land

IMPACT FACTOR 3.2

CITESCORE 4.9

Article

# ANCHOR: An Opportunity to Change Landscape Connectivity Networks and Conservation Delivery At-Scale in the U.S.

Bridgett E. Costanzo, E. Jean Brennan, Elissa M. Olimpi and Justin P. Suraci

Special Issue
Species Vulnerability and Habitat Loss II

Edited by
Dr. Michela Balestri and Dr. Marco Campera

MDPI

https://doi.org/10.3390/land14020385

*land*

MDPI

*Article*

# ANCHOR: An Opportunity to Change Landscape Connectivity Networks and Conservation Delivery At-Scale in the U.S.

**Bridgett E. Costanzo [1,*], E. Jean Brennan [2], Elissa M. Olimpi [3] and Justin P. Suraci [3]**

[1] USDA Natural Resources Conservation Service, Richmond, VA 23229, USA
[2] Independent Researcher, Auberry, CA 93602, USA; jean.brennan@landscapepartnership.org
[3] Conservation Science Partners, Inc., Truckee, CA 96161, USA; elissa@csp-inc.org (E.M.O.); justin@csp-inc.org (J.P.S.)
* Correspondence: bridgett.costanzo@landscapepartnership.org or bridgett.costanzo@usda.gov

**Abstract:** Connectivity modeling has been a tool available to the conservation community since the 1980s that guides our responses to habitat fragmentation. While the sophistication of computer modeling continues to grow, on-the-ground delivery remains challenging and lacks urgency. We present an approach to scale up delivery and do so within effective timeframes. The approach, termed ANCHOR (Areawide Networks to Connect Habitat and Optimize Resiliency), is grounded in connectivity science but executed in a manner that is flexible, expandable, and measurable. ANCHOR goes beyond the traditional protected area focus for establishing connected biomes to maximize the contributions of existing public lands and expand private landowner participation. The approach is applied using an umbrella species to represent a faunal group and/or multiple taxa to deliver co-benefits of landscape connectivity. Public lands receive connectivity rankings that are then used to engage potential connectivity partners who commit land units and collectively monitor improvements in habitat quality and landscape resiliency. The ANCHOR approach can guide unprecedented participation across agencies and departments to create public lands networks, while private and corporate lands establish landscape connections. To illustrate the approach, we present an example of native grasslands conservation in the central and eastern U.S. and an emerging partnership with the Department of Defense.

**Keywords:** connectivity; native grasslands; circuit theory; Omniscape; Northern bobwhite; areawide network; ANCHOR; large landscape

check for updates

Academic Editors: Michela Balestri and Marco Campera

Received: 14 January 2025
Accepted: 30 January 2025
Published: 12 February 2025

**Citation:** Costanzo, B.E.; Brennan, E.J.; Olimpi, E.M.; Suraci, J.P. ANCHOR: An Opportunity to Change Landscape Connectivity Networks and Conservation Delivery At-Scale in the U.S. *Land* **2025**, *14*, 385. https://doi.org/10.3390/land14020385



## 1. Introduction

Over the past few decades, the field of connectivity conservation [1–5] has evolved rapidly thanks to advances in computational technology and the rapid dissemination of scientific information through open-source software. As a result, conservationists have been able to design more forward-looking conservation plans, scalable at the ecosystem-level. But fewer plans have been fully actualized on a range-wide scale. Failure in this context is less about 'the strength of the science' and more about 'the weakness in creating a network' of landholders willing to commit to a common plan and implementation. This paper presents a new coordinated delivery approach to overcome this impediment. The underlying approach delivers conservation through an area-wide network termed ANCHOR (Areawide Networks to Connect Habitat and Optimize Resiliency) to address large-scale conservation objectives, using representative or indicator species models combined with larger landscape conservation models of connectivity and then ranking range-wide individual potential connection sites to facilitate partnership development.

The pilot used to demonstrate the ANCHOR approach focuses on declining grassland ecosystems in the eastern and central U.S., an area that has experienced loss or degradation of 80–90% and is considered the most endangered biome in North America [6–10]. Grassland birds are the most severely declining avian group [11]. The target species initially used in the modeling elements of the ANCHOR approach is the Northern bobwhite (*Colinus virginianus*, hereafter 'bobwhite').

Bobwhites are an indicator of the grassland biome as year-round residents in open habitats, avoiding mature woodlands and most numerous in patchwork areas of fields, early successional forests, pastures, rangelands, and southern pine/oak savannas. It is considered a facultative grassland species as it also occurs in shrubland and depends on woody cover in the winter to prevent snow from reaching the ground and blocking its foraging habitat [12,13]. The species ranges across the southern U.S. from Florida and Texas, north to Massachusetts and southern Ontario, and west to the Great Plains states of Iowa, Kansas, Nebraska, Oklahoma, Texas, and New Mexico. Bobwhite acts as an umbrella species for at least nine other co-occurring bird species found in grasslands and shrublands including Bell's Vireo *(Vireo bellii),* Dicksissel *(Spiza americana*), and Grasshopper Sparrow *(Ammodramus savannarum),* which are listed as species of conservation concern [14]. Bobwhite population trends have paralleled the loss of grasslands across its range, exhibiting a sharp 83% decline over recent decades. The rates of population decline are greater in the northeast and southeast U.S. relative to the western and southwestern regions. Habitat loss and fragmentation are considered leading causes of global declines and extinctions of species, and these factors also threaten all quails on western rangelands [15–18]. The population structure has been described as a metapopulation [19].

Selecting bobwhite to pilot the ANCHOR approach was strategic (see Box 1) as populations continue to decline due in part to the "disconnect between the science of quail management and the broadscale application of quail management" [20–22]. But most recently Natural Resources Conservation Service's (NRCS) Working Land for Wildlife (WLFW) has teamed up with researchers and non-profit conservation organizations including Quail Forever to formulate and publish the Northern Bobwhite, Grasslands, and Savannas Framework [23]. The goal of the framework is to deliver technical and financial assistance to implement conservation practices on private lands across 25 states, totaling 2.8 M hectares (ha) (7 M acres) of applied conservation practices in the first five years (see Section 4). The challenge was how to prioritize resource allocation to accelerate outcomes. The framework provides a platform for testing the ANCHOR approach: defining area-wide connected habitat based on at-scale modeling, then ranking specific sites for degree of connectivity across diverse landholdings.

**Box 1.** Target species characteristics that make the Northern bobwhite strategic for application of the ANCHOR approach.

Species is:
(a) closely associated with various aspects of the structural and species composition that make up the biome to meet habitat needs throughout its life cycle (e.g., nesting, brood rearing, forage, and escape cover),
(b) well studied (e.g., its basic ecology, habitat requirements and management are well researched and largely understood),
(c) non-migratory (e.g., not exposed to environmental policies across nations outside the management control of conservation planning),
(d) of tremendous interest to multiple stakeholders (e.g., in the case of a game species such as the bobwhite has secured dedicated state game funding and wildlife management efforts for decades), and
(e) already a focus of conservation planning (see References [12–23]).

The ANCHOR approach can be applied anywhere and consists of four steps. First step is to develop the integrated species-habitat models at range-wide scales for umbrella or target species, paired with omnidirectional connectivity models that further assess whether connectivity opportunities are distributed in a diffuse or channelized pattern across an ecosystem. The second step uses model outputs to rank land units on public and private lands that could serve as habitat "anchors," with final decisions being made by landholders. The third step is to engage partners at the national, regional, and local levels to join the ANCHOR network by committing to invest in conservation actions at sites ranked highest for connectivity value. The fourth step is an on-going effort in monitoring biotic and abiotic responses at the site level, as well as measuring network-wide improvements in habitat connectivity over time. Each network will identify how to assess conservation outcomes as these will differ greatly, for example between terrestrial and aquatic networks. Improvements in system connectivity will be measured using a combination of graph theory combined with other appropriate methods and stakeholder collaboration.

The approach can be applied to a single priority target species or to an umbrella species to achieve benefits for a faunal group (in our example, declining grassland birds). Benefits can also be "stacked" by combining species models to assess co-benefits, including for more than one taxonomic group (e.g., birds and pollinators). Lastly, it can be expanded geographically by the selection of a suite of species whose distribution models guide connectivity delivery for larger areas (e.g., North America).

As the conservation delivery starting point, the output list of relative site rankings identifies specific sites and management agencies that staff can engage to explore willingness to partner and commit "anchors" toward construction of an ANCHOR network. Rather than promoting a single map of land connectivity targets, the network formation is guided and the resulting connectivity map fluidly defined from among the ranked linkage options. In this manner, we are simultaneously building both a social and land-based connectivity network. This adaptive approach has many practical benefits. First, presentation of static maps to public audiences has been found to alarm communities who fear forced participation either through regulation or land "takings" to achieve conservation objectives and this often derails delivery of the foundational connectivity science. Secondly, by defining the area-wide network flexibly based on land managers' decisions (i.e., to opt-in or opt-out), we create a stronger sense of shared vision among connectivity partners where participants are more willing to manage the habitat to sustain the populations and linear connections—i.e., "feasible connectivity." ANCHOR delivers flexibility, which is not only critical from a conservation delivery standpoint, but is also, as emerging science suggests, increasingly important from an ecological perspective with changing climate conditions and land use transformation [24–27]. In this manner, the ANCHOR approach is systematic, flexible, expandable, and measurable.

