Full Annual Cycle

Climate Change Vulnerability Assessment

For Migratory Birds of the Upper Midwest and Great Lakes Region

Peter P. Marra, Leah A. Culp,
Amy L. Scarpignato, and Emily B. Cohen

Smithsonian
Migratory Bird Ccenter

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

The Migratory
Connectivity Project

UPPER MIDWEST & GREAT LAKES
LANDSCAPE CONSERVATION COOPERATIVE

The Smithsonian Migratory Bird Center was founded in 1991 and is dedicated to understanding, conserving and championing the grand phenomenon of bird migration. The center is located at the Smithsonian's National Zoological Park in Washington, D.C. For more information visit nationalzoo.si.edu/scbi/migratorybirds.

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Cover images: Map shows predicted change in average fall temperature by 2080-2099 under a B1 emissions scenario; data for the map were downscaled by the Center for Applied Biodiversity Informatics, California Academy of Sciences; climate dataset from databasin.org/datasets/1cff40c84349475b966076330b003ec3. Migratory connectivity for Common Terns from the Upper Midwest and Great Lakes region is also illustrated; connectivity data were compiled by the Smithsonian Migratory Bird Center using USGS capture-recapture data. Base map from Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community. Common Tern range map from Bird Life International (www.birdlife.org). Common Tern photo by Tony Hisgett.

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by

Peter P. Marra[1]

Leah A. Culp

Amy L. Scarpignato

Emily B. Cohen

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[1]Primary contact: marrap@si.edu

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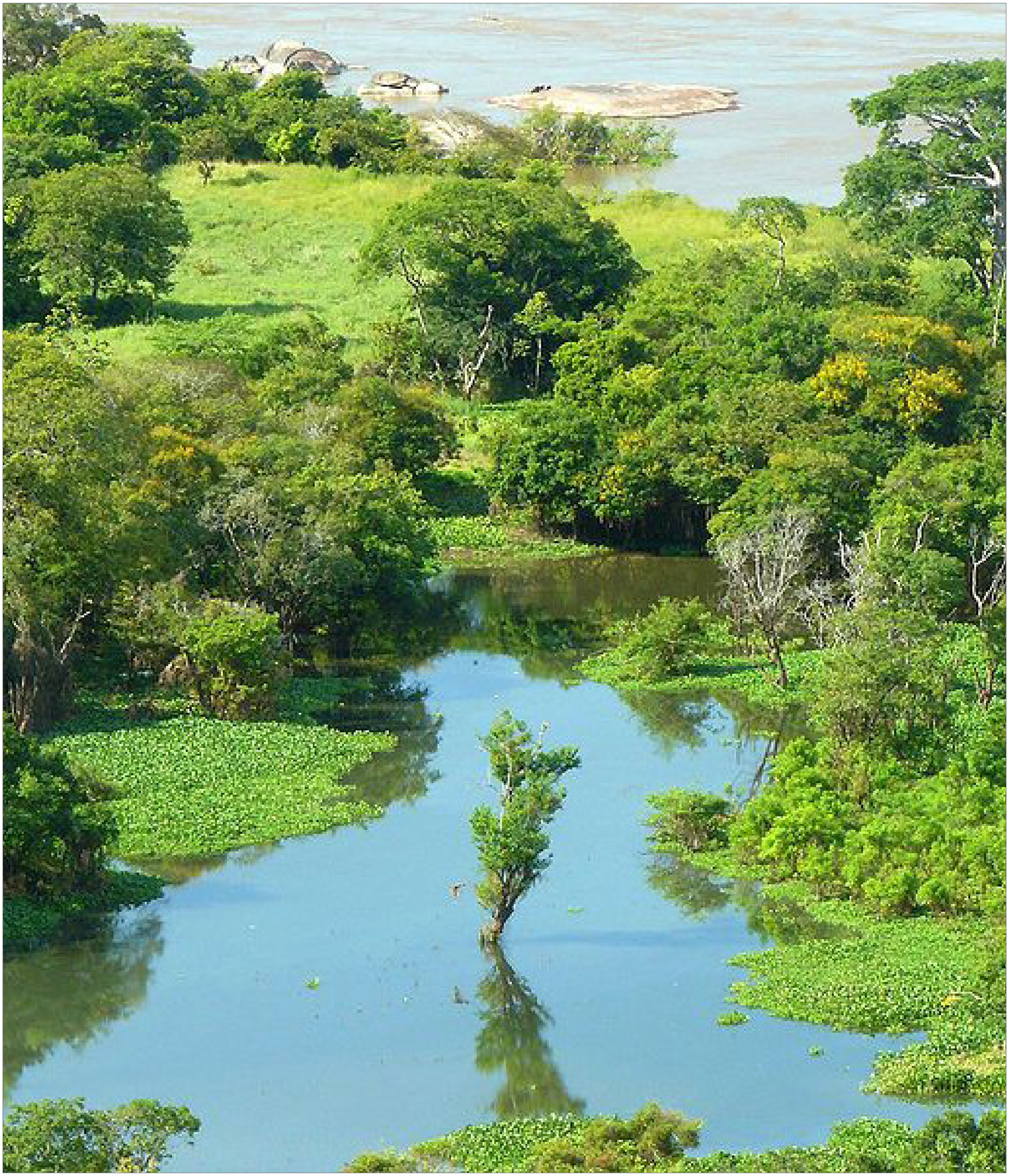
Abstract

Climate change is a serious challenge faced by all flora and fauna on earth. Climate vulnerability analyses are one method to assess risk and are increasingly used as a tool to inform management plans. Ideally, risk should be assessed throughout an animal's entire annual cycle, but migratory animals move across vast regions and can be difficult to track. Consequently, the challenge of conducting comprehensive full annual life cycle analyses has not been well addressed. Here, we developed a method to assess full annual cycle vulnerability to climate change for 46 species of migratory birds that breed in the Upper Midwest and Great Lakes region (UMGL). Our methodology included background risk, climate exposure × climate sensitivity, adaptive capacity to climate change, and indirect effects of climate change. Where possible, we used USGS capture-recapture data and conducted literature searches to determine migratory connectivity. Climate vulnerability was then assessed using the UMGL breeding season climate and winter climate from linked non-breeding regions for each species.

Shorebird flock on migration (photo by G Hoffmann)

We ranked nine species as "highly vulnerable to climate change" (Red-necked Grebe, Forster's Tern, Black Tern, Caspian Tern, Eastern Whip-poor-will, Yellow-bellied Flycatcher, Black-throated Blue Warbler, Worm-eating Warbler, and Rusty Blackbird) and two as having "low vulnerability" (Killdeer and Red-winged Blackbird). In general, vulnerability was driven by poor adaptive capacity to climate change, specifically high breeding site fidelity. Such species may be slow to disperse or expand their range in response to climate change. Projected drying will have its greatest effect on vulnerability in the Mexican and Caribbean non-breeding regions while projected temperature increases will have their greatest effect on the UMGL breeding grounds and South American non-breeding grounds. We identified nine species that were vulnerable to temperature and/or moisture change throughout their annual cycle (Upland Sandpiper, Black Tern, Eastern Whip-poor-will, Acadian Flycatcher, Nashville Warbler, Prairie Warbler, Dickcissel, Bobolink, and Orchard Oriole). All but one of these are considered species of conservation concern in the UMGL. Finally, we provide guidance to how our approach could be applied to adaptive management, including identifying: priority species and habitat types, regions within the non-breeding range for potential conservation partnerships, and research gaps.



Wetland habitat on the non-breeding grounds in Venezuela (photo by P Gutierrez)

1. Introduction

Boundary Waters Canoe Area Wilderness, MN (photo by R Priedhorsky)

Anthropogenic climate change will impact many aspects of life on Earth as we know it, from ecosystem function to provisioning food and water for human populations (IPCC 2014). Historically, climate has played a key role in shaping species life histories, yet much is to be discovered about the evolutionary and ecological effects of rapid, human-induced climate change on wildlife (Parmesan 2006, Dawson et al. 2011). For example, migratory animals are highly mobile and, on the one hand, may be somewhat resilient to climate change if they are able to shift their ranges or their phenology to track suitable climate. On the other hand, they may be vulnerable to climate change because their climatic and ecological requirements are complex, spanning vast geographic distances. They are exposed to a wide range of conditions as they move across continents, and climate change could alter ecological conditions in winter, summer, or migratory locations. Climate change in any of these areas may influence survival, reproductive success, or ecological cues that migrants use to optimize migration timing (Marra et al. 2005, Studds and Marra 2007, Gienapp 2012, Patxon et al. 2014, Cohen et al. 2015). Further, although migratory animals are highly mobile, they must be able to find necessary resources as they expand their ranges in search of appropriate climate. If resources are not able to track the changing climate, survival and reproduction of even mobile animals, such as migratory birds, may suffer (Root and Schneider 2006). Unfortunately, most climate change vulnerability assessments conducted to date have not accounted for this complexity or accounted for climate exposure throughout the annual cycle.

If we hope to understand and predict biological responses and vulnerability to climate change, it is essential to incorporate year-round climate and life history data into assessments for linked populations of migratory birds (Small-Lorenz et al. 2013). To date, most North American vulnerability assessments have focused solely on the breeding season and have not considered the complex annual life cycle of migratory animals (e.g. EPA 2009, Young et al. 2011, Gardali et al. 2012, NatureServe v2.1 connect.natureserve.org/science/climate-change/ccvi). As a result, these assessments have suggested, perhaps incorrectly, that migratory birds are less vulnerable than other taxa—in part due to their high dispersal ability and often relatively broad habitat use. For example, of eight climate change vulnerability assessments that included migratory birds (165 species and subspecies), zero species were classified as extremely vulnerable to climate change, 3% were highly vulnerable, 16% were moderately vulnerable, 50% were not vulnerable and stable, and 21% were not vulnerable and likely to increase (10% were not able to be classified, NatureServe v.2.1, connect.natureserve.org/science/climate-change/ccvi). While it may be true that characteristics like high mobility and broad habitat requirements could mediate the effects of climate change, it is not possible to assess whether this is true for migratory species without incorporating climate from throughout their full annual cycles. Failing to consider risk throughout the full annual cycle can lead to incorrect conclusions and inefficient allocation of resources, decreasing our ability to design conservation efforts in ways that will most improve habitat and reduce threats to vulnerable species.

1.1. LINKING CLIMATE CHANGE THROUGHOUT THE ANNUAL LIFE CYCLE

Responses to climate change may take a variety of forms. Species could shift their ranges to areas with more suitable climate, shift their phenology (i.e. the timing of reproduction and other life history stages), change other behavioral characteristics, or they could undergo morphological and genetic changes (Root et al. 2003, Parmesan 2006, Geyer et al. 2011, Maclean and Wilson 2011). It is clear that the phenologies of many bird species are changing in accordance with recent climate change (Root et al. 2003). Many species are showing both earlier arrival to breeding areas and earlier egg-laying dates in response to warmer temperatures (Dunn and Winkler 1999, Huppop and Winkel 2006, Jonzén et al. 2006, Parmesan 2006). Range shifts are also apparent. A recent estimate suggests that North American birds are experiencing an average northward range expansion of 60 km/year (NABCI 2009, 2010). An overlooked, but critical, issue is that the biology of migratory species is tightly linked to climate on the sedentary (Studds and Marra 2007, Wilson et al. 2011) and migratory (Marra et al. 2005, Patxon et al. 2014, Cohen et al. 2015) non-breeding areas. This complicates our ability to infer when and where future climate change will have the greatest influence (Studds and Marra 2011). For example, climatic conditions on the sedentary non-breeding grounds (i.e. where birds typically have annual fidelity to a local area during the winter and return to the same location year after year) predict spring arrival and laying dates on the breeding grounds (Huppop and Winkel 2006, Studds and Marra 2011). Rainfall on the wintering grounds is an especially important factor to consider when evaluating how can climate affect migratory bird species. For example, studies have demonstrated relationships between rainfall on the wintering grounds and migration timing, body condition, and annual fecundity. Specifically, higher winter rainfall has been correlated with improved body condition, earlier departure from the sedentary non-breeding grounds, and earlier arrival to the breeding grounds (Saino et al. 2007, Studds and Marra 2007), with these relationships probably mediated by food abundance (Studds and Marra 2007, 2011).

If we hope to understand biological responses and vulnerability to climate change, it is essential to incorporate year-round climate and life history data into assessments for linked populations of migratory birds. Breeding and wintering locations are said to be linked when individuals from the breeding population are the same as those in the wintering population. For example, the Kirtland's Warbler (*Setophaga kirtlandii*) breeds in Michigan's lower peninsula then migrates to the Bahamas for the non-breeding season. In a recent study of the Kirtland's Warbler (Rockwell et al. 2012), there was a strong relationship between winter rainfall in the Bahamas and the timing of spring arrival to breeding areas in Michigan. The same study showed that for every one-inch decline in annual Bahamian rainfall, annual fecundity declined by 0.6 young per warbler pair (Figure 1.1; Rockwell et al. 2012). In another study that used 26 years of breeding bird survey

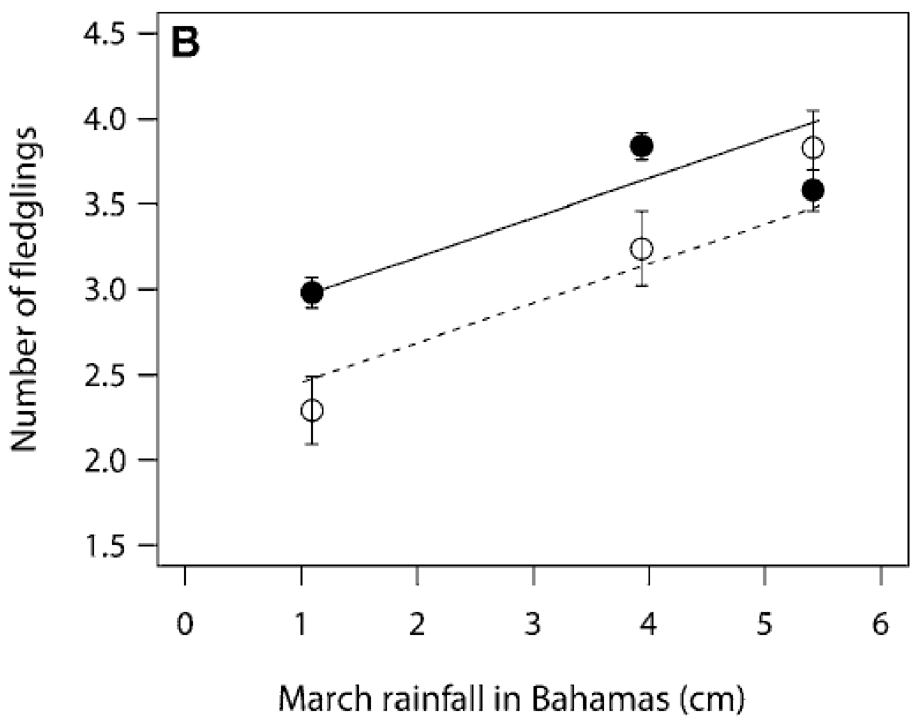


Figure 1.1. Total March rainfall in the Bahamas predicts yearly reproductive success for male Kirtland's Warblers in the Northern Lower Peninsula of Michigan. Figure from Rockwell et al. (2012).

data, American Redstarts (*Setophaga ruticilla*) exhibited a strong positive response to wetter conditions in the western Caribbean where these populations over-winter (Wilson et al. 2011). Unfortunately, climate change is expected to bring drier conditions to many tropical areas (Neelin et al. 2006), which means that we may see migratory birds like the American Redstart delaying spring migration and ultimately arriving late to temperate breeding sites. Meanwhile, temperature at temperate breeding areas are expected to increase, driving plants to leaf out and invertebrates to hatch earlier. This could create a severe phenological mismatch between migratory birds and their breeding season resources (Studds and Marra 2011), which may have consequences on reproduction (Rockwell et al. 2012). Further, evolutionary selection for earlier arrival on the breeding grounds could be constrained by drying conditions on the wintering grounds. These findings illustrate that assessments without year-round climate and life history data are likely to draw inaccurate conclusions about the vulnerability of migratory species.

1.2. ASSESSING VULNERABILITY

Considerable evidence now exists that bird populations can be vulnerable to climate change (Parmesan 2006, Jiguet et al. 2007, Moussus et al. 2011). In an effort to objectively assess the vulnerability of organisms and their environments to climate change, scientists have developed modeling and indexing approaches to integrate multiple types of information (Dawson et al. 2011, Glick et al. 2011). Species or populations may differ in their vulnerability to climate change due to differences in any or all of four primary components; exposure, sensitivity, adaptive capacity, or indirect biotic interactions (IPCC 2014; Dawson et al. 2011). We define these four components in Box 1.

BOX 1.

