, Berlin, Germany.

Mladenoff, J. D., G. E. Host, J. Beoder, and T. R. Crow. 1996. LANDIS: a spatial model of forest landscape disturbance succession and management. Pages 175-179 in M. F. Goodchild, L. T. Steyaert, B. O. Park, C. Johnston, D. Maidment, M. Crane, and S. Glendinning, editors. *GIS and environmental modeling: progress and research issues*. GIS World, Fort Collins, Colorado, USA.

Nelson, J. C., T. J. Fox, M. G. Knutson, J. R. Sauer, and W. E. Thogmartin. 2005. Regional bird conservation internet mapping tool takes flight with GIS.

ArcNews 27:21. <<http://www.esri.com/news/arc-news/summer05articles/regional-bird.html>>

Pattison, D., D. dosReis, and S. Hamilton. 2004. An inventory of GIS-based decision-support tools for MPAs. Prepared by the National Marine Protected Areas Center in cooperation with the National Oceanic and Atmospheric Administration Coastal Services Center. <[http://www.mpa.gov/virtual\\_library/Publications/FINAL\\_Decision%20Sup%20Rpt.pdf](http://www.mpa.gov/virtual_library/Publications/FINAL_Decision%20Sup%20Rpt.pdf)>

Ridgely, R. S., T. F. Allnutt, T. Brooks, D. K. McNicol, D. W. Mehlman, B. E. Young, and J. R. Zook. 2003. Digital Distribution Maps of the Birds of the Western Hemisphere, version 1.0. NatureServe, Arlington, Virginia, USA. URL: <<http://www.natureserve.org/getData/birdMaps.jsp>> (for version 2.1 of the bird distribution maps).

Sauer, J. R. 2004. The North American Breeding Bird Survey, Results and Analysis 1966–2003. Version 2004.1. Patuxent Wildlife Research Center, Laurel, Maryland, USA. URL: <[http://www.mbr-pwrc.](http://www.mbr-pwrc.usgs.gov/bbs/geographic_information/geographic_information_products_.htm)

[usgs.gov/bbs/geographic\\_information/geographic\\_information\\_products\\_.htm](http://www.mbr-pwrc.usgs.gov/bbs/geographic_information/geographic_information_products_.htm)>

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