## 2. Materials and Methods

The ANCHOR approach employs several linked models to define habitat quality and connectivity. The first model produced a habitat suitability surface for the target species (Northern bobwhite). This surface was used to define a resistance layer for the second model to generate species-specific connectivity using circuit theory. Connectivity is assessed across federal land management units to evaluate their relative ranking in terms of connectivity between units, modeling ecological flow to evaluate the potential contribution each unit can offer toward the larger conservation objective (grassland biome conservation).

Modeling Population and Habitat Suitability: The University of Georgia's Martin Gamebird and Management Ecosystem Laboratory (GAME) Lab modeled the distribution of high-quality habitats across grassland ecosystems by creating a habitat suitability model using location datasets across the Northern bobwhite range from two sources: (1) eBird data [28,29] consisting of count data from Cornell Lab of Ornithology's community science platform from the October 2022 release of the eBird Basic Dataset (EBD) [30], and (2) structured survey data collected by the United States Geological Survey (USGS) as part of the annual Breeding Bird Survey (BBS) [31] performed in 2018, 2019, and 2021. Data were first filtered to ensure that non-detections could be inferred and spatial subsampling applied to mitigate spatial biases in sampling. Equal area hexagonal grids were defined across the Northern bobwhite range, with ~5 km between the centroids of adjacent hexagons, using the Discrete Global Grids R package *dggridR* ver. 2.0.4 [32].

A suite of covariates was employed to model the impacts of environmental variation and land use on habitat suitability for bobwhite. These covariates were thematically grouped into those that described topography, climate, land cover, land use, and disturbance in the final model. Land cover variables that captured the mean proportional cover of broad vegetation classes were hypothesized to affect bobwhite abundance and a gradient analysis was used to quantify their spatial heterogeneity. Proportional cover variables, describing the proportional cover of trees, shrubs, perennial forbs and grasses, and bare ground, were generated using the Rangeland Analysis Platform (RAP) land cover datasets (Version 3; [33]) spanning 2016 to 2021. The percentage cover (within a 5 km radius of each pixel) of lands classified as row-crop and pasture-based agriculture were calculated based on the National Land Cover Dataset (NLCD released for 2016 and 2019) [34] averaged across the two years. Considering the different detection processes unique to each of the input datasets (BBS and eBird), the integration of a joint abundance likelihood process was achieved using a statistical hierarchical Bayesian framework [35–40] to fit the model. The ultimate output of this suitability model shows an estimate of the relative density of bobwhite in each grid cell [41].

Land Management Units: To illustrate the ANCHOR approach to landownership we present results for the top ranked federal lands; a subset of the more extensive dataset of federal land holdings representing Department of Defense (DoD) military installations, Army Corps of Engineers (ACE) lands surrounding reservoirs, National Park Service (NPS) lands designated as Park Units, U.S. Forest Service (USFS) National Forests and Grasslands, and Fish and Wildlife Service (FWS) National Wildlife Refuges and Waterfowl Production Areas. Polygon shapefiles representing the boundaries of DoD, ACE, and state lands were supplied by agency contacts and polygon shapefiles for all other federal lands were obtained via publicly available data portals. The national park polygons were from the NPS Boundaries [42] dataset, and we selected only those where the "Unit-Type" attribute was "National Park". The national forest polygons were from the USFS National Forests Dataset (USFS Proclaimed Forests) [43]. The national grasslands polygons were from the USFS dataset of National Grassland Units [44]. The national wildlife refuge polygons were from Environmental Systems Research Institute, Inc. (ESRI) Federal User Community dataset [45]. The waterfowl production area polygons were from ESRI's U.S. Federal dataset Waterfowl Production Areas [46]. Only polygons that were within the boundaries of the continental United States were included in the analysis. All polygons larger than 670 hectares (1500 acres) were imported into Google Earth Engine for processing.

Species-specific Connectivity: The habitat suitability surface inputs were used to develop a circuit-theory based connectivity model using the Omniscape algorithm implemented in the Omniscape.jl software package in Julia (ver. 1.9). Omnidirectional connectivity allows all points on the landscape to serve as potential sources and targets of animal movement [47,48]. The algorithm uses a moving window approach, iteratively treating every pixel in the source strength layer with a value greater than zero as a target for electrical current and connecting that pixel to all other non-zero pixels within the moving window radius, which serve as current sources. The moving window size thus sets the maximum distance between movement start and end points. A moving window radius of 250 kilometer (km) was used, representing the potential movement of bobwhite over several generations. This moving window radius was determined to be appropriate given both the relatively coarse nature of raster inputs (5 km $\times$ 5 km) and the objective of identifying important areas for conserving or enhancing bobwhite connectivity over large spatial scales (i.e., regionally rather than locally important connectivity areas).

Modeling Connectivity: Connectivity is estimated as current flow, proportional to the expected probability of movement through a given location. Three connectivity values were calculated for each land unit. First, average connectivity values were calculated across all pixels within each polygon. Second, average current flow was weighted by polygon area, with larger polygons weighted more heavily than smaller polygons (i.e., area-weighted connectivity). This was achieved by splitting all polygons into quartiles based on acreage and multiplying the polygon's average connectivity by a correction factor of 0.25, 0.50, 0.75, or 1, depending on the quartile assigned to each polygon. Polygons of a smaller size were assigned a lower correction value and polygons of a larger size were assigned a higher correction value. Third, the local connectivity ratio was calculated as the ratio of the land unit's average connectivity and the average connectivity within the surrounding landscape (the average connectivity value across all pixels within a 10 km buffer area). A buffer distance of 10 km surrounding each land unit was selected based on bobwhite dispersal distances and relevance to private lands management around each public land unit. This metric was designed to add additional context when considering private lands conservation around a public land "anchor site." A local connectivity ratio greater than 1 indicates that the connectivity value of the land unit is greater than that of the surrounding local area, suggesting that the unit may provide important connectivity habitat in an area of otherwise low habitat connectivity unless we additionally focus on private landowners in the network. Ratios less than 1 indicate that the surrounding landscape has a higher connectivity value than the land unit itself, potentially indicating a need for restoration on the public land unit to increase habitat connectivity.

Modeling derived two input layers for each connectivity model: source strength (the predicted probability or intensity of movement from a given location) and landscape resistance (the difficulty an animal experiences moving through each pixel on the landscape). For both input layers, we used the habitat suitability surface, filtering out the 99th percentile of predicted values (502 bobwhite/25 km$^2$) to remove outlier values that would otherwise skew the distribution of predicted bobwhite relative densities. To derive source strength, a natural logarithm transformation to habitat suitability was applied to further highlight potential variation in abundance, and then the layer rescaled to have values ranging from 0 (no source strength) to 1 (maximum source strength) using a standard min-max normalization based on the range of values within the extent of the model (e.g., range-wide or within specific regions, both were assessed). To generate resistance layers a negative exponential function was used following the work of Keely and associates [49] to transform the abundance layer into landscape resistance.

Ecological Connectivity Flow value: This assessment was based on normalized current flow, an output of the Omniscape.jl algorithm calculated as a function of current flow and flow potential, where flow potential represents the current flow expected under null resistance conditions (i.e., current flow with no barriers or restrictions) [50,51]. Normalized current flow was calculated by dividing current flow by flow potential, with a value assigned to each pixel across the conterminous United States [52]. This normalized current flow dataset was then clipped to the extent of each unit buffer polygon and the average normalized current flow value was calculated for each polygon. The global standard deviation of all units was calculated and compared to each within-installation normalized current flow average.

## 3. Results

Modeling Population and Habitat Suitability: The range-wide habitat suitability model showed substantial variation in suitability for bobwhite across the model domain. High suitability was most evident in southern portions of the species' range particularly throughout large portions of Florida, southern Georgia, the southern portions of the Gulf States, and southern Texas to central Oklahoma. Other modeled areas of high suitability included areas along the western slopes of the Appalachian Mountains and some smaller areas along the Nebraska-Kansas border. Suitability was predicted to be low along the westernmost portions of the model range including much of New Mexico and Colorado, at the northern edge of the model domain and throughout the Midwest and Northeast (see Figure 1).