Components of Climate Change Vulnerability

Exposure: Rate and magnitude of climate change experienced by organisms and their populations throughout their annual cycle

Sensitivity: Degree to which the survival, persistence, fitness, performance, or regeneration of a species or population is dependent on climate-related variables

Adaptive capacity: A species capacity to cope with climate change by persisting in situ, shifting to more suitable local micro habitats, or migrating to more suitable regions. The concept of adaptive capacity can also be used to describe the potential for management actions to reduce negative impacts (Klausmeyer and Shaw 2009). For example, in areas where groundwater withdrawals can be regulated, managers may be able to increase the potential adaptive capacity of wetland species by minimizing drainage or water withdrawals

Indirect biotic interactions: In addition to the above components, we have also included a fourth factor describing extrinsic, indirect, effects of climate change. This includes the effect of climate change on specific resources required by a species. We added this component to our vulnerability assessment because there is evidence that climate change will have the greatest effect on species survival through indirect effects and biotic interactions (Parmesan 2006, Cahill et al. 2012)

Ultimately, vulnerability assessments are used to help inform management and conservation decisions. For example, they can help select species or habitats to target for conservation efforts, prioritize areas for land acquisition, or direct monitoring efforts. Vulnerability assessments can also be used to identify specific factors

Bird bands from USGS Bird Banding Laboratory

that may contribute to vulnerability. Such information can be critical to guiding adaptive management strategies that could reduce vulnerability (Glick et al. 2011). Yet another use of vulnerability assessments for migratory animals is to identify key partnerships between conservation organizations that bridge conservation efforts across the annual life cycle and connect the various locations necessary for species survival and reproduction.

1.3. MIGRATORY CONNECTIVITY

Migratory birds move annually between breeding and stationary non-breeding locations. The linking of individuals and populations across periods of the annual cycle is termed migratory connectivity (Webster et al. 2002, Marra et al. 2006). Research has shown that events between periods of the annual cycle are inextricably linked (Marra et al. 1998) such that the annual cycle is a continuous series of events rather than discrete periods. Understanding where individuals and populations exist throughout the annual cycle can have important implications for understanding complex population dynamics driven by annual climatic variability (Webster and Marra 2005, Wilson et al. 2012, Small-Lorenz 2013). Unfortunately, our understanding of migratory connectivity for most species is rudimentary. Tools to track the annual movements of birds were expensive and heavy. Until just recently, the primary source of information used to provide direct estimates of migratory connectivity was the marking and recapturing of banded birds (Box 2). These data, which are stored and maintained at the USGS Bird Banding Laboratory (BBL) in Patuxent, Maryland, have until now yielded little information on migratory connectivity. This is true for most species largely because there has yet to be a comprehensive analysis of the BBL database.

BOX 2.

USGS Bird Banding Laboratory

- Banding and encounter records date back to 1914
- Nearly all N. American breeding bird species have been banded over the BBLs 100 years of existence
- Over 1,200,000 birds are banded and 85,000 recovered annually
- More than 73,000,000 birds have been banded since the beginning of the program
- More than 4,700,000 have been recovered, recaptured, or resighted and reported to the BBL

The BBL database represents an untapped resource of data for estimating migratory connectivity for countless species of birds. Recapture data are especially useful for annual cycle vulnerability analyses. An illustration of the utility of the BBL database comes from a recent analysis of Grey Catbirds (*Dumetalla* *carolinensis*; Figure 1.2; Ryder et al. 2011). Two geographically distinct breeding populations of catbirds winter in distinct geographic and climatic areas undoubtedly changing each population's vulnerability to climate change. Including the migratory connectivity, and thus the appropriate winter climate exposure, of migratory species into vulnerability assessments is essential to improving the reliability of these estimates.

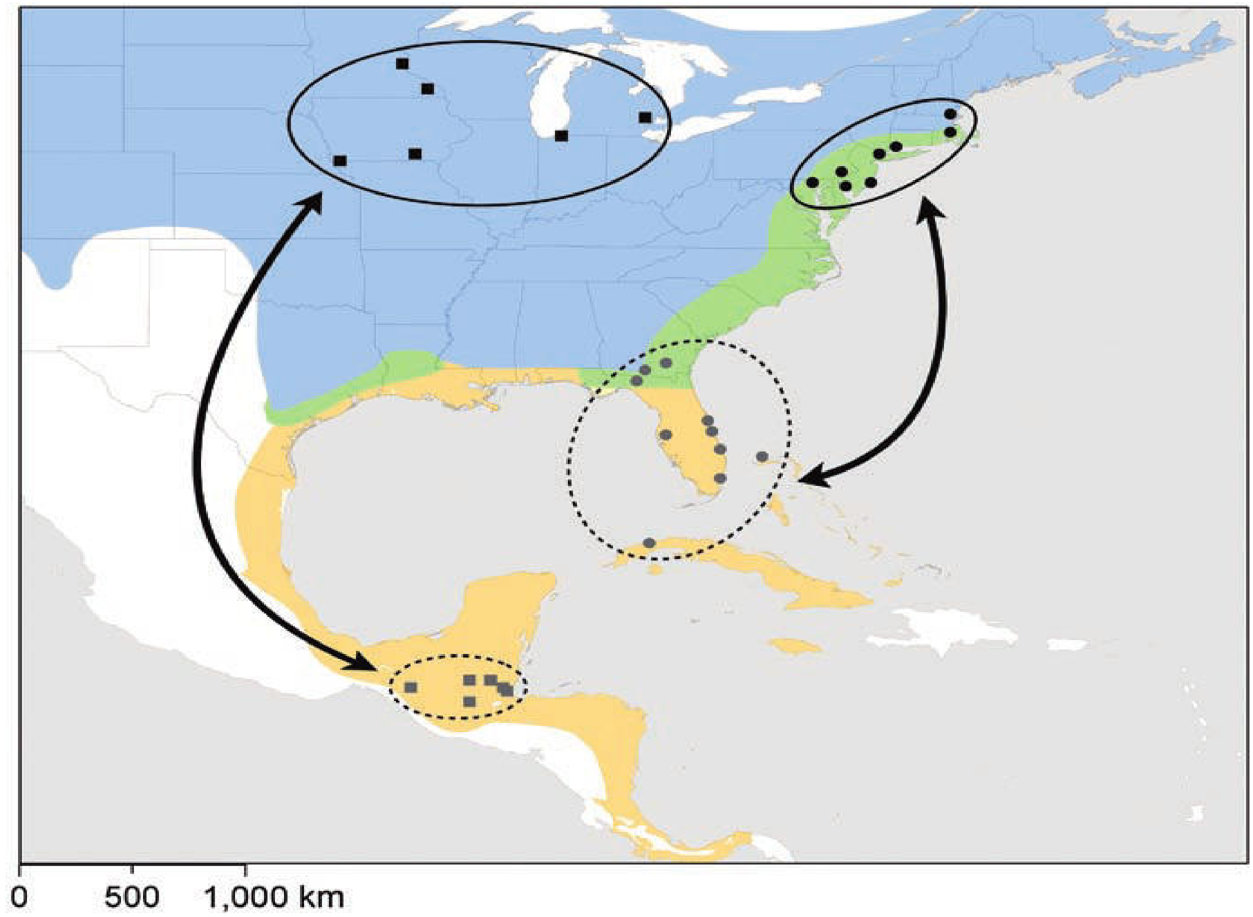


Figure 1.2. USGS Bird Banding Laboratory mark-recapture data overlaid with breeding (blue), year-round (green), and wintering (orange) distributions of Gray Catbirds. Mark-recapture patterns suggest strong regional connectivity. Figure from Ryder et al. (2011).

1.4. FULL ANNUAL CYCLE VULNERABILITY APPROACH

Resource managers often need to develop prioritized management plans for migratory bird species. As a result, agencies and conservation groups require information about which species are most vulnerable to climate change, and what actions are most likely to promote adaptation. We expect that most of the approximately 150 breeding passerine species in the Upper Midwest Great Lakes (UMGL) region may be affected by climate change during some portion of their annual cycle, e.g., by changes in temperature on breeding areas, changes in precipitation on tropical wintering grounds, or by events en route.

Here, we provide methodology for conducting a full annual cycle climate change vulnerability analysis and address the following four objectives (Box 3) for breeding, nongame migratory birds in the UMGL region. This is the first effort to separate and evaluate multi-season and spatially explicit components of vulnerability. This approach will provide managers with the information necessary to develop the strategic partnerships necessary to protect species across continental scales.

BOX 3.

Objectives

1. Quantify vulnerability to climate change for a select group of migratory bird species in the UMGL region

2. Determine at which stage (where and when) of the annual cycle species are most likely to be affected

3. Assess which factors contribute most to a species' vulnerability in terms of life history traits, habitat needs, and exposure to climate change

4. Define potential intrinsic or management-based adaptation strategies that could be adopted by managers

The ever-accelerating pace of climate change and its effects on the natural world must be addressed so that managers can make informed strategic decisions to protect wildlife species in the future. Vulnerability analyses are key components of most major plans designed to address the risks of climate change (Glick et al. 2011). For example, the National Fish, Wildlife and Plants Climate Adaptation Partnership (2012) calls for adaptive management through decision support tools such as vulnerability assessments. The USFWS Strategic Plan for Responding to Accelerating Climate Change (2009) places species vulnerability assessments and international leadership on climate change and wildlife as top priorities. Furthermore, the Association of Fish and Wildlife Agencies (2009) calls for vulnerability analyses in their Guidance for States to Incorporate Climate Change into State Wildlife Action Plans as well as other management plans. Here we take a comprehensive approach to assessing vulnerability by mapping migratory connectivity and including the annual climatic exposure of linked populations.

2. Methods

2.1. FOCAL AREA

The Upper Midwest - Great Lakes (UMGL) Landscape Conservation Cooperative (LCC) is part of USFWS Region 3 (Region 3 includes Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio and Wisconsin). The UMGL LCC also contains three Bird Conservation Regions (BCRs) (Figure 2.1). BCRs are defined by ecologically distinct regions with similar bird communities, habitats, and resource management issues (www.nabci-us.org/bcrs.htm). The BCRs within the UMGL LCC are: Boreal hardwood transition, Lower Great Lakes/St. Lawrence Plain, and Prairie hardwood transition (Figure 2.1). The diversity of habitats and ecosystems found in the UMGL reflects the broader region's importance to both plants and wildlife, including migratory birds. For example, the largest freshwater resource in North America, coastal wetlands, major rivers, boreal forests, and prairie-hardwoods can all be found in the UMGL. There are numerous challenges that threaten the ecological integrity of the UMGL region, including, a history of intensive land conversion (especially in the southern half), climate change, energy development, water limitations, invasive species, and population growth. Necessarily, conservation biologists and agencies must work together to manage this important region, and the UMGL LCC brings more than 30 agencies and organizations together, connecting science, conservation, and management.

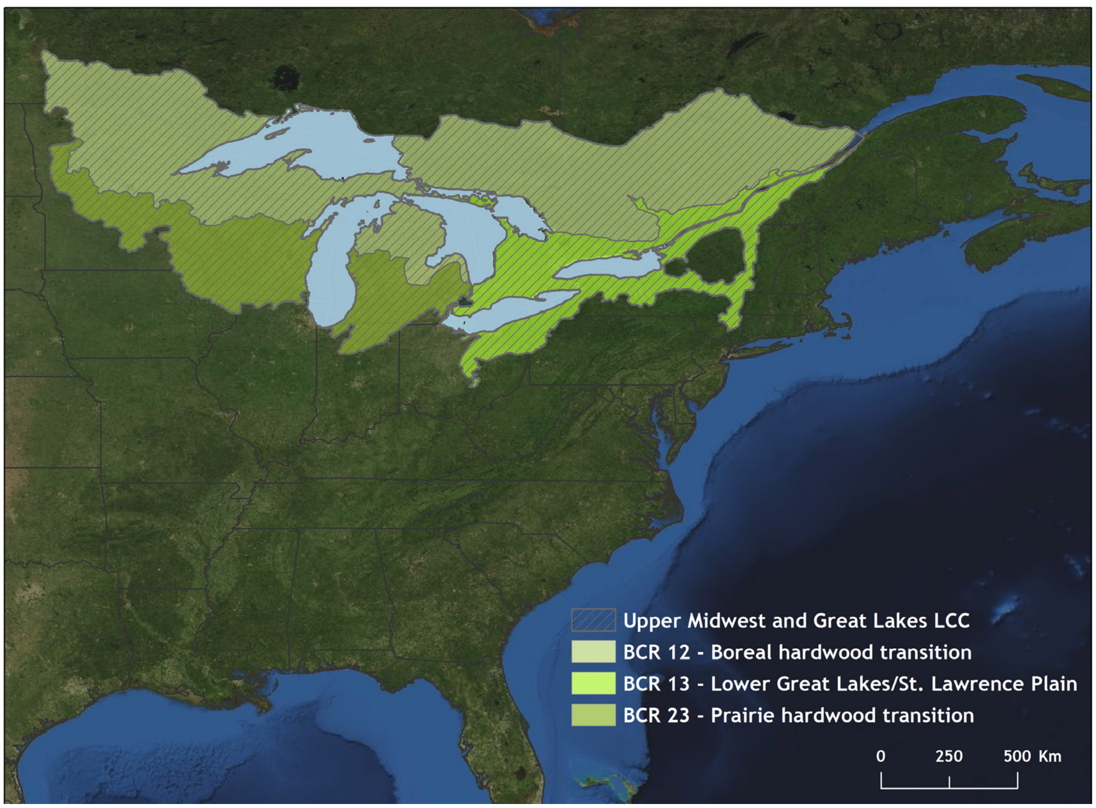


Figure 2.1. Upper Midwest Great Lakes Landscape Conservation Cooperative and Bird Conservation Regions.

2.2. FOCAL SPECIES

We assessed the vulnerability of 46 nongame migratory bird species that breed within the UMGL region (Table 2.1). We chose species that represented a diversity of families, habitat needs, life history characteristics, and conservation status. Twenty-three species are of conservation concern in the UMGL LCC and are of particular interest to local management agencies (USFWS 2008). The remaining 23 species are considered common and not of conservation concern. We selected common species that were taxonomically similar to the ones of conservation concern and that had data available from the BBL.

Table 2.1. Focal species from USFWS Region 3 used in the climate change vulnerability analysis. Species of conservation concern are paired with taxonomically similar common species.

Conservation concern	Common
Pied-billed Grebe *(Podilymbus podiceps)*	Red-necked Grebe *(Podiceps grisegena)*
Black-crowned Night-Heron *(Nycticorax nycticorax)*	Green Heron *(Butorides virescens)*
Peregrine Falcon *(Falco peregrinus)*	American Kestrel *(Falco sparverius)*
Upland Sandpiper *(Bartramia longicauda)*	Killdeer *(Charadrius vociferus)*
Black Tern *(Chlidonias niger)*	Caspian Tern *(Hydroprogne caspia)*
Common Tern *(Sterna hirundo)*	Forster's Tern *(Sterna forsteri)*
Black-billed Cuckoo *(Coccyzus erythropthalmus)*	Yellow-billed Cuckoo *(Coccyzus americanus)*
Short-eared Owl *(Asio flammeus)*	Northern Saw-whet Owl *(Aegolius acadicus)*
Eastern Whip-poor-will *(Antrostomus vociferus)*	Common Nighthawk *(Chordeiles minor)*
Red-headed Woodpecker *(Melanerpes erythrocephalus)*	Yellow-bellied Sapsucker *(Sphyrapicus varius)*
Acadian Flycatcher *(Empidonax virescens)*	Yellow-bellied Flycatcher *(Empidonax flaviventris)*
Wood Thrush *(Hylocichla mustelina)*	Swainson's Thrush *(Catharus ustulatus)*
Worm-eating Warbler *(Helmitheros vermivorum)*	Black-and-white Warbler *(Mniotilta varia)*
Golden-winged Warbler *(Vermivora chrysoptera)*	Tennessee Warbler *(Oreothlypis peregrina)*
Blue-winged Warbler *(Vermivora cyanoptera)*	Nashville Warbler *(Oreothlypis ruficapilla)*
Cerulean Warbler *(Setophaga cerulea)*	American Redstart *(Setophaga ruticilla)*
Prairie Warbler *(Setophaga discolor)*	Yellow Warbler *(Setophaga petechia)*
Canada Warbler *(Cardellina canadensis)*	Black-throated Blue Warbler *(Setophaga caerulescens)*
Field Sparrow *(Spizella pusilla)*	Vesper Sparrow *(Pooecetes gramineus)*
Dickcissel *(Spiza americana)*	Savannah Sparrow *(Passerculus sandwichensis)*
Bobolink *(Dolichonyx oryzivorus)*	Indigo Bunting *(Passerina cyanea)*
Rusty Blackbird *(Euphagus carolinus)*	Red-winged Blackbird *(Agelaius phoeniceus)*
Orchard Oriole *(Icterus spurius)*	Baltimore Oriole *(Icterus galbula)*

2.3. QUANTIFYING MIGRATORY CONNECTIVITY

To quantify the migratory connectivity for our focal species, we used the BBL encounter database. The database contains nearly 5 million encounter records from 1914 to the present describing the movement of birds from their original banding locations to a geographic location where they were re-encountered (Box 2). The encounter records include information about when and where previously banded birds were recaptured alive or recovered dead. The records also include when and where the birds were originally banded. For each species, we exported all records with reliable encounters that were greater than 18 km (10 min block) from the original capture. We filtered the remaining records to include locations within BCRs 12, 13, and 23 during the breeding season (May – Aug) and locations during the sedentary portion of the non-breeding season (Nov – Mar) and during fall (Sep – Oct) and spring (Apr – May) migration. We plotted banding and encounter locations in ArcGIS® (ESRI 2010) and created migratory connectivity maps for each species. We used only locations from the sedentary periods (i.e. UMGL breeding range, May-Aug, and non-breeding range, Nov-Mar) in the vulnerability analyses. Hereafter, we refer to these periods as breeding and non-breeding. Although conditions at migratory stopover areas can play a role in vulnerability, we did not have sufficient information to incorporate these sites for any species.

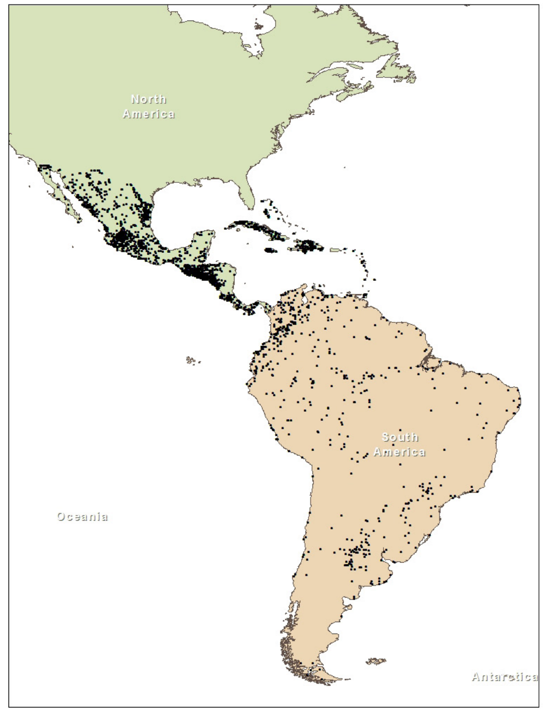


Figure 2.2. Map of spatial variation in BBL tern encounters during Dec to Feb.

A large degree of spatial variation exists in encounter probability, which could confound our ability to interpret connectivity (Figure 2.2, Cohen et al. 2014, Thorup et al. 2014). For this reason, we did not determine precise likelihoods of connectivity between the UMGL and specific non-breeding regions. Instead, we identified regions where possible linkages with the UMGL might occur. For example, when breeding individuals banded in the UMGL were also encountered on the non-breeding grounds during the non-breeding season, we described it as a possible link between the two locations and included the non-breeding region in our vulnerability analysis.

For most species, we summarized migratory connectivity in general terms because we lacked the data to account for spatial variation in detectability. For Caspian and Common Terns, however, many individuals have been banded and encountered throughout their ranges, making more precise quantification of migratory connectivity possible. For these species, we estimated geographic linkages from breeding to non-breeding regions with a multistate capture-recapture model that accounted for regional variation in encounter probabilities by borrowing information across species (Cohen et al. 2014). We included data after 1954 (when electronic banding records became available) for birds banded during breeding (May – Aug) and encountered during stationary non-breeding (Nov – Feb). We did not include migratory locations. For Caspian Terns, > 75,000 individuals were banded during breeding and 123 were encountered during non-breeding. For Common Terns, > 1 million were banded during breeding and 944 were encountered during non-breeding. Models estimate the probability that tern populations from the UMGL region spend the winter in specific non-breeding regions.

In addition to the BBL encounter database and migratory connectivity models, we conducted literature reviews for each species and summarized all migratory connectivity data relevant to the UMGL. This included results derived from various tracking techniques including stable isotopes, genetics, light-level geolocators, and satellite telemetry. For each species, we provide a narrative summarizing all migratory connectivity information between the UMGL and five non-breeding regions (N. America, Mexico, Caribbean, C. America, and S. America). Although the non-breeding regions can be large, depending on the size of each species range, we used this broad scale because data were extremely sparse and inconsistent at the local scales. In addition, we identify where data are lacking or nonexistent and suggest research priorities. For our vulnerability analysis, we included only those non-breeding regions identified as having a possible link with the UMGL (based on BBL data and literature review). For species where we were unable to identify possible migratory connectivity, we included all non-breeding regions within the species range. For Caspian and

Common Terns, we included all non-breeding regions with ≥10% probability of connectivity (determined by the capture-recapture models).

2.4. VULNERABILITY ASSESSMENT FRAMEWORK

We define vulnerability as the evidence that climate change or other anthropogenic factors will negatively affect a population or species within the UMGL region. This could manifest itself as increased rarity, range contraction, local to widespread population decline, or extirpation. Mechanisms for these population changes include reduced survival during the breeding or non-breeding seasons and reduced reproductive output during the breeding season. Our approach can be applied to migratory species and is more comprehensive than other vulnerability assessments currently in use (Small-Lorenz et al. 2013). Although we did include spring and fall migration encounters on the migratory connectivity maps, these points were not used in the vulnerability analysis or in our determination of connectivity.

We integrated climate change-related factors and background risk to provide a more comprehensive approach to vulnerability assessment. In addition, it is relevant to the year-round life cycle of a migratory bird. Our vulnerability assessment combines five components (Box 4).

BOX 4.

Components of the Full Annual Cycle Vulnerability Assessment

i. Background risk (factors unrelated to climate change)

ii. Climate exposure

iii. Climate sensitivity

iv. Adaptive capacity to climate change

v. Indirect effects of climate change

i. Background Risk—Species that are already at risk of extinction due to other anthropogenic stressors may be less resilient and thus more vulnerable to climate change (e.g., species with small or declining populations). We used the Partner's in Flight (PIF) conservation status to define background risk (Punjabi et al. 2012). This is the most comprehensive regional listing for avian taxa, it does not include climate change as a risk factor, and it has a high level of scrutiny—being revised every five years. For taxa not listed in the PIF report (waterbirds and shorebirds), we used the Upper Mississippi River and Great Lakes Region Joint Venture and the Upper Mississippi Valley/Great Lakes Waterbird Conservation Plan, which use PIF methods and cover the UMGL region (Potter et al. 2007, Wires et al. 2010).

PIF and Joint Venture assessments use population abundance, population trend, range size, breeding threats, and stationary non-breeding threats to rate conservation status (Potter et al. 2007, Wires et al. 2010, Punjabi et al. 2012). However, for a subset of the species (n = 31) we used more accurate information on the probability of "quasi"-extinction in lieu of population abundance and population trend (unpubl. data, W. Thogmartin). Quasi-extinction is defined as a drop in population abundance below a specified level. To estimate risk of quasi-extinction, we used a count-based population viability analysis first developed by fisheries biologists (McClure et al. 2003, Holmes et al. 2007) and subsequently used to estimate extinction risk of other rare species of concern (see Thogmartin et al. 2006, Bronte et al. 2010). Population viability was predicted at levels above which demographic stochasticity and Allee effects may become important (Lande et al. 2003, Fagan and Holmes 2006). As such, we did not estimate absolute risk of extinction per se, but rather the potential for quasi-extinction—a drop in the population below some subjective level. Quasi-extinction is used by the World Conservation Union's International Union for the Conservation of Nature (Mace and Lande 1991) and the USA Endangered Species Act (DeMaster et al. 2004). Setting a quasi-extinction level can be subjective and value-laden (Fagan and Holmes 2006). To overcome uncertainty in minimum detection with BBS data, we calculated quasi-extinction for a relative abundance index of 10% of the year 2000 estimate. This, in effect, calculates the probability of obtaining an additional 90% decline from the year 2000 population.

For the 31 species with robust quasi-extinction probabilities, we replaced the PIF assessment with one that uses quasi-extinction risk (in lieu of population abundance and trend), range size, and threats. Ultimately, the background risk category can be viewed separately or in combination with the following climate change-related categories.

ii. Climate Exposure—Exposure is determined by extrinsic factors (Williams et al. 2008, Dawson et al. 2011). Here, we specifically include climate-related exposure due to changes in mean temperature and mean moisture (www.climatewizard.org) by season. Moisture is defined as the actual versus potential evapotranspiration ratio, and we used this variable instead of precipitation because it accounts for the drying effects of reduced precipitation combined with higher temperatures and increased evaporation (www.climatewizard.org). Our approach quantifies exposure seasonally during breeding and non-breeding periods and tailor it to where and when species are present. For migratory birds, this means quantifying exposure for two or more disjointed locations. Assessing climate change seasonally is critical because we do not expect climate perturbations to be uniform throughout the year. For example, mid-century drying effects in the UMGL are expected to be 14 times greater during summer than winter (Figure 2.3; see also Karl et al. 2009). In addition, migratory animals spend each season in different locations and may experience carry-over effects where exposure during one season affects vulnerability during another. For this reason, exposure must be assessed throughout the year in order to understand where and when species are most vulnerable and how seasons might interact with each other to increase or decrease overall vulnerability.

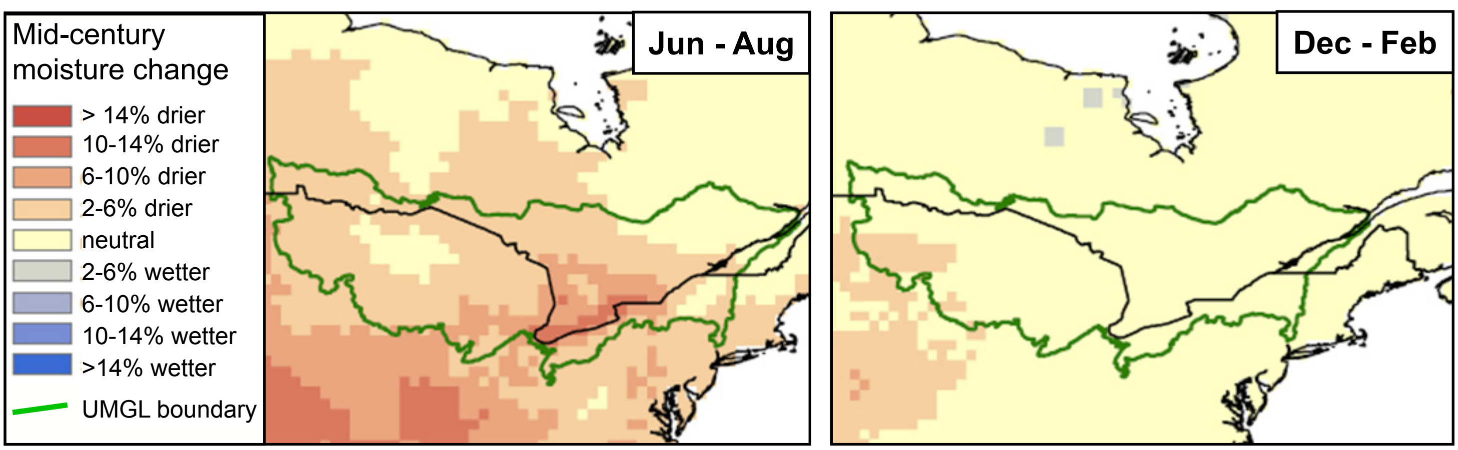


Figure 2.3. N. American mid-century moisture change for breeding (left) and non-breeding (right) periods (climatewizard).

We used the Nature Conservancy's Climate Wizard online tool to quantify mid-century (2040-2069) temperature and moisture change (www.climatewizard.org). Climate data originated from an ensemble of 16 general circulation models downscaled into ArcGIS® (ESRI 2010) raster grids. For our vulnerability analysis, we used seasonal means of temperature and moisture predictions from the 16-model ensemble average. We used the high-emissions scenario, A2 (IPCC SRES 2000), because we wanted to present maximum estimates of vulnerability and because it is most realistic given recent emissions growth—current trends exceed most worstcase scenarios outlined in the Intergovernmental Panel on Climate Change 4th Assessment Report (IPCC 2007). We assessed exposure during summer (Jun – Aug) for areas where species' breeding ranges overlapped with the UMGL. This varied slightly for each species according to breeding range boundaries. We obtained range maps from NatureServe, which now can be found at Bird Life International (www.birdlife.org/datazone/info/spcdownload). We also assessed winter exposure (Dec – Feb) for locations where species are known to occur during the non-breeding period. For each species, we separated the non-breeding range into five general regions (N. America, Mexico, Caribbean, C. America, and S. America) and assessed exposure separately for each. For 10 species, migratory connectivity of UMGL populations is reasonably known, and we focused our assessment of winter exposure on the appropriate region or regions. For the remaining 36 species, we assessed winter exposure for all regions throughout the entire non-breeding range. Thus, for species with large non-breeding ranges, we report multiple exposure estimates for the winter season. For each species, we used the same time frame to quantify breeding and non-breeding exposures—Jun to Aug and Dec to Feb, respectively.

iii. Climate Sensitivity—Sensitivity is defined as a species direct sensitivity to temperature or moisture—i.e. the ability of a species to physiologically tolerate change. Because birds generally have high metabolisms and body temperatures (Gill 1995), they are particularly sensitive to temperature extremes. Although they have behavioral strategies to tolerate high temperatures, such as avoiding sun exposure and activity during the hottest part of the day (Wolf 2000, Kearney et al. 2009), as temperatures increase, evaporative heat loss becomes essential—particularly for small bird species (Wolf 2000). This makes climate change especially dire as temperature is predicted to increase while moisture is expected to decrease in most locations. Although other vulnerability assessments also include indirect effects under sensitivity, we have chosen to assess direct and indirect effects separately (see section *v.* below). Sensitivity, as we describe it here, is determined by intrinsic traits and effectively multiplies the effects of climate exposure. For a simplified example, highly sensitive species may not be as vulnerable if they occur in regions buffered from climate change. Conversely, insensitive species may not be vulnerable even if they occur in regions expected to change rapidly. For this reason, we ultimately combined climate exposure and climate sensitivity scores when calculating total vulnerability.

Unfortunately, little information exists regarding physiological thresholds for avian species. Some insights can be gleaned from reviewing relationships between climate variables and species' distributions. Although such relationships can be confounded by factors unrelated to climate (e.g., competition, management, habitat destruction), there is support for predicting avian response to climate change (e.g., Jiguet et al. 2006 and 2007, Moussus et al. 2011, Hurlbert and Liang 2012). For avian species, this provides some of the only available information regarding sensitivity to climate change. In addition, the data are available for all avian species and can be reliably used for assessing climate change vulnerability. For our assessment, we used historic thermal range of tolerance as a gauge of sensitivity to future temperature change. We followed methods outlined in Jiguet et al. 2006 and 2007 and Moussus et al. 2011. We adapted these same methods to calculate moisture range of tolerance using historic precipitation patterns. We used the Nature Conservancy's Climate Wizard online tool to gather historic climate data (seasonal mean temperature and precipitation, 1951 – 2001). This was done for summer using climate data from each species' entire breeding range (Jun – Aug) and for winter using each species' entire non-breeding range (Dec – Feb). We calculated the range of tolerance as the weighted mean from the 50 hottest (driest) cells minus the weighted mean from the 50 coldest (wettest) cells using ArcGIS® (ESRI 2010). We calculated range of tolerance separately for breeding and non-breeding seasons.

iv. Adaptive Capacity to Climate Change—Adaptive capacity describes the ability of a species to adjust to change. It is determined by intrinsic traits and includes both evolutionary potential and phenotypic plasticity (Williams et al. 2008, Dawson et al. 2011). For most avian taxa, evolutionary potential is largely unknown. Fortunately, more is known about potential plasticity (e.g. life history traits and behavioral characteristics). For this reason and because paleontological evidence suggests phenotypic plasticity may be more important than evolutionary capacity (Dawson et al. 2011), we focused on plasticity of relevant life history traits. In a changing environment, individuals and populations will need to find suitable resources under novel conditions. Species with more flexibility are more likely to take advantage of changing ecosystems, regardless of the specific details of the environmental change. They will be more likely to use novel combinations of resources *in situ* or will be able to move and track changing resources more quickly. Observational and correlational evidence to support this theory is found in several studies of avian taxa (e.g., Jiguet et al. 2007, Moller et al. 2008, Vegvari et al. 2009, Dawson et al. 2011, Moussus et al. 2011, Salido et al. 2011). To asses adaptive capacity, we gathered information on avian life history traits from the Birds of North America (Poole 2005). We included four traits (Box 5) that we considered the most reliable indices of flexible behavior in unpredictable environments as supported by the literature.

BOX 5.