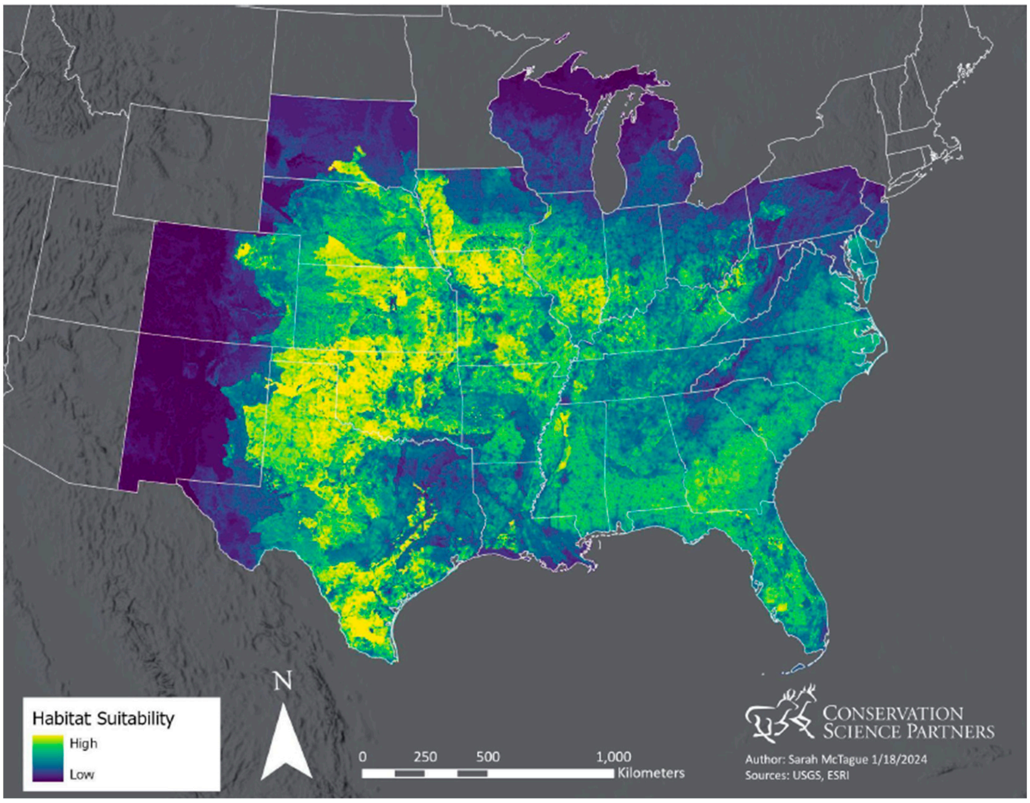


**Figure 1.** Map of habitat suitability for Northern bobwhite based on a hierarchical Bayesian model. Suitability is represented as the relative density of birds in each 5 km × 5 km pixel.

Ecological Connectivity and Landscape-scale Conservation: The ANCHOR uses selected species-habitat suitability model(s) to supply "resistance layers" for the Omniscape connectivity assessments. The Omniscape model outputs were then summarized within polygons representing public land units to quantify the relative connectivity value of each unit within and across ownerships. Each land management unit was assessed in two ways to better capture the full context of connectivity features. First, the average current flow value across all pixels within each land unit polygon was calculated, allowing for the relative ranking of installations based on the overall level of connectivity provided (see Figure 2). Secondly, each management unit was differentiated based on categories of relative flow, i.e., whether current flow across the footprint of a given installation was diffused, channelized, or impeded (see Figure 3).

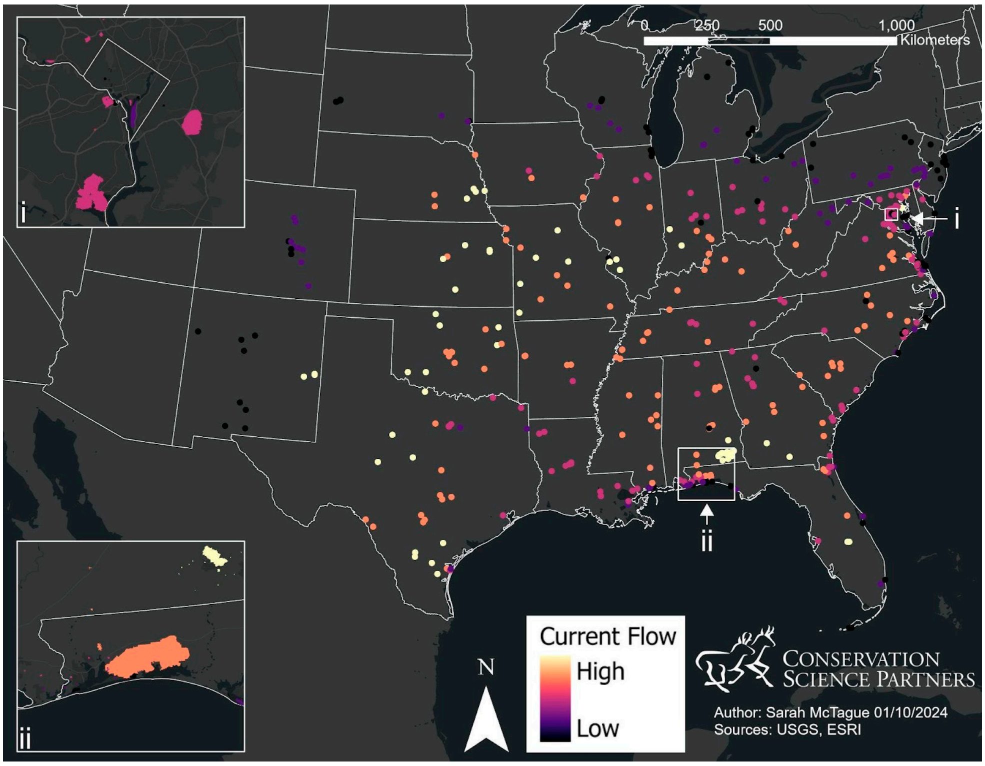


**Figure 2.** Average bobwhite connectivity value for each DoD installation across the bobwhite range. Each point represents the centroid of an installation, and the color scale represents the average value of current flow within the installation boundaries. Inset maps represent the actual boundaries of DoD installations within Washington, D.C. (**i**) and Florida's panhandle (**ii**).

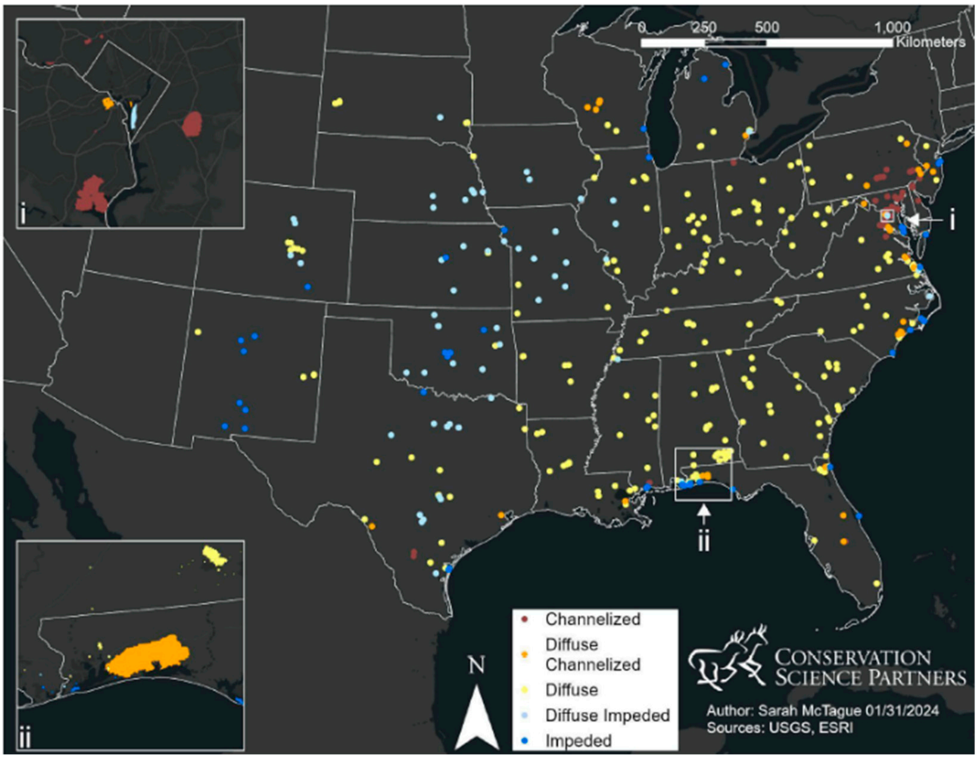


**Figure 3.** Relative flow type for DoD installations, based on the bobwhite range-wide connectivity model. Each point represents the centroid of an installation, and the colors represent the relative flow category. Insert maps represent the actual boundaries of DoD installations within Washington, D.C. (**i**) and Florida's panhandle (**ii**).

Potential Contributions to Landscape-scale Conservation: Modeling produced a national-level analysis of select federal lands. A subset of the land holdings (only the top 10 ranked land units) is presented in this paper in Tables 1–3, providing a summary of federal lands for illustrative purposes. Importantly, these summary data are not intended to be compared across agencies but rather within an agency. Figure 4 illustrates information to assist an agency in visualizing the relative ranking based on the bobwhite range-wide connectivity model across DoD lands to facilitate decision-making.