Components of the Adaptive Capacity Category

Migration strategy: short, medium, long, or ultra long-distant migrant; short distance migratory birds may be less vulnerable because they are better able to adjust to phenological changes (Both and Visser 2001, Salido et al. 2008, Moller et al. 2011, Moussus et al. 2011, Hurlbert and Liang 2012)

Habitat niche specialization: diversity of general habitat types used and micro habitats used such as nesting habitat; generalists may be less vulnerable because it is less likely that all habitat types will disappear due to climate change (Jiguet et al. 2007, Moussus et al. 2011)

Diet niche specialization: diversity of general and specific food groups taken and diversity of foraging strategies used; generalists may be less vulnerable because it is less likely that all food types will be negatively affected by climate change (Vegvari et al. 2009, Angert et al. 2011)

Breeding site fidelity: probability to return to a particular location (within and between breeding seasons); strategies of high fidelity work well in stable environments while nomadic or transient strategies are better suited to unpredictable environments (Dean 1997)

v. Indirect Effects of Climate Change—Habitat vulnerability and changes to important biotic interactions due to climate change are often quantified under sensitivity, or adaptive capacity. In our analysis they are assessed separately because they are primarily determined by extrinsic factors. Although it may be particularly difficult to assess indirect effects, many correlational studies suggest that climate change will affect species survival through biotic interactions rather than direct physiological stressors (Parmesan 2006, Cahill et al. 2012).

An example of indirect effects, this stand of fraser firs has been decimated by the balsam wooly adelgid (photo by B Stansberry)

Some information is available regarding the vulnerability of specific habitat types to climate change and several are known to be extremely vulnerable. For example, the Saltmarsh Sparrow (*Ammodramus caudacutus*) uses salt marshes exclusively throughout the year, which are particularly vulnerable to sea level rise from climate change (IPCC 2014). Consequently, Saltmarsh Sparrows would rank highly vulnerable under the indirect effects category. This parameter does not overlap with the category for habitat niche specialization above because here, we address specific predictions of how climate change will affect particular habitats. For species that use more than one habitat, we considered vulnerability of all those used and took an average. Much less is known regarding biotic interactions and potential changes to species relationships due to climate change, although even a descriptive assessment could be informative. Possible biotic interactions we considered included: changes in prey or other resources, predators, disease, parasites, and competitors. For example, warming of lakes and other water bodies is expected to make aquatic toxins more prevalent (USDA 2012), which would decrease prey quality for aquatic foraging species and increase vulnerability.

To assess indirect effects of climate change, we conducted a literature review of the vulnerability of habitats and biotic interactions. Although the category tends to be more subjective than others in the vulnerability framework, we provide detailed descriptive narratives of indirect effects for each species and indicate which data are well supported and where information gaps exist. This is sometimes thought of as a sensitivity factor and thus combined with exposure to climate change. However, because our assessment of indirect effects is a general summary of habitat and other resource vulnerability from the literature, exposure has already been factored in.

2.5. SCORING AND CALCULATING VULNERABILITY

Components of the vulnerability assessment were each scored separately on a 5-point scale with five being most vulnerability. Scores are defined below and color-coding was used throughout this report to aid interpretation. We used the same scale to score total vulnerability.

Score	< 1	No vulnerability or positive response
	1.0-1.9	Low vulnerability
	2.0-2.9	Moderate vulnerability
	3.0-3.9	High vulnerability
	4.0-5.0	Very high vulnerability

We calculated total vulnerability as an average of all the individual categories. Climate exposure and sensitivity were included as a combined score rather than their individual effects (see section *2.4 ii×iii* below):

TOTAL VULNERABILITY = average of [background risk score + climate exposure & sensitivity combined score + adaptive capacity score + indirect effects score]

We also report a score for just the climate change related factors, which can be compared to background risk. Calculation was similar to total vulnerability but excluded the background risk:

CLIMATE CHANGE VULNERABILITY = average of [climate exposure & sensitivity combined score + adaptive capacity score + indirect effects score]

i. Background Risk Scoring and Calculation

Where quasi-extinction risk was available (31 species):

BACKGROUND RISK = average of [quasi-extinction risk score + maximum from breeding and non-breeding range size scores + maximum from breeding and non-breeding PIF threats scores]

Where quasi-extinction risk was not available (15 species), we converted PIF conservation scores to a 5-point scale and used either the PIF breeding score or the non-breeding score (whichever was greater, Punjabi et al. 2012) as our background risk subscore:

BACKGROUND RISK (ALTERNATE) = maximum from breeding and non-breeding PIF scores

		Quasi-extinction
Score	1	Quasi-extinction probability < 0.01 and 95% CI includes 0
	2	Probability ≥ 0.01 and < 0.10; 95% CI does not include 0
	3	Probability ≥ 0.10 and < 0.25; 95% CI does not include 0
	4	Probability ≥ 0.25 and < 0.50; 95% CI does not include 0
	5	Probability ≥ 0.50; 95% CI does not include 0

		Range size
Score	1	range size ≥ 4,000,000 km2
	2	range size ≥ 1,000,000 km2 and < 4,000,000
	3	range size ≥ 300,000 km2 and < 1,000,000
	4	range size ≥ 80,000 km2 and < 300,000
	5	range size < 80,000 km2

		Threats (from PIF)
Score	1	No threat: future conditions for breeding populations expected to improve
	2	Low threat: future conditions for breeding populations are expected to remain stable; no significant threats
	3	Moderate threat: slight to moderate decline in the future suitability of breeding conditions is expected
	4	High threat: severe deterioration in the future suitability of breeding conditions is expected
	5	Very high threat: extreme deterioration in the future suitability of breeding conditions is expected; species is in danger of extirpation from substantial portions of range leading to a major range contraction, or has a low probability of successful reintroduction across a substantial former range

See Punjabi et al. 2012 for more details

ii. Climate Exposure Scoring and Calculation

We calculated temperature and moisture exposure subscores separately for each region and season:

- Summer temperature change in the UMGL
- Summer moisture change in the UMGL
- Overall winter temperature change: all relevant, species-specific, non-breeding regions combined (identified through migratory connectivity)
- Regional winter temperature change: individual, species-specific, non-breeding regions (N. America, Mexico, Caribbean, C. America, and S. America)
- Overall winter moisture change: all relevant, species-specific, non-breeding regions combined (see above)
- Regional winter moisture change: individual, species-specific, non-breeding regions (see above)

We also calculated total, species-specific, climate exposure subscores:

TOTAL CLIMATE EXPOSURE = average of [summer temperature score + summer moisture score + overall winter temperature score + overall winter moisture score]

Temperature		
Score	0	< 0.6° C increase[†]
	1	0.6-1.19° C increase
	2	1.2-1.79° C increase
	3	1.8-2.39° C increase
	4	2.4-2.99° C increase
	5	≥ 3.0° C increase

Moisture		
Score	0	< 2.0% change
	1	2.0-3.9% change
	2	4.0-5.9% change
	3	6.0-7.9% change
	4	8.0-9.9% change
	5	≥ 10% change

[†]No species are expected to experience decreased temperatures by mid-century.

Scoring thresholds derived from

IPCC (2007)—Global temperatures have risen ~0.2° C per decade over the last 20 years and will continue to rise at the same rate or greater over the next two decades, in addition, temperatures will rise 2.0-5.4° C by the end of the century under the A2 emissions scenario

Pryor (2014)—Midwest temperatures have risen ~0.8° C over the last century and are projected to rise ~2.7° C by mid-century and ~4.7° C by the end of the century

Freeley et al. (2010)—Distribution models of tropical vegetation show an average decline in area of 48% (45% decline in species diversity) under a 2° C warming trend, compared to an average decline in area of 62% (67% decline in species diversity) under 4° C warming trend

USFS (2013)—Describes negative effects on temperate forests due to warming of < 1° C over the last 30 years, in addition, the authors place their precipitation scale on 2%-increments of change

iii. Climate Sensitivity Scoring and Calculation

We calculated temperature and moisture sensitivity subscores separately by season:

- Summer thermal range of tolerance on the breeding grounds
- Summer moisture range of tolerance on the breeding grounds
- Winter thermal range of tolerance on the non-breeding grounds
- Winter moisture range of tolerance on the non-breeding grounds

We also calculated total climate sensitivity subscores:

TOTAL CLIMATE SENSITIVITY = average of [summer thermal sensitivity score + summer moisture sensitivity score + winter thermal sensitivity score + winter moisture sensitivity score]

Temperature

Score	0	range > 20.0° C
	1	range between 16.0-19.9° C
	2	range between 12.0-15.9° C
	3	range between 8.0-11.9° C
	4	range between 4.0-7.9° C
	5	range < 4.0° C

Moisture

Score	0	range > 150 cm
	1	range between 120-149 cm
	2	range between 90-119 cm
	3	range between 60-89 cm
	4	range between 30-59 cm
	5	range < 30 cm

Scoring breaks and range of values derived from:

Jiguet et al. (2007)—On average, birds with a thermal range < 4° C were flexible 57% of the time; with a range of 4-8° C flexible 57-68% of the time; with a range of 8-12° C flexible 68-75% of the time; with a range of 12-16° C flexible 82-89% of the time; with a range of 16-20° C flexible 93-96% of the time; and with a range > 20° C flexible 100% of the time

Moussus et al. (2011)—On average, birds with a thermal range < 4° C were flexible 32-36% of the time; with a range of 4-8° C flexible 41-52% of the time; with a range of 8-12° C flexible 66-82% of the time; with a range of 12-16° C flexible 93-100% of the time; with a range of 16-20° C flexible 100% of the time; with a and range > 20° C flexible 100% of the time

ii × iii. Climate Effect (Climate Exposure & Sensitivity)

We calculated a climate effect subscore (climate exposure and climate sensitivity combined):

CLIMATE EFFECT = (climate exposure score × climate sensitivity score)^{½}

Taking the square root ensures that the combined score remains on a 5-point scale, similar to the other categories

iv. Adaptive Capacity to Climate Change Scoring and Calculation

ADAPTIVE CAPACITY = average of [migration strategy score + breeding habitat specialization score + breeding diet specialization score + breeding site fidelity score + non-breeding habitat specialization score + non-breeding diet specialization score]

Migration Strategy

Score	1	Entirely sedentary and non-migratory
	2	Partial or short-distance migrant (breeding and non-breeding ranges completely or almost completely overlap and there is < 1500 km between centers of distributions)
	3	Medium-distance migrant (there may be some overlap between breeding and non-breeding ranges and there is 1500-4000 km between centers of distributions)
	4	Long-distance migrant (none or very little overlap between breeding and non-breeding ranges and there is 4000-7000 km between centers of distributions)
	5	Ultra long-distance migrant (> 7000 km between centers of distributions)

Continued on next page

iv. Adaptive Capacity Continued

Continued from previous page

Habitat Specialization

Score	1	Extremely flexible habitat use: e.g. uses very diverse number of habitats for macro habitat and micro nesting habitat (> 4); or uses 4 types for one (macro or micro) and > 4 for the other
	2	Flexible in at least one aspect of habitat use: e.g. uses diverse number of habitats for both macro and micro (4 types); or uses 3 types for one (macro or micro) and 4 types for the other; or uses 1-2 types for one (macro or micro) and > 4 for the other
	3	Moderately flexible or specialized in one aspect of habitat use: e.g. uses 3 habitat types for both macro and micro; or uses 2 types for one (macro or micro) and 3-4 for the other; or uses just 1 type for one (macro or micro) and 4 for the other
	4	Moderately specialized habitat use: e.g. uses 2 habitats for both macro and micro; or uses 1 type for one (macro or micro) and 2-3 for the other
	5	Extremely specialized habitat use: e.g. uses just 1 habitat type for both macro and micro

Diet Specialization

Score	1	Extremely flexible diet and foraging: e.g. takes a very diverse number of food groups and species (> 4) and uses wide variety of foraging strategies (> 4); or takes 4 food groups combined with > 4 strategies, or vice versa
	2	Flexible in at least one aspect of diet and foraging: e.g. takes diverse number of food groups (4) and uses variety of foraging strategies (4); or takes 1-3 food groups combined with ≥ 4 foraging strategies, or vice versa
	3	Moderately flexible or specialized in one aspect of diet and foraging: e.g. takes 3 different food groups and uses 3 foraging strategies; or takes 2 food groups and uses 3-4 foraging strategies, or vice versa; or takes just 1 food group and uses 4 foraging strategies, or vice versa
	4	Moderately specialized diet and foraging: e.g. takes 2 different food groups and uses 2 different foraging strategies; or takes 1 food group and uses 2-3 foraging strategies, or vice versa
	5	Extremely specialized diet and foraging: e.g. specialized on just a few species from a single food group and limited to just one foraging strategy

Breeding Site Fidelity

Score	1	No site fidelity at all: nomadic and breeds wherever and whenever conditions are right
	3	Some site fidelity: species will attempt breeding once at beginning of the breeding season but moves quickly after failure and attempts to breed at a new location; or species shifts breeding location between years according to conditions
	5	High site fidelity: once an individual has dispersed after juvenile period, it remains faithful to its breeding location and returns every year, sometimes to the exact same territory

v. Indirect Effects of Climate Change Scoring and Calculation

We assessed separately four different indirect effects of climate change. Vulnerability for these four factors was assessed for each bird species entire breeding and non-breeding range

- Habitat vulnerability on the breeding grounds
- Changes in other resources on the breeding grounds (vulnerability of biotic interactions)
- Habitat vulnerability on the non-breeding grounds
- Changes in other resources on the non-breeding grounds (vulnerability of biotic interactions)

We also calculated overall indirect subscores:

INDIRECT EFFECTS = average of [breeding habitat vulnerability score + breeding biotic interactions vulnerability score + non-breeding habitat vulnerability score + non-breeding biotic interactions vulnerability score]

<u>Habitat Vulnerability</u>

Score	0	Overall increase in area or quality of the habitats used
	1	No change in area or quality of any of the habitats used
	2	Some decrease in area or quality (e.g., 10-20% of habitat types are vulnerable, or potential loss of 10-20% of habitat area)
	3	Moderate decrease in area or quality (e.g., 20-50% of habitat types are vulnerable, or potential loss of 20-50% of habitat area)
	4	Large decrease in area or quality (e.g., 50-70% of habitat types are vulnerable, or potential loss of 50-70% of habitat area)
	5	Extreme decrease in area or quality (e.g., >70% of habitat types are vulnerable, or potential loss of >70% of habitat area)

<u>Biotic Interaction Vulnerability</u>

Score	0	Overall increase in resources and/or decrease in predators, disease vectors, or competitors is expected
	1	No change in resources and/or predators, disease vectors, or competitors is expected
	2	Some decrease in resources and/or increase in predators, disease vectors, or competitors is expected
	3	Moderate decrease in resources and/or increase in predators, disease vectors, or competitors is expected
	4	Large decrease in resources and/or increase in predators, disease vectors, or competitors is expected
	5	Extreme decrease in resources and/or increase in predators, disease vectors, or competitors is expected

3. Results Summary

Black Tern was ranked highly vulnerable (photo by O Runolfsson)

3.1. BACKGROUND RISK AND CLIMATE CHANGE VULNERABILITY SCORES

We assessed climate change vulnerability of 46 migratory bird species that breed in the UMGL (Table 3.1). Total vulnerability included background risk, climate exposure × climate sensitivity, adaptive capacity to climate change, and indirect effects of climate change. Two species were ranked as having low vulnerability, nine species were ranked as being highly vulnerable, and the remainder were categorized as having moderate levels of vulnerability (median score = 2.6 out of 5.0, Figure 3.1, Table 3.1). On average,

Table 3.1. Vulnerability scores and subscores for 46 migratory species breeding in the Upper Midwest Great Lakes LCC. Total vulnerability includes background risk and climate change vulnerability. Climate change vulnerability includes exposure x sensitivity, adaptive capacity, and indirect effects. Maximum score is 5 for all columns. Scores < 2.0 (yellow) are considered low vulnerability while scores ≥3.0 (dark orange) are considered high vulnerability.

	Total vulnerability	Background risk	Climate change vulnerability	Exposure and sensitivity	Adaptive capacity	Indirect effects
* Pied-billed Grebe	2.7	3.3†	2.5	0.7	3.6	3.3
Red-necked Grebe	3.1	3.3	3.1	1.6	4.0	3.8
Green Heron	2.7	3.0	2.6	1.4	3.3	3.1
* Black-crowned Night-Heron	2.4	3.3†	2.2	0.7	2.9	2.9
American Kestrel	2.1	3.6†	1.6	0.7	2.8	1.2
* Peregrine Falcon	2.1	3.1†	1.8	0.6	3.1	1.8
Killdeer	1.7	1.7	1.8	1.1	2.9	1.3
* Upland Sandpiper	2.4	2.0	2.6‡	2.1	4.3	1.3
Caspian Tern	3.2	2.8	3.3‡	2.6	3.5	3.9
* Black Tern	3.3	2.8	3.5‡	2.9	4.1	3.6
* Common Tern	2.9	2.8	3.0	1.4	3.9	3.6
Forster's Tern	3.3	3.0	3.4	2.5	3.5	4.2
Yellow-billed Cuckoo	2.3	2.1	2.4	2.0	3.6	1.5
* Black-billed Cuckoo	2.5	2.7	2.4	2.1	3.6	1.5
* Short-eared Owl	2.1	3.0†	1.8	0.8	2.9	1.7
Northern Saw-whet Owl	2.2	2.8†	1.9	1.2	3.0	1.7
Common Nighthawk	2.2	2.9†	1.9	1.1	3.6	1.0
* Eastern Whip-poor-will	3.2	3.7	3.1	2.9	4.3	2.0
* Red-headed Woodpecker	2.0	2.2	1.9	1.4	3.0	1.4
Yellow-bellied Sapsucker	2.3	2.4	2.3	2.0	3.3	1.7
Yellow-bellied Flycatcher	3.2	3.7	3.1	2.6	3.8	2.8
* Acadian Flycatcher	2.8	2.4	2.9‡	2.4	3.9	2.5

*Species of conservation concern in USGS Region 3; †background risk score is at least 20% greater than climate change vulnerability; ‡climate change vulnerability score is at least 20% greater than background risk vulnerability for species of conservation concern was greater than for common species, although this difference was not statistically different (median scores = 2.7 and 2.3, respectively, W = 334, p = 0.13).