**Table 1.** Top 10 ranked areas by agency and their size in area (ha). Ranking scores were weighted by area size as an indicator of potential carrying capacity of the target species (Northern bobwhite).

| | DoD ^ | ACE | NPS | FWS | USFS |
|---|---|---|---|---|---|
| Top Ranked | Total Area (Hectares) | Total Area (Hectares) | Total Area (Hectares) | Total Area (Hectares) | Total Area (Hectares) |
| 1 | 3196 | 9023 | 16,835 | 23,841 | 1,232,227 |
| 2 | 41,111 | 7846 | 33,306 | 165,902 | 603,953 |
| 3 | 37,961 | 11,452 | 28,976 | 18,423 | 550,615 |
| 4 | 25,090 | 9606 | 37,838 | 12,975 | 1,102,445 |
| 5 | 23,759 | 13,964 | 4411 | 19,569 | 296,473 |
| 6 | 43,152 | 17,225 | 27,681 | 18,556 | 33,953 |
| 7 | 23,555 | 10,530 | 11,776 | 30,234 | 305,052 |
| 8 | 24,960 | 8429 | 49,574 | 16,521 | 388,296 |
| 9 | 56,098 | 3277 | 10,805 | 8607 | 13,395 |
| 10 | 73,526 | 4045 | 5059 | 20,478 | 345,480 |

^ Department of Defense (DoD), Army Corps of Engineers (ACE), National Park Service (NPS), Fish and Wildlife Service (FWS), and U.S. Forest Service (USFS).

**Table 2.** Area-weighted connectivity values for Northern bobwhite within the top ranked land units for each federal agency. All values are relative and are not intended to be compared across agencies but rather within an agency.

| | DoD ^ | ACE | NPS | FWS | USFS |
|---|---|---|---|---|---|
| Top Ranked | Average Connectivity | Average Connectivity | Average Connectivity | Average Connectivity | Average Connectivity |
| 1 | 20.71 | 10.09 | 11.73 | 9.76 | 7.95 |
| 2 | 8.78 | 9.09 | 7.71 | 7.3 | 6.79 |
| 3 | 8.62 | 8.94 | 7.45 | 7.13 | 5.89 |
| 4 | 8.48 | 8.73 | 7.05 | 9.17 | 5.77 |
| 5 | 8.36 | 8.61 | 9.12 | 6.71 | 7.57 |
| 6 | 8.31 | 7.96 | 6.17 | 6.7 | 7.08 |
| 7 | 7.91 | 7.95 | 6.9 | 6.51 | 6.19 |
| 8 | 7.57 | 7.8 | 5.17 | 6.48 | 5.74 |
| 9 | 7.16 | 10 | 6.87 | 8.54 | 16.24 |
| 10 | 7 | 9.92 | 6.04 | 6.37 | 5.31 |

^ Department of Defense (DoD), Army Corps of Engineers (ACE), National Park Service (NPS), Fish and Wildlife Service (FWS), and U.S. Forest Service (USFS).

**Table 3.** Local connectivity ratio values for top ranked federal land units. Local connectivity ratio compares connectivity value within the land unit to surrounding lands within a 10 km radius.

| | DoD ^ | ACE | NPS | FWS | USFS |
|---|---|---|---|---|---|
| Top ranked | Local Connectivity Ratio | Local Connectivity Ratio | Local Connectivity Ratio | Local Connectivity Ratio | Local Connectivity Ratio |
| 1 | 1.12 | 0.8 | 0.48 | 0.89 | 0.94 |
| 2 | 0.95 | 0.84 | 0.92 | 1.01 | 0.99 |

**Table 3.** *Cont.*

| | DoD ^ | ACE | NPS | FWS | USFS |
|---|---|---|---|---|---|
| **Top ranked** | **Local Connectivity Ratio** | **Local Connectivity Ratio** | **Local Connectivity Ratio** | **Local Connectivity Ratio** | **Local Connectivity Ratio** |
| 3 | 0.9 | 0.89 | 1.02 | 0.98 | 0.98 |
| 4 | 0.98 | 0.82 | 0.96 | 0.71 | 0.99 |
| 5 | 1.07 | 0.98 | 0.97 | 0.98 | 1.02 |
| 6 | 1.04 | 1.02 | 0.95 | 1.03 | 1.02 |
| 7 | 0.98 | 0.91 | 1 | 0.93 | 1.02 |
| 8 | 0.92 | 0.87 | 0.98 | 0.98 | 1.07 |
| 9 | 1 | 0.63 | 0.99 | 0.97 | 1.01 |
| 10 | 0.97 | 0.9 | 0.96 | 0.96 | 1.05 |

^ Department of Defense (DoD), Army Corps of Engineers (ACE), National Park Service (NPS), Fish and Wildlife Service (FWS), and U.S. Forest Service (USFS).

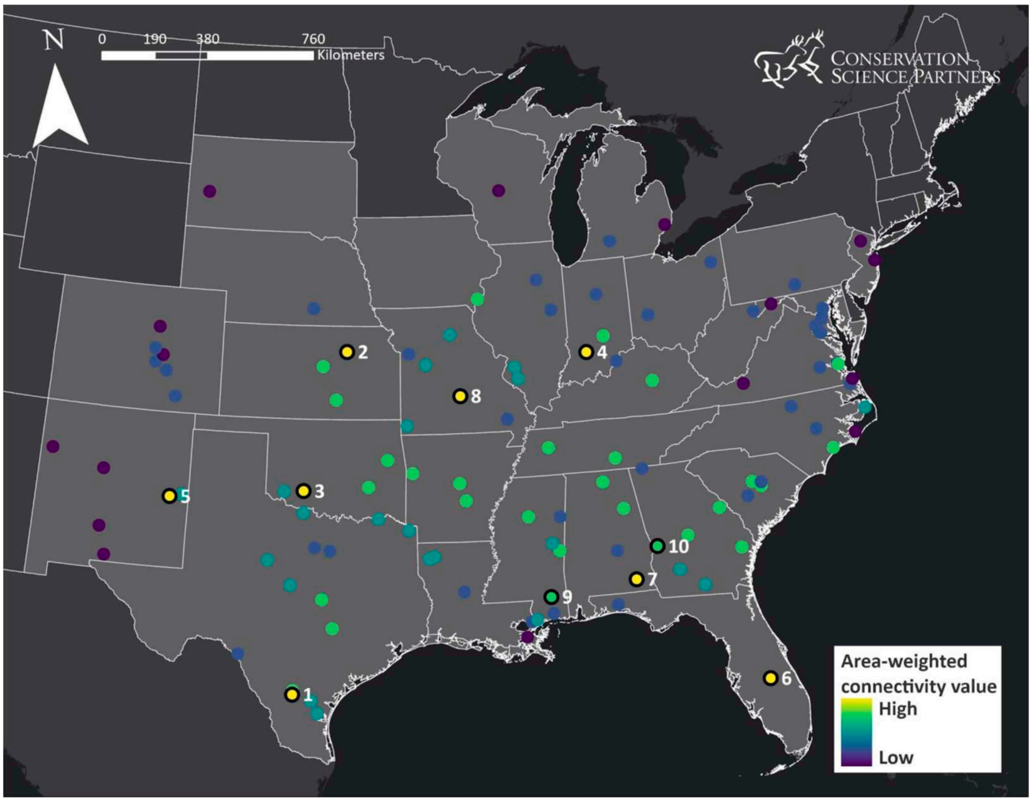


**Figure 4.** Area-weighted connectivity across DoD land units, based on the bobwhite range-wide connectivity model. Lighter gray shading indicates the geographic extent of the model. Each point represents the centroid of a land unit, and the color ramp represents the area-weighted connectivity value within the land unit's boundaries. Points with a black outline represent the top 10 land units, i.e., those with the highest area-weighted connectivity values (corresponding to the top ranked DoD land units in Tables 1–3).

Categories of Relative Flow: The lands within each unit were further classified into one of five relative flow categories: impeded, diffuse-impeded, diffuse, diffuse-channelized, and channelized. The categories were broken down starting with diffuse flow, which had a range of one standard deviation centered on 1, and each subsequent category was calculated by adding or subtracting one standard deviation. Categories were based on the methodology of McRae and colleagues (McRae [50]) with definitions as follows: Diffuse flow: Connectivity is relatively high across the landscape and is represented by multiple potential movement pathways through natural areas or suitable bobwhite habitats. Conservation efforts aimed at maintaining these natural areas in their current state may be appropriate here. Channelized flow: Connectivity is relatively high across the landscape but concentrated in one or a few high-flow areas (perhaps natural corridors through more developed landscapes or rugged natural terrain). Channelized areas require management to maintain a high level of connectivity and prevent further development in high-flow areas. Impeded flow: Connectivity is relatively low across the landscape, potentially due to high intensity of human land use or impassable terrain. For intensive human development, restoration would be required to increase connectivity (see Figure 3).

## 4. Discussion

Native Grassland Example: ANCHOR was conceived and is being delivered as a dynamic approach to establishing effective habitat connectivity at scale. The first application of the ANCHOR approach uses a game species as the modeling target. This was felt to be a strategic foundation to capture sustained financial investments made by both state agencies and recreational hunting organizations and serves to attract partners in creating an area-wide connected network. The first ANCHOR network is being established in 25 states across the eastern and central U.S., based on the WLFW Northern Bobwhite, Grasslands, and Savannas Framework. Top ranked ANCHOR sites are areas of high bobwhite connectivity, and in most cases also high habitat quality, that guide investment of financial support and technical assistance across landownership to create the necessary connectivity between them to link populations. Ranking was size-weighted as an indicator of potential carrying capacity of the target species based on the well-established island biogeography theory that suggests area size can enhance population resilience in response to stochastic events and climatic changes that erode habitat quality over time [53–56]. As noted earlier, the flexibility of the ANCHOR approach allows reranking based on other factors beyond or in addition to size (Suraci [52]).

Flexible Network: As the basis of ANCHOR, the Omniscape modeling approach by design allows for omnidirectional establishment of connectivity. This is a significant advantage over other modeling approaches when working with private lands and the public, as it is not reliant on or presented as a static map whose rigidity could be alarming. Instead, a shared vision within rural communities, and with partner agencies results in joint decision-making based on ranking scores generated by the models. A strong science-backed process that considers stakeholder concerns and restrictions is more lasting. Agencies will make independent but coordinated decisions regarding which of the highest ranked sites will be offered to the ANCHOR connectivity partnership.

ANCHOR Site Designation: Ranking scores are shared with each partner agency in a technical report that details ranking scores for all land units and includes maps that depict relative ranking scores across the target landscape. Public land managers use ranking scores to focus their evaluation of site-specific information and determine each land unit's measure of habitat suitability or potential for management improvements, then decide their capability and willingness to maintain appropriate conservation practices (see Table 4) in the context of supporting the area-wide network to increase carrying capacity and build landscape resilience. The ANCHOR approach seeks to connect sites ranked highly by the modeling effort and deemed suitable by agency land managers willing to commit to continued conservation management.

**Table 4.** USDA conservation practices (CP) creating, planting, or restoring lands, as funded through the USDA NRCS Environmental Quality Incentives Program (EQIP) hypothesized to have a positive impact on bobwhite as reported in the national survey performed in 2017 *.

| Conservation Practice (CP) Name | CP Number |
|---|---|
| Prescribed burning | CP338 |
| Prescribed grazing | CP528 |
| Brush management | CP314 |
| Weed treatment | CP315 |
| Forest stand improvement (forest thinning) | CP666 |
| Vegetation establishment through forage | CP512 |
| Range plantings | CP550 |
| Conservation cover | CP327 |
| Field borders | CP386 |
| Hedgerows | CP422 |
| Native grass plantings | CP2 |
| Permanent wildlife habitat | CP4 |
| Grass waterways | CP8 |
| Wildlife food plots | CP12 |
| Contour grass strips | CP15 |
| Grass filter-strips | CP21 |
| Riparian buffers | CP22 |
| Rare and declining habitat | CP25 |
| Marginal pasture buffers for wildlife | CP29 |
| Marginal pasture buffers for wetlands | CP30 |
| Upland bird habitat buffers | CP33 |
| Longleaf pine (establish) | CP36 |
| State acres for wildlife enhancement | CP38 |
| Pollinator habitat | CP42 |

* Courtesy of University of Georgia's Martin GAME Laboratory.

Each agency or partner will make site-specific assessments following their own priorities, planning documents, and internal guidance to decide which of the highest ranked sites are offered to the ANCHOR network. In the case of DoD, a 29-point questionnaire was distributed across all installations to collect detailed information such as acres of potentially suitable grasslands, management practices employed, species occurrences, and the level of interest of installation leadership and adjacent private landowners in grasslands management. DoD is using the results of this questionnaire to further prioritize ANCHOR sites and support final decision-making. The Forest Service is completing its own Omniscape modeling (a species-agnostic model) and has an existing searchable database known as Forest Service Activity Tracking System (FACTS) that documents monitoring and site management actions for national forests and grasslands. The information derived from modeling efforts and FACTS will inform ANCHOR site decisions. In this manner, each agency informs the ranking scores produced by ANCHOR models to further prioritize land units and implement the ANCHOR approach.

Incorporating site-specific information, decisions are made regarding agency commitment at that land unit, and each ANCHOR partner submits shapefiles and a metadata sheet detailing site establishment and management practices. A publicly available web portal will continuously provide a map of the growing network plus searchable information on the habitats provided. All data, reports, and maps will be made available dynamically online as they are approved and updated [57]. The resulting mapped anchors will expand over time as trust is established and commitment builds. Collectively, public land management agencies will make long-term commitments to "anchor" the cooperative conservation effort and ensure species have stable and connected habitats supporting their core populations.

The Role of Private Landowners: It is assumed that habitats on private lands remain fluid in aggregate over time reflecting the voluntary nature of private landowner participation. In the United States, programs funded under the United States Department of Agriculture (USDA) Farm Bill [58] provide the largest source of conservation implementation funds ($6B annually under current legislation) on private lands. Stability comes not from any single property or participating individual landowner but from this long-term commitment of Congress to support conservation on agricultural lands and from the strategic approach of ANCHOR itself across landscapes. To the extent possible, USDA Farm Bill Programs will support anchored habitats and wildlife on adjacent private lands through Working Lands for Wildlife and other voluntary program opportunities, including increasing technical and financial assistance for private landowners near designated anchors.

Under the WLFW Northern Bobwhite, Grasslands, and Savannas Framework (NRCS [23]), USDA NRCS is delivering conservation practices funded by the Environmental Quality Incentives Program (EQIP) totaling 2.8 M ha (7 M acres) over the first 5 years of the plan, 2023–2027. Private landowners are also participating in USDA's Farm Services Agency Conservation Reserve Program (CRP) [59,60] implementing conservation practices that will vary regionally and are hypothesized to have a positive impact on bobwhite as reported in the national survey performed in 2017 (see Table 4) in creating, planting, or restoring lands. Landowner contracts for CRP are 10–15 years and for EQIP range from 2 to 10 years. Conservation practices delivered by USDA and other partners through voluntary program participation will parallel those installed on public and other private land anchors (i.e., non-government organizations, large family holdings, corporations, etc.) to collectively achieve the goal of connected landscapes and wildlife populations.

ANCHOR Commitment: By establishing an ANCHOR site, public lands managers or private landowners commit to conserving portions of their lands to benefit grassland ecosystems and declining grassland birds. Managing these public lands within their mandates to achieve the agency's mission is an easier conservation decision than species-by-species efforts and ANCHOR provides a landscape context that magnifies local efforts and regional results. In the pilot project, federal agencies have already demonstrated interest in ANCHOR and its ability to meet connectivity goals to conserve biodiversity and improve landscape resilience. A five-year commitment is presented as a minimum partner agreement to participate in the launch of ANCHOR in a manner that is least intimidating to potential partners and decision-makers with financial and policy considerations. By joining the network, owners and managers of designated ANCHOR sites also commit to monitoring. Working with science and conservation partners, the NRCS Working Lands for Wildlife team has developed a rapid assessment protocol being used across the Framework area to collect on-site data and field measurements of the bird community and vegetation response to conservation efforts. The flexibility embedded in the ACHOR approach allows public-private stakeholders, including agencies, partners, and private landowners, to consider many factors before committing a land unit to the ANCHOR network.

## 5. Conclusions

Habitat loss, fragmentation, and decline in ecosystem health threaten populations, species, and ecosystem function. This is especially true in this era of rapid land use and climate change. The scale and rapidity of recurring climatic hazards can have a profound impact on many ecological systems and their functions. Conservation partnerships must provide connected habitats to optimize resilience and maintain species and ecosystems if natural systems are to survive current and projected threats. It is our collective responsibility to ensure that our conservation investments are directed to the right places more effectively and quickly given the rapidly changing climate and land use changes. But this responsibility is even more imperative among agencies and land stewards entrusted with managing public lands, held in trust for the benefit of the entire nation.

The ANCHOR approach facilitates systematic investments to create broader and more effective public-private connectivity partnerships. There is no equivalent national effort to date to actualize the delivery of landscape connectivity that links public lands ownership across agencies and government departments while integrating private lands. We still have a piecemeal approach to connect delivery across U.S. federal lands ownerships despite the many orders governing these agencies (see Table 5). ANCHOR seeks to facilitate timely decision-making, by delivering the science to guide conservation action to the action agencies and by establishing a stepwise implementation path—to move beyond policy, planning, and partnership development—to reach landscape conservation delivery, at the scales necessary to be impactful in the 21st century.