For 10 species, background risk (which included PIF conservation status and was unrelated to climate change) was at least 20% greater than climate change vulnerability (which included climate-change related factors: climate exposure × climate sensitivity, adaptive capacity to climate change, and indirect effects of climate change) while for 13 species the opposite was true (Table 3.1). However, on average, background risk and climate change vulnerability were not different (median scores = 2.7 and 2.6, respectively, W = 1115, p = 0.66, Figure 3.1).

Common Terns have high breeding site fidelity (photo by DGE Robertson)

For most species, the adaptive capacity category (which included migration strategy, habitat specialization, diet specialization, and breeding site fidelity) was the leading

Table 3.1. Continued

	Total vulnerability	Background risk	Climate change vulnerability	Exposure and sensitivity	Adaptive capacity	Indirect effects
Swainson's Thrush	2.8	3.3†	2.6	1.8	3.7	2.3
* Wood Thrush	2.8	2.7	2.8	2.9	3.5	2.0
* Worm-eating Warbler	3.2	3.3	3.1	3.1	3.8	2.4
* Golden-winged Warbler	2.8	2.7	2.9	2.8	3.8	2.0
* Blue-winged Warbler	2.8	2.4	2.9‡	3.2	3.8	1.7
Black-and-white Warbler	2.5	1.8	2.7‡	2.1	3.8	2.3
Tennessee Warbler	2.8	3.1	2.7	2.5	3.5	2.0
Nashville Warbler	2.7	2.1	3.0‡	3.1	3.7	2.1
American Redstart	2.3	1.8	2.5‡	2.0	3.1	2.4
* Cerulean Warbler	2.9	2.8	3.0	2.4	4.0	2.3
Yellow Warbler	2.2	1.5	2.4‡	1.6	3.0	2.7
Black-throated Blue Warbler	3.0	3.7†	2.8	2.9	3.5	2.1
* Prairie Warbler	2.7	2.4	2.8	3.1	3.2	1.9
* Canada Warbler	2.8	2.3	3.0‡	2.5	4.0	2.6
* Field Sparrow	2.2	2.0	2.2	2.4	3.3	1.0
Vesper Sparrow	2.2	2.1	2.2	2.5	3.2	1.0
Savannah Sparrow	2.0	1.5	2.2‡	1.4	3.4	1.8
Indigo Bunting	2.0	1.7	2.1‡	2.6	2.6	1.0
* Dickcissel	2.6	3.0†	2.5	3.1	3.4	0.9
* Bobolink	2.6	2.5	2.6	2.5	4.1	1.2
Red-winged Blackbird	1.5	1.3	1.6	0.5	2.5	1.7
* Rusty Blackbird	3.0	3.3	2.9	1.5	4.0	3.1
* Orchard Oriole	2.3	2.0	2.4	2.9	3.0	1.3
Baltimore Oriole	2.1	1.8	2.2‡	2.7	2.9	1.2

*Species of conservation concern in USGS Region 3; †background risk score is at least 20% greater than climate change vulnerability; ‡climate change vulnerability score is at least 20% greater than background risk

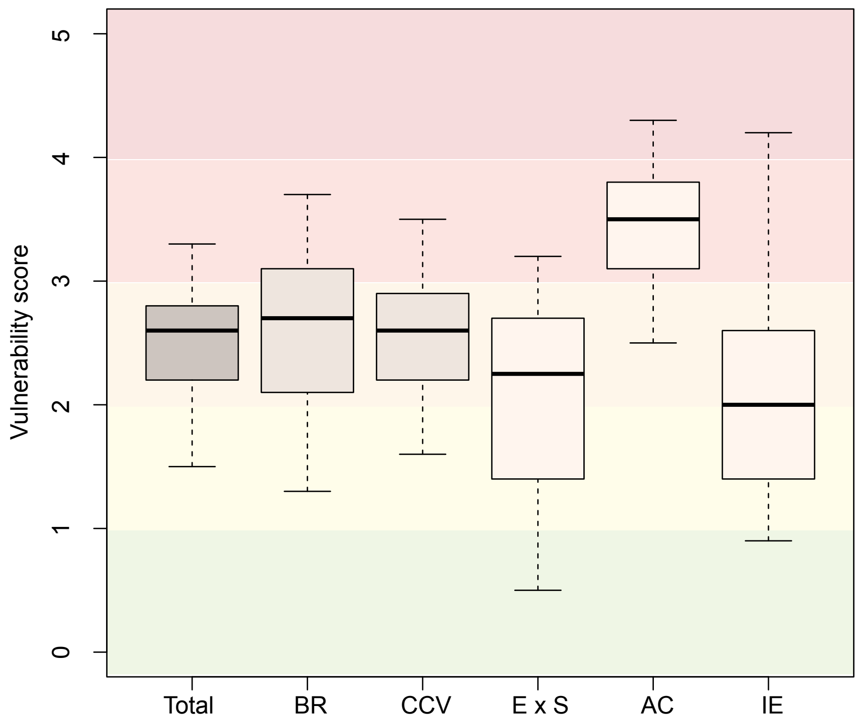


Figure 3.1. Distribution of vulnerability scores for 46 migratory species breeding in the UMGL. Total vulnerability (Total) includes background risk (BR) and climate change vulnerability (CCV). Climate change vulnerability includes exposure x sensitivity (E x S), adaptive capacity (AC), indirect effects (IE).

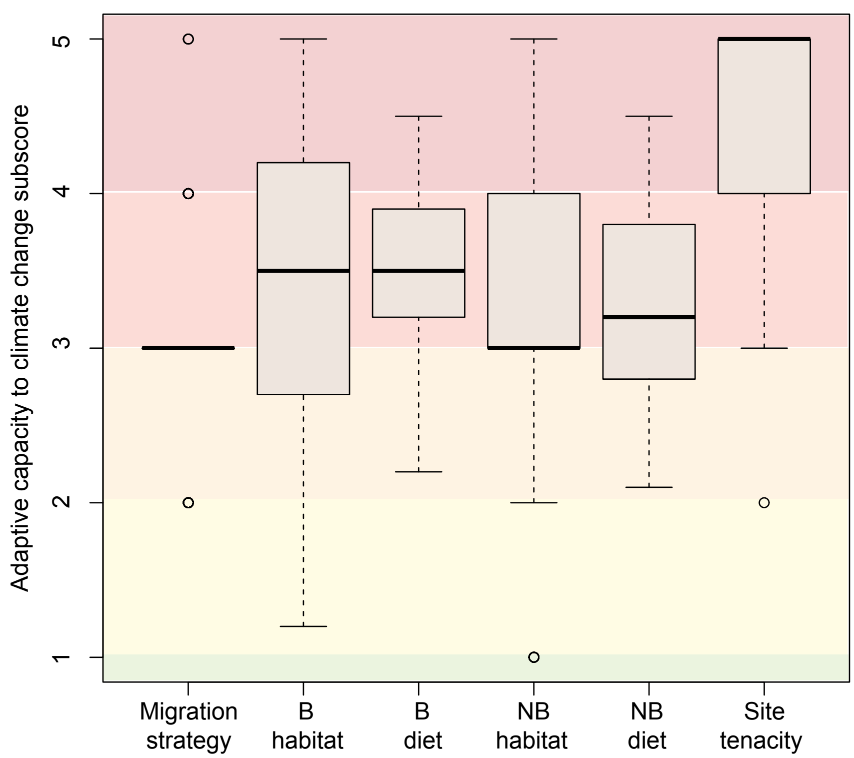


Figure 3.2. Distribution of adaptive capacity subscores for 46 migratory species breeding in the UMGL (migration strategy, breeding habitat specialization, breeding diet specialization, non-breeding habitat specialization, non-breeding diet specialization, and breeding site tenacity).

contributor to total vulnerability—relative to background risk, climate exposure × climate sensitivity, and indirect effects of climate change (Table 3.1, Figure 3.1). Within the adaptive capacity category, species with high scores were, on average, reluctant to move to new breeding locations between years (breeding site fidelity median score = 5.0) and were fairly specialized in their breeding habitat use and breeding diet (breeding habitat and diet specialization median scores both = 3.5, Figure 3.2).

3.2. INFLUENCE OF BREEDING VERSUS NON-BREEDING SEASON

General predictions of mean climate change varied among regions and seasons. North America is expected to experience greater

Amazon rainforest from above, Brazil (photo by Lubasi)

Mangrove forest, Brazil (photo by CP Barreto)

temperature increases in winter compared to Mexico, Caribbean, Central America, or South America and compared to the UMGL region in the summer (mean temperature increases = 3.7, 2.0, 1.6, 1.8, 2.0, and 2.9° C, respectively). Mexico in the winter will experience the greatest drying and moisture deficits compared to N. America, Caribbean, C. America, and S. America in the winter and compared to UMGL in the summer (mean moisture loss = 8, 0, 6, 4, 1, and 4%, respectively).

The climate exposure × climate sensitivity combined effect on avian vulnerability was significantly different among regions and seasons. On average, temperature increases on the UMGL breeding grounds will have a larger effect on vulnerability compared to most non-breeding locations (UMGL median score = 2.9; N. America median score = 0.6, W = 854, $p < 0.001$; Mexico median score = 2.0, W = 828, $p = 0.017$; Caribbean median score = 1.6, W = 726, $p = 0.003$; and C. America median score = 2.0, W = 860, $p = 0.15$; Figure 3.3). The exception was S. America where the effect of temperature will be as great as on the UMGL (S. America median score = 2.4, W = 620, $p = 0.25$, Figure 3.3). In contrast, moisture changes (i.e. drying) in the Mexican and Caribbean non-breeding regions will have a greater effect on vulnerability compared

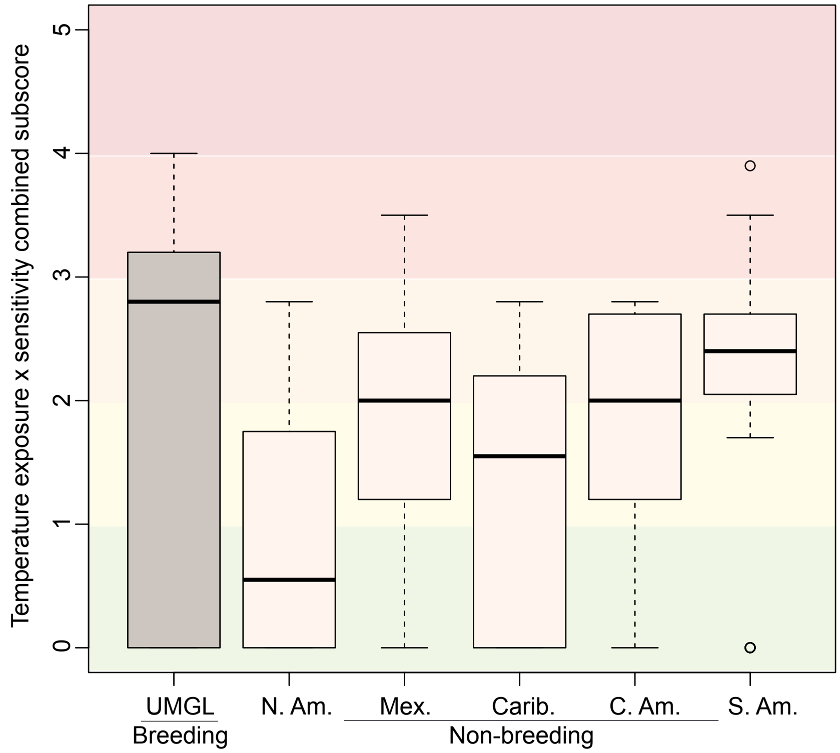


Figure 3.3. Distribution of the combined temperature exposure x sensitivity subscores for 46 migratory species breeding in Upper Midwest Great Lakes and wintering in five non-breeding regions (N. America, Mexico, Caribbean, C. America, and S. America).

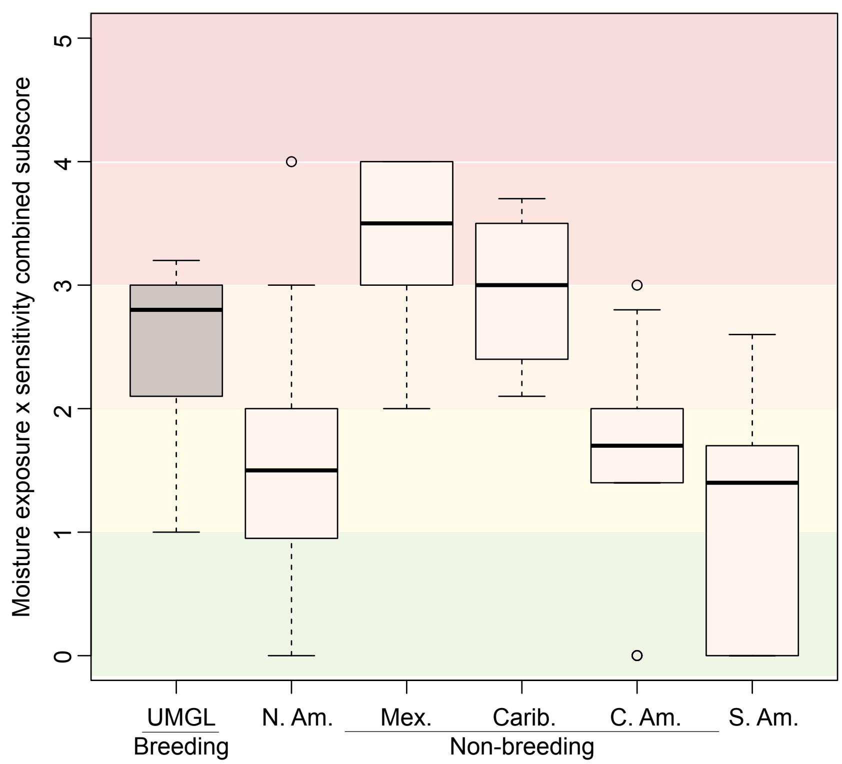


Figure 3.4. Distribution of the combined moisture exposure x sensitivity subscores for 46 migratory species breeding in the Upper Midwest Great Lakes and wintering in five non-breeding regions (N. America, Mexico, Caribbean, C. America, and S. America).

to anywhere else, including the UMGL breeding grounds (UMGL median score = 2.8 out of 5.0; Mexico median score = 3.5, W = 1042, $p < 0.001$; Caribbean median score = 3.0, W = 742, $p = 0.002$; Figure 3.4).

3.3. HABITAT DIFFERENCES

When species were grouped according to dominant breeding habitat type, some variation in total vulnerability was found. Species that used coniferous forest or wetland habitats had higher total vulnerability on average compared to species that used deciduous forest or woodland, mixed forest, shrubland, grassland, or open habitat (median vulnerability scores = 3.0, 2.8, 2.6, 2.6, 2.4, 2.3, and 2.1, respectively). There was a trend for differences in vulnerability among dominant breeding habitat type ($\chi2 = 11.4$, $p = 0.08$, Figure 3.5). Sample sizes were not even or large across habitat types, so including additional species in the analysis may increase differences.

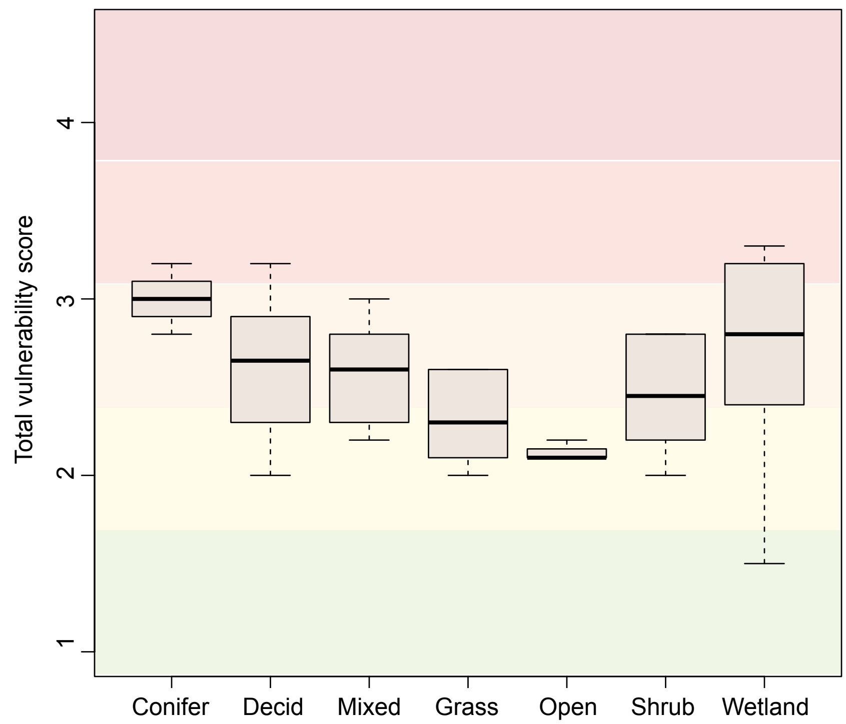


Figure 3.5. Distribution of total vulnerability scores for species that primarily use coniferous forest, deciduous forest or woodland, mixed forest, grassland, open habitat, shrubland, and wetland habitat during the breeding season.

Boreal forest, Quebec (photo by Peupleloup)

3.4. SENSITIVITY ANALYSIS

i. Background risk—In the 15 cases for which we could not calculate quasi-extinction risk due to lack of BBS data, we deferred to the PIF conservation status score (see 2.3.i). For these species, the PIF conservation status score indicated a high background risk (median score = 3.1, Figure 3.6). For the remaining 31 species, background risk was most strongly influenced by the threats category (quasi-extinction risk median score = 1.0, range size median score = 2.0, threats median score = 3.1, Figure 3.6).

Domestic cats are one non-climate change threat

ii. Temperature climate exposure—Vulnerability was most strongly influenced by mean temperature increase during summer on the UMGL (UMGL-summer temperature exposure median score = 4.0, N. America-winter temperature exposure median score = 3.0, Mexico-winter temperature exposure median score = 3.0, Caribbean-winter temperature median score = 2.0, C. America-winter temperature median score = 2.0, S. America-winter temperature median score = 3.0, Figure 3.7).

ii. Moisture climate exposure—Vulnerability was most strongly influenced by mean drying during winter in Mexico (UMGL-summer moisture exposure median score = 2.0, N. America-winter moisture exposure median score = 1.0, Mexico-winter moisture exposure median score = 4.0, Caribbean-winter moisture median

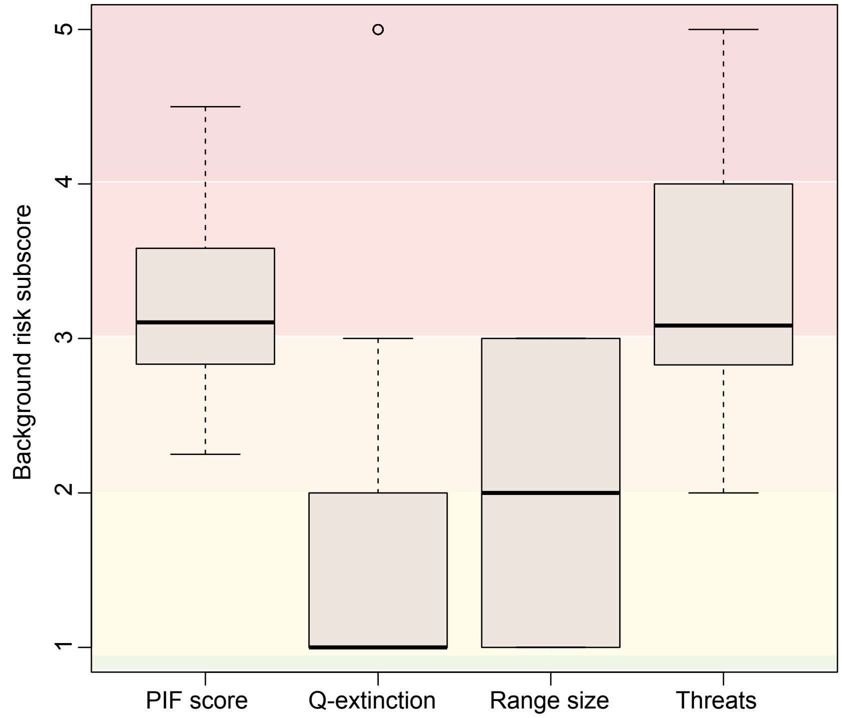


Figure 3.6. Distribution of background risk subscores for 46 migratory species breeding in the UMGL (PIF conservation status, quasi-extinction risk, range size, and PIF threats).

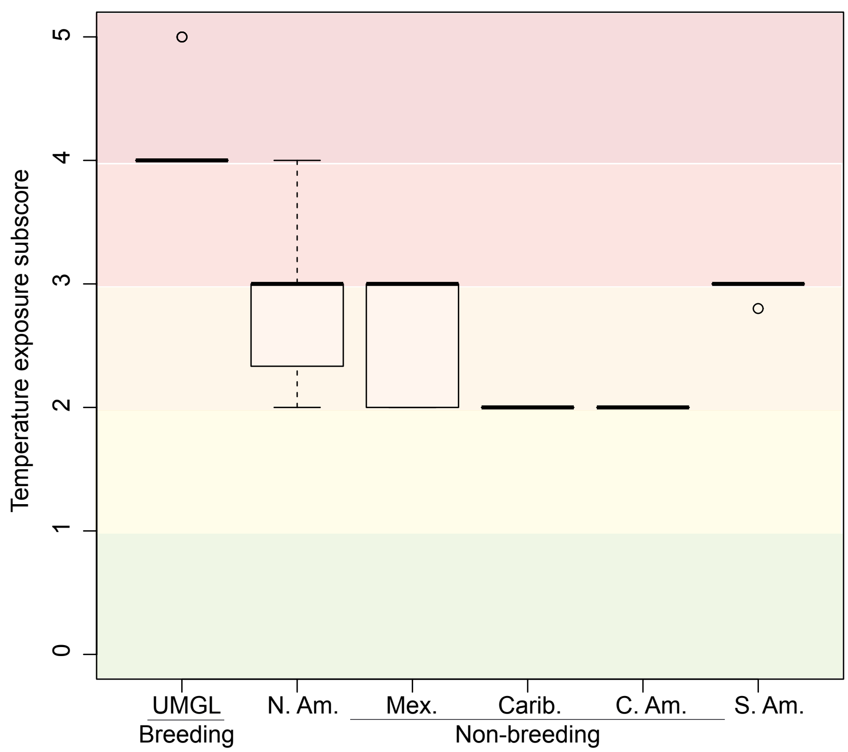


Figure 3.7. Distribution of temperature exposure subscores for 46 migratory species breeding in the Upper Midwest Great Lakes and wintering in five non-breeding regions (N. America, Mexico, Caribbean, C. America, and S. America).

Several species are very sensitive to moisture change during the non-breeding season

score = 3.0, C. America-winter moisture median score = 1.0, S. America-winter moisture median score = 1.0, Figures 3.8 and 3.9).

iii. Climate sensitivity—Vulnerability was most strongly influenced by sensitivity to moisture during the breeding season (breeding thermal sensitivity median score = 2.0, non-breeding thermal sensitivity median score = 2.0, breeding moisture sensitivity median score = 4.0, non-breeding moisture sensitivity median score = 3.0, Figure 3.10).

iv. Adaptive capacity to climate change—As noted above (see section 3.1), vulnerability in the adaptive capacity category was most strongly influenced by breeding site fidelity (i.e. a reluctance to move to new breeding locations within and between years; migration strategy median score = 3.0, breeding habitat specialization median score = 3.5, breeding diet specialization median score = 3.5, non-breeding habitat specialization median score = 3.0, non-breeding diet specialization median score = 3.2, and breeding site fidelity median score = 5.0, Figure 3.2).

v. Indirect effects of climate change—Vulnerability was most strongly influenced by breeding habitat vulnerability (breeding

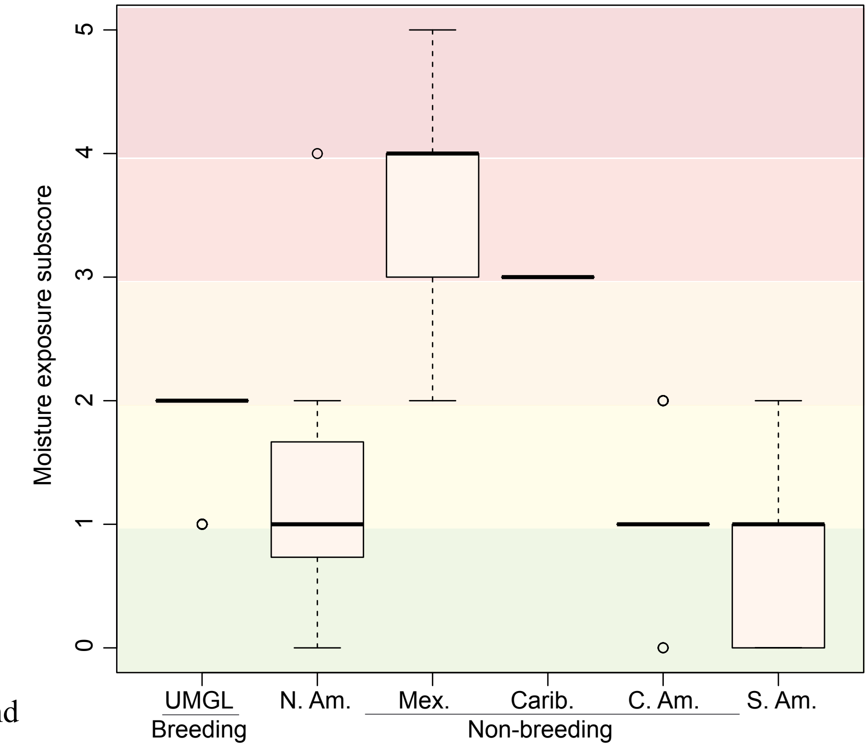


Figure 3.8. Distribution of moisture exposure subscores for 46 migratory species breeding in the Upper Midwest Great Lakes and wintering in five non-breeding regions (N. America, Mexico, Caribbean, C. America, and S. America).

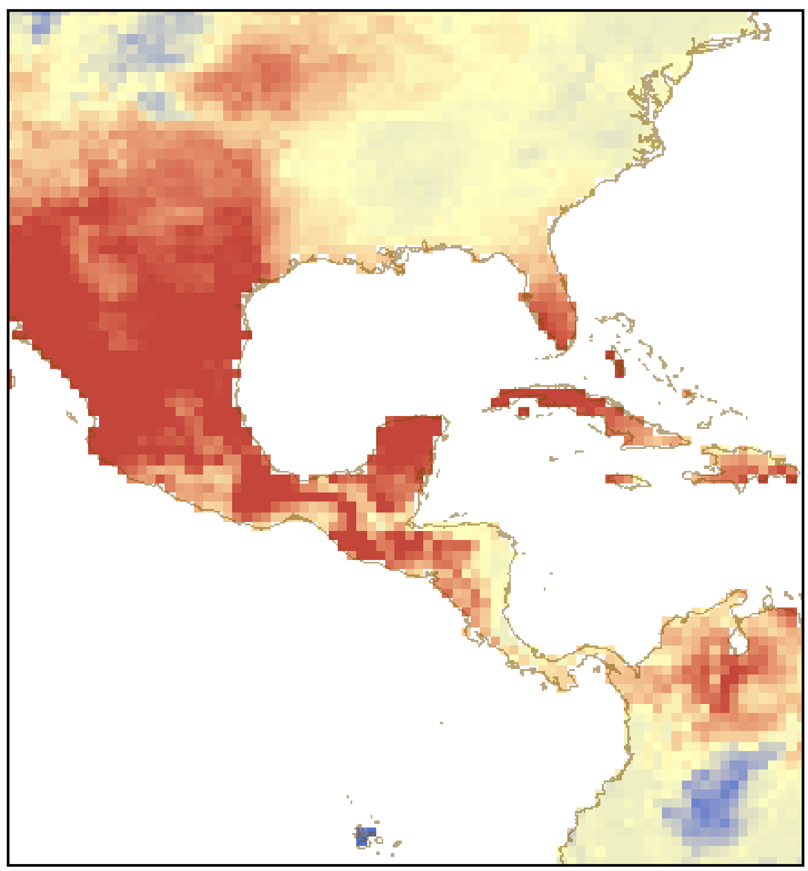


Figure 3.9. Mean moisture change during winter (Dec - Feb) is expected to be greatest in Mexico.

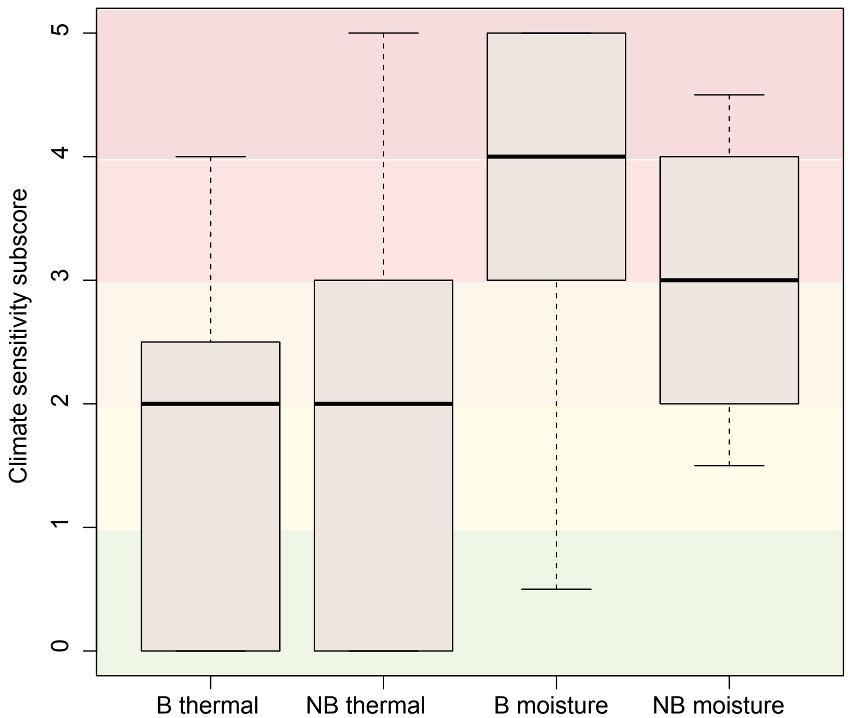


Figure 3.10. Distribution of climate sensitivity subscores for 46 migratory species breeding in the UMGL (breeding thermal range of sensitivity, non-breeding thermal range of sensitivity, breeding moisture range of sensitivity, and non-breeding moisture range of sensitivity).

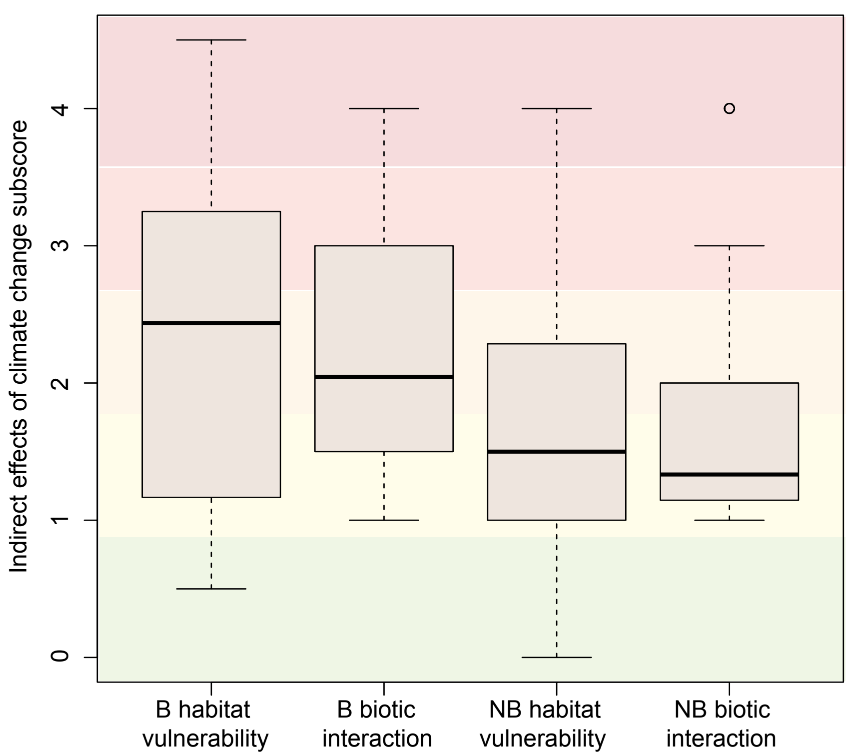
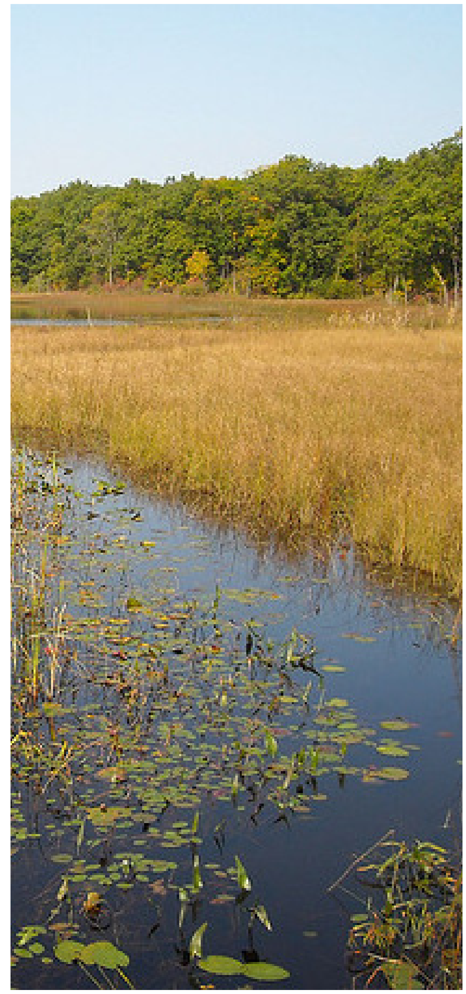


Figure 3.11. Distribution of indirect effects of climate change subscores for 46 migratory species breeding in the UMGL (breeding habitat vulnerability, breeding vulnerability of biotic interactions, non-breeding habitat vulnerability, and non-breeding vulnerability of biotic interactions).