**Table 5.** U.S. federal policies and instructions to support connectivity of wildlife habitat on working landscapes relevant to native grasslands and avifauna conservation.

| Issuing Authority | Order or Instruction | Year. Title [Reference No.] |
|---|---|---|
| Department of Interior (DOI) | Revised and reissued Department Manual 604 DM-1 | 2024. Implementing Landscape-level Approaches to Resource Management. ver.1, chapter 3. Best Practices: Resource Planning, Management, and Mitigation [61] |
| National Park Service (NPS) | Policy Memorandum 24-02 | 2024. Landscape and Seascape Conservation and Ecological Connectivity through Cooperative Conservation [62] |
| Fish and Wildlife Service (FWS) | Department Policy Manual Updated 601 FW3, 602 FW 1, 602 FW 2, 602 FW 3 | 2024. Biological Diversity (601) [63] and update on refuge planning to center landscape-level approaches (602) [64] |
| Bureau of Land Management (BLM) | Instruction Memorandum 2023-005 | 2024 of the Conservation and Landscape Health Rule [65] 2022. Habitat Connectivity on Public Lands [66]. |
| Department of Agriculture (USDA) | Secretarial Memorandum 1077-013 | 2024. Conserving and Restoring Terrestrial Wildlife Habitat Connectivity and Corridors in the United States [67] |
| Council on Environmental Quality (CEQ) | Memorandum for Heads of Federal Departments and Agencies | 2023. Guidance for Federal Departments and Agencies on Ecological Connectivity and Wildlife Corridors [68] |
| Presidential Executive Order | Executive Order EO14072 | 2022. Strengthening the Nation's Forests, Communities, and Local Economies [69] |
| Department of Defense (DoD) | DoD Requires installations develop Integrated Natural Resources Management Plans (INRMPs) | 2008, 2010. Conserving Biodiversity on Military Lands: A Guide for Natural Resource Managers 3rd Edition. Chapter 8.2. Fragmentation and connectivity [70] |

Because the ANCHOR approach utilizes Omniscape connectivity modeling, the results are omnidirectional in identifying connectivity opportunities. Thus, the unavailability of any one land unit or the reluctance of any individual, partner or group to participate in ANCHOR does not diminish alternate opportunities to establish habitat connections. Strategic planning and delivery of connectivity becomes an iterative, adaptive process that is more sustainable under real-world pressures. Voluntary USDA Farm Bill Conservation Programs support landowners in joining the developing network and building on habitats already committed to the ANCHOR network. Together it maximizes conservation efforts in the private sector while offering agricultural producers the flexibility they need to maintain economic viability. Both public and private ANCHOR partners have the option of determining their own timelines for participation, though five years is the minimum initial commitment, and the expectation is that any anchoring land unit that is withdrawn from the network will be replaced by another simultaneously (e.g., if DoD needs to expand a bombing range, they can offer another site as a replacement anchor). Though larger private land holdings will be included in the ANCHOR network (e.g., corporate), generally public lands will literally anchor the network (and wildlife populations) while private lands will augment and connect the more stable public sites. In this manner, connectivity partnerships will strengthen and grow over time to deliver protected and managed habitats whose connections facilitate wildlife movements and increase the sustainability of large landscapes.

ANCHOR takes a practical approach with maximum flexibility offered to potential partners to rapidly advance conservation implementation. Integrated support models further allow multiple taxa associated with the biome to be considered together in formulating strategic partnerships to complement the relative contributions and generate measures of co-benefits. For example, preliminary work has already been conducted to integrate habitat values from a monarch butterfly (*Danaus plexippus*) habitat suitability models and the current bobwhite connectivity model with the goal of producing anchor site rankings that reflect both bird and pollinator benefits in grasslands.

As noted in the Introduction, the field of connectivity science is well established. Available methods were recently reviewed to provide guidance to compare systematic conservation planning and ecological connectivity modeling approaches [71–73], including online resources, modeling programs, tools, and examples to guide connectivity design [74–77]. This paper supplements that body of work with guidance to identify and engage a strategic public-private network committed to accelerating and expanding the delivery of landscape connectivity (i.e., the application of the ANCHOR approach). Deploying ANCHOR will require the leadership of agencies and government officials to serve as "brokers or bridgers" [78] and strategically engage and activate those making important land management decisions [79,80]. As broader partnerships form, the network governance will be determined by the agencies, organizations, and landowners involved. In this example, we highlight the work of the NRCS WLFW team who have liaised with other agencies across 25 states in the central and eastern U.S. to conserve native grasslands using bobwhite as an indicator, guided by the Northern Bobwhite, Grasslands and Savannas Framework.

The contribution of this approach starts with identifying and guiding the delivery of conservation practices on lands held in the public trust. The approach demonstrates an adaptive path forward that unifies partners and catapults connectivity agents past the myriads of existing methods, maps, plans, steering committees, and workgroups, toward strategic and expedited delivery of connected landscapes which demonstrably benefit biodiversity and wildlife conservation, ecosystem health, and rural nature-based economies.

**Author Contributions:** Conceptualization, B.E.C. and J.P.S.; methodology, J.P.S.; formal analysis J.P.S.; data curation and writing underlying technical reports, E.M.O. and J.P.S.; original draft preparation, E.J.B.; project administration, B.E.C., E.M.O. and J.P.S.; funding acquisition, J.P.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded under a USDA Natural Resources Conservation Service award to Pheasants Forever/Quail Forever, funding number C001-24-01.

**Data Availability Statement:** The data supporting the reported results are pre-decisional and not available to the public at the time of submission but will be posted online as approved by the agencies. For additional information contact Bridgett Costanzo at bridgett.costanzo@usda.gov, or at Bridgett.Costanzo@LandscapePartnership.org.

**Acknowledgments:** We thank Patrick Freeman and Sarah McTague of Conservation Science Partners for their substantial contributions to analytical and mapping work. Many thanks go to James Martin of University of Georgia, and Jessica McGuire of Quail Forever for brainstorming sessions that resulted in the science foundation of ANCHOR. Thanks also go to James Martin and the impressive team at the University of Georgia GAME Lab for developing the species-habitat dataset and resulting model.

**Conflicts of Interest:** Authors Elissa M. Olimpi and Justin P. Suraci were employed by Conservation Science Partners, Inc. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