Wetland habitat

habitat vulnerability median score = 2.4, breeding biotic interaction median score = 2.0, non-breeding habitat vulnerability median score = 1.5, non-breeding biotic interaction median score = 1.3, Figure 3.11). Furthermore, during the breeding season, the most vulnerable habitats were coniferous or boreal forests followed by wetlands. Therefore, species that primarily used those two habitats for breeding, had greater breeding habitat vulnerability scores as well as greater indirect effects scores.

3.5. MIGRATORY CONNECTIVITY

Despite its importance, little information is available about the migratory connectivity of North American birds. We used all available sources of information to determine the migratory connectivity for the UMGL populations of the 46 migratory species included here (Table 3.2). Of these, 13% had more than 100 breeding to non-breeding band encounters, 2% had 10 to 100, 30% had less than 10, and 54% had none. We conducted capture-recapture models of migratory connectivity of two species—Caspian and Common Tern. Our literature search found migratory connectivity information on 11 species and included data from stable isotope analysis, genetic analysis, morphology, light-level geolocators, and satellite telemetry. From the combined results (banding, modeling, and literature search), we were able to draw some conclusions regarding migratory connectivity for 10 species (Black-crowned Night-Heron, American Kestrel, Peregrine Falcon, Caspian Tern, Common Tern, Wood Thrush,

Table 3.2. Summary of migratory connectivity data, including number of banding data points (breeding to stationary non-breeding banding encounters originating from the UMGL), relevant literature, and inclusion of stationary non-breeding regions in vulnerability analysis (NA = N. America, MEX = Mexico, CAR = Caribbean, CA = C. America, SA = S. America). For 10 species, we were able to determine whether migratory connectivity was likely between the UMGL and each non-breeding region, but not the proportion of migrants to each region. We excluded non-breeding areas with no UMGL migratory connectivity. Regions left blank are not in the species range.

	Banding data	Literature review	Non-breeding region				
			NA	MEX	CAR	CA	SA
* Pied-billed Grebe	0		YES	YES	YES	YES	YES
Red-necked Grebe	0		YES				
Green Heron	0		YES	YES	YES	YES	YES
* Black-crowned Night-Heron	114		YES‡	x	YES	YES	x
American Kestrel	125	Hobson et al. 2009	YES	x	x	x	x
* Peregrine Falcon	165	Fuller et al. 1998	YES	x	YES	YES	YES‡
Killdeer	8		YES	YES	YES	YES	YES
* Upland Sandpiper	0						YES
Caspian Tern	266†		YES	x	YES	x	x
* Black Tern	2			YES		YES	YES
* Common Tern	279†		YES		YES	YES	YES
Forster's Tern	31		YES	YES	YES		
Yellow-billed Cuckoo	1						YES
* Black-billed Cuckoo	0						YES
* Short-eared Owl	0		YES	YES	YES		YES
Northern Saw-whet Owl	6		YES	YES			
Common Nighthawk	0				YES		YES
* Eastern Whip-poor-will	0		YES	YES		YES	
* Red-headed Woodpecker	3		YES				
Yellow-bellied Sapsucker	3		YES	YES	YES	YES	
Yellow-bellied Flycatcher	0			YES		YES	
* Acadian Flycatcher	0					YES	YES

*Species of conservation concern in USGS Region 3; †Capture-recapture model preformed; ‡non-breeding range in this region included in part

American Redstart, Cerulean Warbler, Yellow Warbler, and Red-winged Blackbird). When information about migratory connectivity from the UMGL was available, we determined whether UMGL populations may be connected to each non-breeding region. We did not assign a probability of connectivity to each non-breeding region because we had limited data. However, we excluded from the vulnerability analysis those non-breeding regions where the data did not support migratory connectivity with UMGL populations (Table 3.2). For the remaining 36 species, we included all non-breeding regions within each species range.

Banding data suggest Red-winged Blackbirds from the UMGL winter in N. America (photo by P Wilton)

Table 3.2. Continued.

	Banding data	Literature review	Non-breeding region				
			NA	MEX	CAR	CA	SA
Swainson's Thrush	0	Kelly et al. 2005		YES		YES	YES
* Wood Thrush	0	Stutchbury et al. 2011, Stanley et al. 2012, Rushing et al. 2013		YES		YES	
* Worm-eating Warbler	0			YES	YES	YES	
* Golden-winged Warbler	0					YES	YES
* Blue-winged Warbler	1			YES	YES	YES	
Black-and-white Warbler	1	Dugger et al. 2004	YES	YES	YES	YES	YES
Tennessee Warbler	0			YES	YES	YES	YES
Nashville Warbler	0	Lovette et al. 2004	YES	YES	YES		
American Redstart	0	Norris et al. 2006		YES	YES	YES	x
* Cerulean Warbler	0	Jones et al. 2008					YES
Yellow Warbler	0	Boulet et al. 2006		YES‡	x	YES	YES
Black-throated Blue Warbler	0	Rubenstein et al. 2002, Royle and Rubenstein 2004			YES	YES	
* Prairie Warbler	0		YES		YES	YES	
* Canada Warbler	0					YES	YES
* Field Sparrow	3		YES	YES			
Vesper Sparrow	1		YES	YES			
Savannah Sparrow	3		YES	YES	YES		
Indigo Bunting	3			YES	YES	YES	
* Dickcissel	0			YES		YES	YES
* Bobolink	0						YES
Red-winged Blackbird	325		YES‡	x	x		
* Rusty Blackbird	2	Hobson et al. 2010	YES‡				
* Orchard Oriole	0			YES		YES	YES
Baltimore Oriole	6		YES	YES	YES	YES	YES

*Species of conservation concern in USGS Region 3; †Capture-recapture model preformed; ‡non-breeding range in this region included in part

4. Discussion

Effective management of migratory animals requires a full annual and full life cycle approach to how we think about their biology and conservation. The approach presented here assesses vulnerability of migratory birds to climate change using species-specific seasonal and geographic scales. To date, several climate vulnerability assessments have been developed and conducted (e.g., EPA 2009, Young et al. 2011, Gardali et al. 2012) but none have attempted to account for the full annual cycle of events. Focusing solely on climate change during the breeding season ignores the majority of the animal's annual cycle. For example, we found that the effect of temperature and moisture change in the UMGL breeding areas had a moderate influence on vulnerability for some avian species while the effect of projected climate changes on the non-breeding areas varied greatly among species. From the results of our analyses, it is clear that an approach that overlooks exposure to climate change outside the breeding season could draw inaccurate conclusions about the vulnerability of migratory species to climate change.

Our approach to assessing climate change vulnerability offers several advantages over previous methodologies. A comprehensive evaluation of climate throughout a species annual cycle is important for both migratory and non-migratory species. In addition, we do not expect patterns of climate change to be consistent or in the same direction for each season and location, thus it does not make sense to use annual averages of climate exposure. The result may be a dilution of climate exposure and an underestimate of vulnerability. In addition, our approach embraces the complex life histories of many taxa, particularly migratory ones. Using a full annual cycle approach is the only way to evaluate potential carry-over effects between seasons and locations. Although carry-over effects may be indirect, they have been shown to influence some demographic parameters that may affect population viability (Huppop and Winkel 2006, Studds and Marra 2011, Rockwell et al. 2012).

Over one million Common Terns have been banded during the breeding season, facilitating our ability to decipher migratory connectivity (photo by M Kinsey Bruns).

Migratory connectivity is a critical component to the study of migratory species, whether the subject is the impact of climate change or the drivers of population dynamics. Knowing where birds from the UMGL spend the non-breeding season gives focus to the most relevant regions and habitat types. For most migratory animals, migratory connectivity research is still in its infancy and much remains to be discovered. Nevertheless, our analysis of BBL banding found at least some breeding to non-breeding band encounters for 46% of our focal species and several of these had more than 100 encounters. We were able to do an extensive capture-recapture model for Caspian Tern and Common Tern, revealing very different patterns of migratory connectivity. Land managers in the UMGL now know that most Caspian Terns breeding around the Great Lakes spend the winter in the southeastern U.S. and the Caribbean. Using this information, we predict that Caspian Terns from the UMGL may be more vulnerable than previously thought because of high exposure to moisture change in the Caribbean. Such information will enable a more targeted conservation strategy for this species and may foster collaborative management between the UMGL and the southeastern U.S. and/or Caribbean nations.

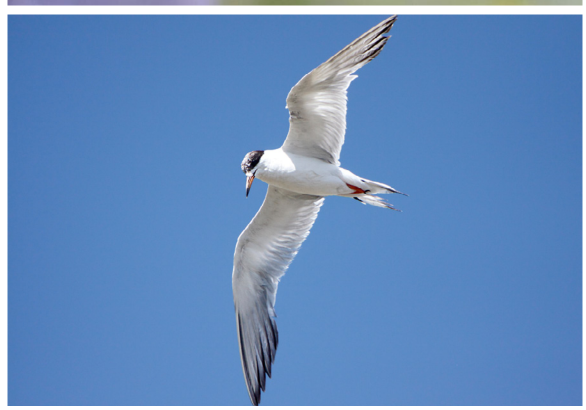
Red-necked Grebes were ranked as highly vulnerable, largely due to poor adaptive capacity to climate change and their dependence on wetlands.

Many of the species we considered in this analysis continue to have significant information gaps regarding migratory connectivity, including many that did not have any breeding to non-breeding band encounters. Although obtaining this information is notoriously challenging, there have been major advancements in the last decade in the field of animal movement tracking (e.g. stable isotope analysis, genetic analysis, archival tags, and satellite telemetry). As the field continues to progress, it is critical that information on migratory connectivity be employed to its full extent by conservation biologists. The vulnerability assessment approach presented here is an example of how knowledge of migratory connectivity can be a valuable and necessary resource. As more information becomes available, vulnerability should continue to be reassessed and refined.

Our approach focuses on migratory connectivity between the sedentary breeding and non-breeding locations and excludes the spring and fall migratory periods. Although the migratory period plays a substantial role in annual survival (Sillett and Holmes 2002) and exposure to climate change may be important during these periods (Ewert et al. in review), we did not include it here because migration routes and stopover sites are generally not fixed locations. Rather, sites may shift from year to year, making it hard to assess climate exposure. In addition, migration routes and important stopover sites are often not well known for species. We did not want lack of information to prevent us from presenting a full annual cycle approach. Therefore, we proceeded with the best data at hand and focused on the sedentary periods of the annual cycle.

We designed this assessment as an easy tool for use by anyone with access to Climate Wizard, peer-reviewed literature, and PIF conservation status. Although a full annual cycle approach is an improvement over previous vulnerability assessments, our approach does have limitations. Our evaluation of climate exposure consisted of the predicted change in mean temperature and moisture for a given season and location. Several studies predict that climatic stochasticity will also increase under climate change (Stakhiv 2011). Stochasticity in climate may be just as important to population viability as mean climate variables. For example, mean temperature may increase slowly over the decades, but the temperature of extreme heat waves may increase much more in a shorter period of time. The ability of species to survive extreme events will depend on several compounding factors, some of which were used in our vulnerability assessment. We did not include climatic stochasticity in our assessment because we did not have ready access to data on number and magnitude of extreme events for individual regions. We believe that the inclusion of stochasticity would improve the tool and look forward to adding it when possible. As mentioned above, information on migratory connectivity is an important component of this assessment. Lack of this information, however, should not prevent vulnerability analyses from being conducted. Instead, conservation biologists should use the information at hand and continue to reassess vulnerability as more data become available. We also cannot overlook the value of identifying specific information gaps in migratory connectivity, which our analysis does. Ultimately, this is an evolving tool, and we hope that it will continue to improve as more information becomes available regarding climate change and migratory connectivity.

This approach is designed to be broadly applicable to species of many regions and needs. It can and should be adapted to other methods, particularly as climate change science continues to advance and evolve (e.g. the fifth IPCC report on climate change was just finalized in March 2014). Here we used the full annual cycle approach to assess vulnerability of 46 migratory bird species that breed in the UMGL. The results we present apply to mid-century (2040-2069) climate change under an A2 high emissions scenario (IPCC SRES 2000). In addition, we used the 16-general circulation model ensemble available from Climate Wizard to predict climate change exposure. We recognize that it may be more appropriate to use a different time frame, emissions scenario, or ensemble of models, depending on management location and priority. The approach presented here can easily accommodate such modifications and still provide a comprehensive full annual cycle assessment.



Caspian, Black, and Forster's Terns all ranked highly vulnerable, primarily due to poor adaptive capacity to climate change and reliance on freshwater wetlands (photos by F Pestana, O Runolfsson, A Vernon)

4.1. THE MOST VULNERABLE SPECIES

We had four objectives specific to the UMGL region (Box 6 and see section 1.4).

BOX 6.

Objectives

1) Quantify vulnerability to climate change for 46 migratory bird species in the UMGL region

2) Determine at which stage (where and when) of the annual cycle species are most likely to be affected

3) Assess which factors contribute most to a species' vulnerability in terms of life history traits, habitat needs, and exposure to climate change

4) Define potential intrinsic or management-based adaptation strategies that could be adopted by managers

The first objective was to quantify climate change vulnerability for a suite of migratory birds. None of the species in our analyses were ranked as very highly vulnerable, though 20% were in the next category of highly vulnerable. These were Red-necked Grebe, Forster's Tern, Black Tern, Caspian Tern, Eastern Whip-poor-will, Yellow-bellied Flycatcher, Worm-eating Warbler, Black-throated Blue Warbler, and Rusty Blackbird. Only two species (4%) had low vulnerability—Killdeer and Red-winged Blackbird, leaving 76% of species in the moderately vulnerable category. Half of the species that we analyzed are considered common and not of conservation concern by the UMGL LCC. Our analysis, however, found that five of these may be highly vulnerable to climate change specific factors (excluding background risk), possibly warranting increased monitoring and/or management status. These were Red-necked Grebe, Caspian Tern, Forster's Tern, Yellow-bellied Flycatcher, and Nashville Warbler. Although a few species of conservation concern had low climate change vulnerability (Peregrine Falcon, Short-eared Owl, Red-headed Woodpecker), we do not recommend downgrading their management status because other factors, such as habitat loss or competition with invasive species, may be causing their populations to decline in the UMGL LCC.

When we separated our vulnerability assessment into climate change-specific vulnerability versus background risk, we found that five species were highly vulnerable to both. These were Red-necked Grebe, Forster's Tern, Eastern Whip-poor-will, Yellow-bellied Flycatcher, and Worm-eating Warbler. For these species, the combined effect of background risk (factors like habitat loss and small population size) and climate change may exacerbate vulnerability in the future, and heightened management should be a top priority. For ten species, background risk appeared to be the main factor driving vulnerability: Pied-billed Grebe, Black-crowned Night-Heron, American Kestrel, Peregrine Falcon, Short-eared Owl, Northern Saw-whet Owl, Common Nighthawk, Swainson's Thrush, Black-throated Blue Warbler, and Dickcissel. Whereas for 14 species, climate change appeared to be most important: Upland Sandpiper, Caspian Tern, Black Tern, Common Tern, Acadian Flycatcher, Blue-winged Warbler, Black-and-white Warbler, Nashville Warbler, American Redstart, Yellow Warbler, Canada Warbler, Savannah Sparrow, Indigo Bunting, and Baltimore Oriole. Among these species, the relative importance of climate change during the breeding versus non-breeding seasons varied greatly. Breeding season climate change was most important for Acadian Flycatchers (temperature), American Redstarts (moisture), and Canada Warblers (temperature); non-breeding season climate change was most important for Caspian Terns (moisture), Black Terns (temperature), Common Terns (temperature and moisture), Black-and-white Warblers (moisture), Nashville Warblers (moisture), Yellow Warblers (moisture), Indigo Buntings (moisture), and Savannah Sparrows (moisture); and both breeding and non-breeding season climate change were important for Upland Sandpipers (breeding moisture and non-breeding temperature), Blue-winged Warblers (breeding temperature and non-breeding moisture), and Baltimore Orioles (moisture).