1. Sawyer, S.C.; Epps, C.W.; Brashares, J.S. Placing Linkages Among Fragmented Habitats: Do Least-Cost Models Reflect How Animals Use Landscapes? *J. Appl. Ecol.* **2011**, *48*, 668–678. [CrossRef]
2. McRae, B.; Popper, K.; Jones, M.; Schindel, S.; Buttrick, K.; Hall; Unnasch, R.; Platt, J. *Conserving Nature's Stage: Mapping Omnidirectional Connectivity for Resilient Terrestrial Landscapes in The Pacific Northwest*; The Nature Conservancy: Portland, OR, USA, 2016; p. 47. Available online: http://nature.org/resilience (accessed on 1 October 2024).
3. Fleishman, E.; Anderson, J.; Dickson, B.G. Single-Species and Multi-Species Connectivity Models for Large Mammals on the Navajo Nation. *West. N. Am. Nat.* **2017**, *77*, 237–251. [CrossRef]
4. Dickson, B.G.; Albano, C.M.; Anantharaman, R.; Beier, P.; Fargione, J.; Graves, T.A.; Gray, M.E.; Hall, K.R.; Lawler, J.J.; Leonard, P.B.; et al. Circuit-theory applications to connectivity science and conservation. *Conserv. Biol.* **2019**, *33*, 239–249. [CrossRef]
5. Jennings, M.K.; Zeller, K.A.; Lewison, R.L. Supporting Adaptive Connectivity in Dynamic Landscapes. *Land* **2020**, *9*, 295. [CrossRef]
6. Reed, F.; Noss, R.; LaRoe, E.T., III; Scott, J.M. *Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation. Biological Report 28*; National Biological Survey: Washington, DC, USA, 1995; p. 68.
7. Foley, J.A.; DeFries, R.; Asner, G.P.; Barford, C.; Bonan, G.; Carpenter, S.R.; Chapin, F.S.; Coe, M.T.; Daily, G.C.; Gibbs, H.K.; et al. Global Consequences of Land Use. *Science* **2005**, *309*, 570–574. [CrossRef] [PubMed]
8. Suttie, J.M.; Reynolds, S.G.; Batello, C. *Grasslands of the World*; No. 34; Food & Agriculture Org.: Rome, Italy, 2005; p. 514. Available online: https://www.fao.org/4/y8344e/y8344e00.htm (accessed on 1 October 2024).
9. Estes, D.; Brock, M.; Homoya, M.; Dattilo, A. *A Guide to Grasslands of the Mid-South*; Natural Resources Conservation Service: Washington, DC, USA; Tennessee Valley Authority: Knoxville, TN, USA; Austin Peay State University: Clarksville, TN, USA; Botanical Research Institute of Texas: Fort Worth, TX, USA, 2016; p. 28. Available online: https://www.segrasslands.org/guide%E2%80%93to-the-grasslands-of-the-midsouth (accessed on 1 October 2024).
10. Bengtsson, J.; Bullock, J.M.; Egoh, B.; Everson, C.; Everson, T.; O'Connor, T.; O'Farrell, P.; Smith, H.G.; Lindborg, R. Grasslands—More important for ecosystem services than you might think. *Ecosphere* **2019**, *10*, e02582. [CrossRef]
11. Rosenberg, K.V.; Dokter, A.M.; Blancher, P.J.; Sauer, J.R.; Smith, A.C.; Smith, P.A.; Stanton, J.C.; Panjabi, A.; Helft, L.; Parr, M.; et al. Decline of the North American Avifauna. *Science* **2019**, *366*, 120–124. [CrossRef]
12. *Rangeland Wildlife Ecology and Conservation*; McNew, L.B., Dahlgren, D.D., Beck, J.L., Eds.; Springer Publishing: Berlin/Heidelberg, Germany, 2023; p. 1017. [CrossRef]
13. Cornel Laboratory of Ornithology. Northern Bobwhite. Available online: https://www.allaboutbirds.org/guide/Northern_Bobwhite/lifehistory# (accessed on 1 September 2024).
14. Crosby, A.D.; Elmore, R.D.; Leslie, D.M., Jr.; Will, R.E. Looking Beyond Rare Species as Umbrella Species: Northern Bobwhites (*Colinus virginianus*) and Conservation of Grassland and Shrubland Birds. *Biol. Conserv.* **2015**, *186*, 233–240. [CrossRef]
15. Morgan, J.J.; Foley, M.K.; Hodges, J.L.; Schaeffer, J.M. *Bobwhite Almanac: State of Bobwhite*; National Bobwhite and Grasslands Initiative (NBGI) Technical Committee Publication: Clemson, SC, USA, 2022; p. 58. Available online: https://nbgi.org/download/nbcis-bobwhite-almanac-state-of-the-bobwhite-2020/ (accessed on 1 October 2024).
16. Hernández, F.; Leonard, L.A.; DeMaso, S.J.; Sands, J.P.; Wester, D.B. On Reversing the Northern Bobwhite Population Decline: 20 Years Later. *Wildl. Soc. Bull.* **2013**, *37*, 177–188. [CrossRef]
17. Brennan, L.A. How Can We Reverse the Northern Bobwhite Population Decline? *Wildl. Soc. Bull.* **1991**, *19*, 544–555. Available online: https://www.jstor.org/stable/3782170 (accessed on 1 October 2024).
18. Rosenblatt, C.J.; Gates, R.J.; Matthews, S.N.; Peterman, W.E.; Stricker, N.J. An Integrated Population Model to Project Viability of a Northern Bobwhite Population in Ohio. *Ecosphere* **2021**, *12*, e03731. [CrossRef]
19. Fies, M.L.; Puckett, K.M.; Larson-Brogden, B. Breeding Season Movements and Dispersal of Northern Bobwhites in Fragmented Habitats of Virginia. *Natl. Quail Symp. Proc.* **2002**, *5*, 173–179.
20. Brennan, L.A. Strategic Planning Update. *Natl. Quail Symp. Proc.* **2000**, *4*, 59.
21. Brennan, L.A. The Disconnect Between Quail Research and Management. In *Wildlife Science: Connecting Research and Management*; Sands, J.P., DeMaso, S.J., Schnupp, M.J., Brennan, L.A., Eds.; CRC Press: Boca Raton, FL, USA; Taylor and Francis Group: Boca Raton, FL, USA, 2012; pp. 119–128.
22. National Bobwhite Conservation Initiative (NBCI). *The Comprehensive Guide to Creating, Improving & Maintaining Bobwhite Habitat*; National Bobwhite Technical Committee: Clemson, SC, USA, 2015; p. 87. Available online: https://nbgi.org/download/nbci-the-comprehensive-guide-to-creating-improving-managing-bobwhite-habitat/ (accessed on 1 October 2024).

23. *Northern Bobwhite, Grasslands and Savannas Framework: A Framework for Conservation Action*; Working Lands for Wildlife; National Resources Conservation Service (NRCS): Washington, DC, USA, 2022; p. 40. Available online: http://www.nrcs.usda.gov. (accessed on 29 January 2025).
24. Zeller, K.A.; Lewsion, R.; Fletcher, R.J., Jr.; Tulbure, M.G.; Jennings, M.K. Understanding the Importance of Dynamic Landscape Connectivity. *Land* **2020**, *9*, 303. [CrossRef]
25. Pacifici, M.; Rondinini, C.; Rhodes, J.R.; Burbidge, A.A.; Cristiano, A.; Watson, J.E.M.; Woinarski, J.C.Z.; Di Marco, M. Global Correlates of Range Contractions and Expansions in Terrestrial Mammals. *Nat. Commun.* **2020**, *11*, 2840. [CrossRef] [PubMed]
26. Fletcher, R.J., Jr.; Betts, M.G.; Damschen, E.I.; Hefley, T.J.; Hightower, J.; Smith, T.A.H.; Fortin, M.-J.; Haddad, N.M. Addressing the problem of scale that emerges with habitat fragmentation. *Global Ecol. Biogeogr.* **2023**, *32*, 828–841. [CrossRef]
27. Pease, B.S. Ecological scales of effect vary across space and time. *Ecography* **2024**, *8*, e07163. [CrossRef]
28. Johnston, A.; Hochachka, W.M.; Strimas-Mackey, M.E.; Gutierrez, V.R.; Robinson, O.J.; Miller, E.T.; Auer, T.; Kelling, S.T.; Fink, D. Analytical Guidelines to Increase the Value of Community Science Data: An Example Using eBird Data to Estimate Species Distributions. *Divers. Distrib.* **2021**, *27*, 1265–1277. [CrossRef]
29. Sullivan, B.L.; Aycrigg, J.L.; Barry, J.H.; Bonney, R.E.; Bruns, N.; Cooper, C.B.; Damoulas, T.; Dhondt, A.A.; Dietterich, T.; Farnsworth, A.; et al. The eBird enterprise: An integrated approach to development and application of citizen science. *Biol. Conserv.* **2014**, *169*, 31–40. [CrossRef]
30. eBird. Available online: https://www.ebird.org/science/download-ebird-data-products (accessed on 1 March 2023).
31. Ziolkowski, D.; Lutmerding, M.; Aponte, V.; Hudson, M.-A.R. 2022 Release—North American Breeding Bird Survey Dataset (1966-2021). 2022. Available online: https://www.usgs.gov/data/2022-release-north-american-breeding-bird-survey-dataset-1966-2021 (accessed on 1 March 2023).
32. Barnes, R.; Sahr, K. dggridR: Discrete Global Grids for R. R Package Version 2.0.4, 2017. Available online: https://github.com/r-barnes/dggridR (accessed on 1 March 2023).
33. Allred, B.W.; Bestelmeyer, B.T.; Boyd, C.S.; Brown, C.; Davies, K.W.; Duniway, M.C.; Ellsworth, L.M.; Erickson, T.A.; Fuhlendorf, S.D.; Griffiths, T.V.; et al. Improving Landsat predictions of rangeland fractional cover with multitask learning and uncertainty. *Methods Ecol. Evol.* **2021**, *12*, 841–849. [CrossRef]
34. Earth Resources Observation and Science (EROS) Center. National Land Cover Database. Available online: https://www.usgs.gov/centers/eros/science/national-land-cover-database (accessed on 1 December 2023).
35. Sauer, J.R.; Link, W.A.; Royle, J.A. Hierarchical Models and Bayesian Analysis of Bird Survey Information. In *Bird Conservation Implementation and Integration in the Americas, Proceedings of the Third International Partners in Flight Conference, Monterey, CA, USA, 20–24 March 2002*; USDA Forest Service General Technical Report PSW-GTR-191; Ralph, C.J., Terrell, R.D., Eds.; Department of Agriculture, Forest Service, Pacific Southwest Research Station: Albany, CA, USA, 2005; Volume 2, pp. 762–770.
36. Pacifici, K.; Reich, B.J.; Miller, D.A.W.; Gardner, B.; Stauffer, G.; Singh, S.; McKerrow, A.; Collazo, J.A. Integrating Multiple Data Sources in Species Distribution Modeling: A Framework for Data Fusion. *Ecology* **2017**, *98*, 840–850. [CrossRef]
37. Pacifici, K.; Reich, B.J.; Miller, D.A.W.; Pease, B.S. Resolving Misaligned Spatial Data with Integrated Species Distribution Models. *Ecology* **2019**, *100*, e02709. Available online: https://pmc.ncbi.nlm.nih.gov/articles/PMC6851831/pdf/ECY-100-na.pdf (accessed on 1 October 2024).
38. Edwards, B.P.M.; Smith, A.C. bbsBayes: An R Package for Hierarchical Bayesian Analysis of North American Breeding Bird Survey Data. *J. Open Res. Softw.* **2021**, *9*, 19. [CrossRef]
39. Smith, A.C.; Edwards, B.P.M. North American Breeding Bird Survey Status and Trend Estimates to Inform a Wide Range of Conservation Needs, Using a Flexible Bayesian Hierarchical Generalized Additive Model. *Ornithol. Appl.* **2021**, *123*, 1–16. [CrossRef]
40. Smith, A.C.; Binley, A.D.; Daly, L.; Edwards, B.P.M.; Ethier, D.; Frei, B.; Iles, D.; Meehan, T.D.; Michel, N.L.; Smith, P.A. Spatially Explicit Bayesian Hierarchical Models Improve Estimates of Avian Population Status and Trends. *Ornithol. Appl.* **2023**, *126*, duad056. [CrossRef]
41. Lewis, W.B.; Harsh, S.; Freeman, P.; Nolan, V.; Suraci, J.; Costanzo, B.E.; Martin, J.A. Integrating Multiple Data Sources with Species Distribution Models to Predict the Distribution and Abundance of Northern Bobwhites (*Colinus virginianus*) in the United States. *Ecol. Model.* **2025**. *to be submitted*.
42. Available online: https://public-nps.opendata.arcgis.com/datasets/nps::nps-boundary-1/about (accessed on 1 December 2023).
43. Available online: https://www.arcgis.com/home/item.html?id=3451bcca1dbc45168ed0b3f54c6098d3 (accessed on 1 December 2023).
44. Available online: https://www.arcgis.com/home/item.html?id=b8db5d69787c408d9654a1f36438acbd (accessed on 1 December 2023).
45. Available online: https://www.arcgis.com/home/item.html?id=1d7d70b51c094ae2aba9f56b16fd3d86 (accessed on 1 December 2023).
46. Available online: https://hub.arcgis.com/datasets/fedmaps::waterfowl-production-areas/about (accessed on 1 December 2023).
47. Landau, V.A.; Shah, V.B.; Anantharama, R.; Hall, K.R. Omniscape.jl: Software to compute omnidirectional landscape connectivity. *J. Open Source Softw.* **2021**, *6*, 2829. [CrossRef]

48. Hall, K.R.; Anantharaman, R.; Landau, V.A.; Clark, M.; Dickson, B.G.; Jones, A.; Platt, J.; Edelman, A.; Shah, V.B. Circuitscape in Julia: Empowering Dynamic Approaches to Connectivity Assessment. *Land* **2021**, *10*, 301. [CrossRef]
49. Keeley, A.T.H.; Beier, P.; Gagnon, J.W. Estimating Landscape Resistance from Habitat Suitability: Effects of Data Source and Nonlinearities. *Landsc. Ecol.* **2016**, *31*, 2151–2162. [CrossRef]
50. McRae, B.H.; Dickson, B.G.; Keitt, T.H.; Shah, V.B. Using Circuit Theory to Model Connectivity in Ecology, Evolution, and Conservation. *Ecology* **2008**, *89*, 2712–2724. [CrossRef]
51. Zeller, K.A.; McGarigal, K.; Whiteley, A.R. Estimating landscape resistance to movement: A review. *Landsc. Ecol.* **2012**, *27*, 777–797. [CrossRef]
52. Suraci, J.P.; Littlefield, C.E.; Nicholson, C.C.; Hunter, M.C.; Sorensen, A.; Dickson, B.G. Mapping Connectivity and Conservation Opportunity on Agricultural Lands Across the Conterminous United States. *Biol. Conserv.* **2023**, *278*, 109896. [CrossRef]
53. MacArthur, R.H.; Wilson, E.O. *The Theory of Island Biogeography*; Princeton University Press: Princeton, NJ, USA, 1967; p. 203.
54. Costanzi, J.-M.; Steifetten, Ø. Island Biogeography Theory Explains the Genetic Diversity of a Fragmented Rock Ptarmigan (*Lagopus muta*) Population. *Ecol. Evol.* **2019**, *9*, 3837–3849. [CrossRef]
55. Guo, Q. *Island Biogeography Theory: Emerging Patterns and Human Effects. Reference Module in Earth Systems and Environmental Sciences*; Elsevier Inc.: Amsterdam, The Netherlands, 2015; p. 5. [CrossRef]
56. Yu, J.; Yan, Y.; Wang, G.; Zhang, Q. Habitat Fragmentation Reduced Plant Functional Diversity in the Agro-pastoral Ecotone of Inner Mongolia. *Ecol. Indic.* **2024**, *169*, 112975. [CrossRef]
57. Available online: https://www.landscapepartnership.org/key-issues/anchor/anchor-resources (accessed on 1 December 2024).
58. Available online: https://www.fsa.usda.gov/programs-and-services/farm-bill/index (accessed on 1 December 2024).
59. Available online: https://www.fsa.usda.gov/resources/programs/conservation-reserve-program (accessed on 1 December 2024).
60. Available online: https://www.nrcs.usda.gov/getting-assistance/conservation-practices (accessed on 1 December 2024).
61. Available online: https://www.doi.gov/sites/doi.gov/files/elips/documents/604-dm-1.pdf (accessed on 1 December 2024).
62. Available online: https://www.nps.gov/subjects/policy/upload/PM_24-02.pdf (accessed on 1 December 2024).
63. Available online: https://www.fws.gov/policy-library/601fw3 (accessed on 1 December 2024).
64. Available online: https://www.fws.gov/policy-library/602fw3 (accessed on 1 December 2024).
65. Available online: https://www.blm.gov/policy/ib-2024-035-change-1 (accessed on 1 December 2024).
66. Available online: https://www.blm.gov/policy/im-2023-005-change-1 (accessed on 1 December 2024).
67. Available online: https://www.usda.gov/directives/sm-1077-013 (accessed on 1 December 2024).
68. Available online: https://www.nationalparkstraveler.org/sites/default/files/attachments/230318-corridors-connectivity-guidance-memo-final-draft-formatted.pdf (accessed on 10 February 2025).
69. Available online: https://www.govinfo.gov/app/details/DCPD-202200306 (accessed on 10 February 2025).
70. Available online: https://www.denix.osd.mil/biodiversity/ch-8/connectivity/ (accessed on 1 December 2024).
71. Pulsford, I.; Lindenmayer, D.; Wyborn, C.; Lausche, B.; Worboys, G.L.; Vasilijević, M.; Lefroy, T. Connectivity Conservation Management. In *Protected Area Governance and Management*; Worboys, G.L., Lockwood, M., Kothari, A., Feary, S., Pulsford, I., Eds.; ANU Press: Canberra, Australia, 2015; Chapter 27; pp. 851–888.
72. Hilty, J.; Worboys, G.L.; Keeley, A.; Woodley, S.; Lausche, B.; Locke, H.; Carr, M.; Pulsford, I.; Pittock, J.; White, J.W.; et al. *Guidelines for Conserving Connectivity Through Ecological Networks and Corridors. Best Practice Protected Area Guidelines Series No. 30*; IUCN: Gland, Switzerland, 2020; p. 122. [CrossRef]
73. Faselt, J.; Keeley, A.; Laur, A.; Oppler, G. *Technical Guidance on Systematic Conservation Planning with Connectivity. Center for Large Landscape Conservation: Bozeman, MT, USA*; Convention on the Conservation of Migratory Species of Wild Animals: Bonn, Germany, 2024; p. 43.
74. Available online: https://conservationcorridor.org/corridor-toolbox/programs-and-tools/ (accessed on 1 December 2024).
75. Available online: https://conservationcorridor.org/corridor-toolbox/programs-and-tools/tools-decision-table/ (accessed on 1 December 2024).
76. Available online: https://conservationcorridor.org/corridor-examples/ (accessed on 1 December 2024).
77. McKinney, M.; Scarlett, L.; Kemmis, D. *Large Landscape Conservation: A Strategic Framework for Policy and Action*; Lincoln Institute for Land Policy: Cambridge, MA, USA, 2010; p. 52.
78. Bixler, R.P. *Northwest Boreal Landscape Conservation Cooperative: An Assessment of a Large-Scale Conservation Social Network*; A Report to the Northwest Boreal Landscape Conservation Cooperative; RGK Center for Philanthropy and Community Service: Fairbanks, AK, USA, 2016; p. 26. Available online: https://www.researchgate.net/profile/Patrick-Bixler/publication/311102012_Northwest_Boreal_Landscape_Conservation_Cooperative_An_Assessment_of_a_Large-scale_Conservation_Social_Network/links/583da5d808ae61f75dc46a42/Northwest-Boreal-Landscape-Conservation-Cooperative-An-Assessment-of-a-Large-scale-Conservation-Social-Network.pdf (accessed on 1 December 2024).

79. Bixler, R.P.; Johnson, S.; Emerson, K.; Nabatchi, T.; Reuling, M.; Curtin, C.; Romolini, M.; Grove, J.M. Networks and Landscapes: A Framework for Setting Goals and Evaluating Performance at the Large Landscape Scale. *Front. Ecol. Environ.* **2016**, *14*, 145–153. [CrossRef]
80. Scarlett, L.; McKinney, M. Connecting People and Places: The Emerging Role of Network Governance in Large Landscape Conservation. *Front. Ecol. Environ.* **2016**, *14*, 116–125. [CrossRef]