The Eastern Whip-poor-will's high vulnerability was driven by a high degree of specialization, which may make them less able to adapt to climate change (photo © Judd Patterson)

It is well established that the coniferous and boreal forests are very highly vulnerable to climate change due to a variety of factors including: fire, predation from insectivorous and microbiotic pests, and succession by hardwoods (e.g. Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, and USFS 2013). Not surprisingly, we found that species breeding predominantly in coniferous forest were more likely to be classified as highly vulnerable (67% of coniferous forest species were ranked as highly vulnerable). Wetlands are also predicted to be very highly vulnerable to climate change (due to drying and decreased productivity as a result of decreased dissolved oxygen; e.g. Goulatowitsch et al. 2009, Heino et al. 2009, Karl et al. 2009, USDA 2012, Li et al. 2013, and USFS 2013). We found that species breeding primarily in wetland habitat were also often highly vulnerable (40% of wetland species were ranked as highly vulnerable). Species breeding in other dominant habitat types (deciduous forest/woodland, mixed forest, shrubland, grassland, and open) were rarely categorized as highly vulnerable. The increased probability that these two habitat types will decline and alter as the climate changes may exacerbate the vulnerability of bird species that are already on the edge due to other background risk factors and climate exposure throughout their annual cycle.

4.2. WHEN AND WHERE VULNERABILITY IS GREATEST

When we isolated the effect of temperature change (temperature exposure × temperature sensitivity), we found that 37% of the 46 species analyzed were highly vulnerable to temperature change on the UMGL breeding grounds including: Red-necked Grebe, Forster's Tern, Caspian Tern, Eastern Whip-poor-will, Acadian Flycatcher, Blue-winged Warbler, Golden-winged Warbler, Nashville Warbler, Black-throated Blue Warbler, Cerulean Warbler, Prairie Warbler, Canada Warbler, Worm-eating Warbler, Field Sparrow, Dickcissel, Bobolink, and Orchard Oriole. Whereas 13% of species analyzed were highly vulnerable to temperature change on the non-breeding grounds: Upland Sandpiper, Black Tern, Acadian Flycatcher, Dickcissel, Bobolink, and Orchard Oriole. Four species were highly vulnerable to temperature change on both the breeding and non-breeding grounds, thus compounding their overall vulnerability throughout the annual cycle: Acadian Flycatcher, Dickcissel, Bobolink, and Orchard Oriole. Vulnerability to temperature change on the non-breeding grounds was driven in part by exposure in S. America, where some regions are expected to experience large increases in winter temperature.

Yellow-bellied Flycatcher ranked highly vulnerable due to a combination of poor adaptive capacity to climate change and high background risk (photo by SP Barrette)

Unfortunately, there is a lot of uncertainty among models predicting moisture change, and some of the 16-model ensemble used here predict opposite patterns. Even with this complication, however, we found that bird species in Mexico are expected to experience a 6-11% decrease in winter moisture. The magnitude of this effect suggests that it is a real drying trend and probably a conservative estimate. It is likely our results also underestimate the magnitude of moisture loss in other non-breeding regions (Neelin et al. 2006), and it would be beneficial to assess exposure to moisture change in a more nuanced way by analyzing wet and dry general circulation models separately. Nevertheless, the effect of moisture change (moisture exposure × moisture sensitivity) showed a similar pattern to the effect of temperature change. We found that 33% of species analyzed were highly vulnerable to moisture change on the UMGL breeding grounds: Red-necked Grebe, Upland Sandpiper, Black Tern, Black-billed Cuckoo, Acadian Flycatcher, Wood Thrush, Blue-winged Warbler, Golden-winged Warbler, Cerulean Warbler, Prairie Warbler, Worm-eating Warbler, American Redstart, Dickcissel, Bobolink, and Baltimore Oriole. Whereas 9% of species were highly vulnerable to moisture change on the non-breeding grounds: Eastern Whip-poor-will, Nashville Warbler, Prairie Warbler, and Indigo Bunting. One of these species, Prairie Warbler, was highly vulnerable to moisture change during both the breeding and non-breeding seasons. Vulnerability to moisture change on the non-breeding grounds was driven in part by exposure in Mexico and the Caribbean, which are expected to become much drier. The four species listed above as highly vulnerable to non-breeding moisture change all winter primarily in Mexico and the Caribbean. Other species with similar non-breeding ranges were less sensitive to moisture change and may be able to withstand the drying climate expected in those areas.

These results illustrate how important it is to conduct a comprehensive vulnerability assessment throughout the annual cycle. Some species that appear to be resilient to temperature and moisture change during one season are actually highly vulnerable at other times of the year. If only breeding ground variables are assessed, we risk underestimating vulnerability. In addition, it is vital to know which species may be vulnerable throughout the year. Making things more complicated is the fact that carry-over effects of climate between seasons are possible. For example, we know that for some bird species moisture on the non-breeding grounds can influence breeding ground abundance (Wilson et al. 2011) as well as timing of arrival to breeding areas (Saino et al. 2007, Studds and Marra 2007), which can in turn influence the number of young fledged. We found that 58% the warbler species that we studied were most vulnerable to changes in moisture during the non-breeding season—particularly moisture change in Mexico and the Caribbean: Blue-winged Warbler, Black-and-white Warbler, Tennessee Warbler, Nashville Warbler, Yellow Warbler, Black-throated Blue Warbler, and Prairie Warbler. For species that spend the non-breeding season in Mexico and the Caribbean, there may be indirect consequences of climate change that do not manifest until arrival on the breeding grounds. It is critical that we understand how factors on the non-breeding grounds influence timing, condition, and survival during spring (Paxton et al 2014, Cohen et al 2015) so that we can make sense of trends seen in N. America during the breeding season (Wilson et al. 2011).

4.3. TRAITS CONTRIBUTING MOST TO VULNERABILITY

We evaluated the individual contributions of five categories to overall vulnerability including: background risk, climate exposure, climate sensitivity, adaptive capacity to climate change, and indirect effects of climate change. Of these, adaptive capacity to climate change had the largest impact on vulnerability, with adaptive capacity scores 25-75% greater than other categories. We defined adaptive capacity as species plasticity and ability to adjust to change. We used four behavioral and life history traits as measurements of plasticity: migration strategy, habitat niche specialization, diet niche specialization, and breeding site fidelity. Theory and data suggest that more flexible species will be better able to adapt to a changing environment (e.g. Jiguet et al. 2007, Moller et al. 2008, Vegvari et al. 2009, and Dawson et al. 2011). We found that breeding site fidelity was the biggest contributor to adaptive capacity, with fidelity scores 43-67% greater than other adaptive capacity traits. Thus, species that return to the same breeding site year after year are less able to exploit changing resources. However, the majority of species we considered had high breeding site fidelity (median score 5.0 out of 5.0, SD = 0.9). It would be informative to investigate a suite of species with more variation in this trait.


The Worm-eating Warbler's high vulnerability was largely driven by poor adaptive capacity to climate change and temperature change on UMGL breeding grounds; background risk and temperature change on UMGL breeding grounds were the largest contributors to the Black-throated Blue Warbler's high vulnerability score

4.4. APPLICATIONS TO ADAPTIVE MANAGEMENT

Conducting a vulnerability assessment is the first step towards managing species under the threat of climate change. The next step is to use this information to develop adaptive management strategies and conservation plans (AFWA 2009). Such planning can help to reduce or mitigate future vulnerability, both in the short and long term (IPCC 2014). Strategies may include measures designed to:

- Increase resistance to climate change,
- Make a population or species more resilient to climate change, and/or
- Assist transformation or adaptation to climate change.

Our vulnerability assessment identified a number of areas that may help focus adaptive management strategies (Box 7). These strategic points are also supported by several goals outlined by the National Fish, Wildlife, and Plants Climate Adaptation Partnership (2012), including: conserve habitat, enhance management capacity across jurisdictions, increase knowledge and information, and reduce non-climate stressors.

BOX 7.

Potential Adaptive Management Strategies

1. Upgrade conservation status of a number species

2. Prioritize conservation of coniferous forest and wetland habitats

3. Prioritize conservation of species located at the northern limit of their breeding ranges—particularly those that specialize on deciduous forest or woodland, shrubland, grassland, or open habitat

4. Prioritize conservation of species that winter in the southeastern U.S., Mexico, and the Caribbean and establish partnerships with conservation managers in those regions

5. Focus research on determining where UMGL species spend the non-breeding season

Species that may be candidates for upgrading of conservation status based on our analyses include the Red-necked Grebe, Caspian Tern, Forster's Tern, Yellow-bellied Flycatcher, and Nashville Warbler. These species are currently not considered of conservation concern, but their high vulnerability to climate change may warrant increased observation and management. We found a handful of species were highly vulnerable to both background risk (as we calculated it) and climate change. These species may be in double jeopardy and may warrant special status: Red-necked Grebe, Forster's Tern, Eastern Whip-poor-will, Yellow-bellied Flycatcher, and Worm-eating Warbler.

We found that the majority of species were most limited in their lack of adaptive capacity (rather than exposure or sensitivity). For example, the adaptive capacity score for Upland Sandpipers was 32% greater than the effects of climate on either the breeding or non-breeding grounds. Their extremely long migration distance (over 8,800 km on average) and specialized requirement for grassland habitat during both breeding and non-breeding seasons make them less likely to adapt to climate change. Management strategies that protect the specific habitat and diet resources needed by species like Upland Sandpipers may help them cope with climate change. A robust approach may be to protect an integrated network of a variety of habitat types. This could help maximize the ability of species to find suitable habitat somewhere. We also found that breeding site fidelity was a limiting factor for many species and the strongest indicator of vulnerability. Measures to conserve habitat should include creating connectivity between habitat units on the breeding grounds. This may facilitate population range shifts and genetic connectivity across the landscape for those species with high breeding site fidelity.

Poor adaptive capacity to climate change was the biggest contributor to Rusty Blackbird high vulnerability, which was driven by high breeding site fidelity, highly specialized habitat requirements throughout the year, and highly specialized breeding season diet (photo by R Corcoran, USFWS)

Another approach would be to protect specific habitat types. Coniferous forest has been found to be highly vulnerable to climate change, and we found that species specializing on coniferous forest were more vulnerable than others. If these species are to continue to breed and thrive in the UMGL region, action will have to be taken to protect existing forests from degradation and destruction. It is beyond the scope of this assessment to identify where in the UMGL or the non-breeding regions these species may be more or less vulnerable. However, other studies are investigating vulnerability at local scales in the UMGL and it may be prudent to partner with these organizations to specific identify areas for protection (e.g. areas where forest is expected to increase or where temperature refugia exist). In Mexico and the Caribbean, where the highest non-breeding vulnerabilities occur, it may be wise to invest in such local-scale research. Wetlands are another highly vulnerable habitat type where we found several highly vulnerable species. For this reason, measures to conserve water use throughout the UMGL region should be a top priority. This may include increased water efficiency in urban and agricultural environments as well as reuse and recycling. Purchase of water rights and watershed protection are also important so that greater control may be exerted during times of drought. Maintaining or restoring vegetation around wetlands may also increase the resilience of these habitats and help them maintain cooler water temperatures.

Species that are at the northern edge of their range currently have limited presence in the UMGL region. However, they may become more common with climate change as habitats and species ranges are expected to shift northward. Species from our vulnerability assessment that are at the northern edge of their breeding range include: Acadian Flycatcher, Blue-winged Warbler, Cerulean Warbler, Prairie Warbler, Worm-eating Warbler, and Orchard Oriole. All of these species primarily occupy either deciduous forest/woodland or shrubland habitat. It may be prudent to focus on conserving these habitat types in an effort to create suitable areas for population expansion and movement.

Not only is climate change occurring at a vast scale, but migratory animals operate over broad regions that can span multiple continents. Conservation organizations and agencies must adapt and work across these large spatial scales to effectively manage species and populations. This includes creating both domestic and international partnerships. One way to facilitate cooperation is through networking and increasing communication regarding monitoring, data sharing, data development, and adaptive management (NFWPCAS 2012), especially for shared species and populations. Organizations and cooperatives such as the Landscape Conservation Cooperatives, Habitat Joint Ventures, and Partner's in Flight already work across broad regions and may be models for expanding cooperation and communication to help protect species from climate change throughout their annual cycle.

5. Species Accounts

Red-winged Blackbird flock in flight (photo by B Webster)

Vulnerability assessment results for each of the 46 species are presented below. Each species account summarizes vulnerability scores and subscores (Table 5.1). The maximum score for each category is 5.0. A score of < 2.0 is considered low vulnerability, 2.0 to 2.9 moderate vulnerability, 3.0 to 3.9 high vulnerability, and ≥ 4.0 very high vulnerability. See Methods (Section 2) for more details. Species accounts are organized in taxonomic order.

Table 5.1. Descriptions and calculations of vulnerability scores and subscores that are summarized in the following species accounts.

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
Description							
Vulnerability inclusive of all factors (climate change and background risk)	Combination of exposure and sensitivity to climate change on the breeding grounds		Combination of exposure and sensitivity to climate change on the NB grounds		The ability of a species to adjust to climate change	Habitat vulnerability and changes to important biotic interactions due to climate change	Vulnerability due to factors unrelated to climate change
Calculation							
Mean of breeding climate effect, NB climate effect, adaptive capacity, indirect effects, and background risk	(Breeding climate exposure × sensitivity)1/2 Where exposure is calculated for the portion of the species range that overlaps with the UMGL LCC, Jun – Aug; and sensitivity is calculated for the species entire breeding range, Jun – Aug		(NB climate exposure × sensitivity)1/2 Where exposure is calculated for all relevant regions of the species NB range (i.e. accounting for migratory connectivity), Dec – Feb; and sensitivity is calculated for the species entire NB range, Dec – Feb		Mean of migration strategy, breeding habitat specialization, breeding diet specialization, NB habitat specialization, NB diet specialization, and breeding site fidelity	Mean of breeding habitat vulnerability, NB habitat vulnerability, breeding biotic interactions, and NB biotic interactions	Depending on available data, either (a) the mean of quasi-extinction risk, range size, and threats, or (b) the PIF conservation score

Wetland habitat on the breeding grounds in Michigan (photo by L Betts, USDA/NRCS)

5.1. Pied-billed Grebe
(Podilymbus podiceps)

USFWS Region 3 status: conservation concern
AOU number: 0060
AOU abbreviation: PBGR

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.7	**0**	**1.4**	**0**	**1.4**	**3.6**	**3.3**	**3.3**

(maximum score of 5 for all columns)

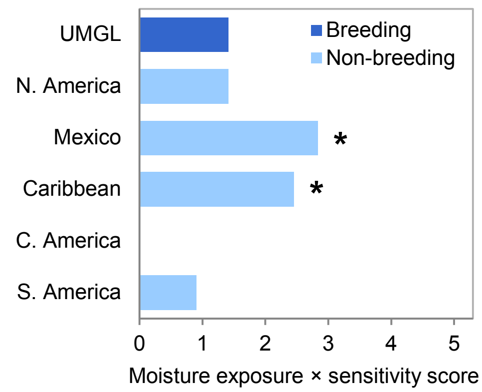
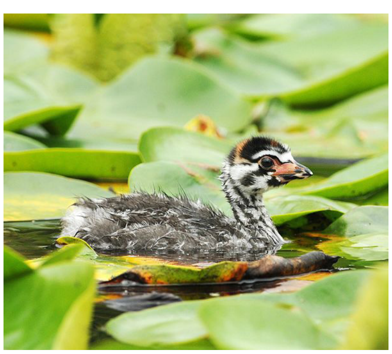


Figure 5.1. Pied-billed Grebe subscores for moisture exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). Temperature results not shown as all scores equaled zero. *Non-breeding score ≥ 20% greater than breeding.

SUMMARY

Total vulnerability for Pied-billed Grebe (including climate-change related factors and background risk) was moderate, scoring 2.7 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability, mostly due to the grebe's specialization on freshwater wetland habitat during both the breeding and non-breeding seasons and due to its high breeding site fidelity. Indirect effects of climate change also played a large role because of the high vulnerability of aquatic habitats. Temperature change was not expected to have much effect on vulnerability (neither breeding nor non-breeding) because Pied-billed Grebes are relatively insensitive to temperature change throughout the annual cycle. Moisture change, however, is expected to have a small to moderate effect with the greatest impact occurring on the Mexican and Caribbean non-breeding grounds (Figure 5.1). This drying of the non-breeding grounds is of particular concern given the Pied-billed Grebe's reliance on aquatic habitats and fauna. Pied-billed Grebe has an extensive non-breeding range, including N. America, Mexico, Caribbean, C. America, and S. America. We had very little connectivity information from banding data (Figure 5.2) and no information from the literature. Thus, we were unable to deduce possible migratory connectivity, and we maintained a broad approach to analyzing vulnerability. Unfortunately, our lack of understanding of migratory connectivity for the species limits our ability to predict vulnerability. A better understanding of the extent to which Pied-billed Grebes from the UMGL over-winter in Mexico and the Caribbean should be a research priority.



Pied-billed Grebe chick (photo by M Layne)

MIGRATORY CONNECTIVITY

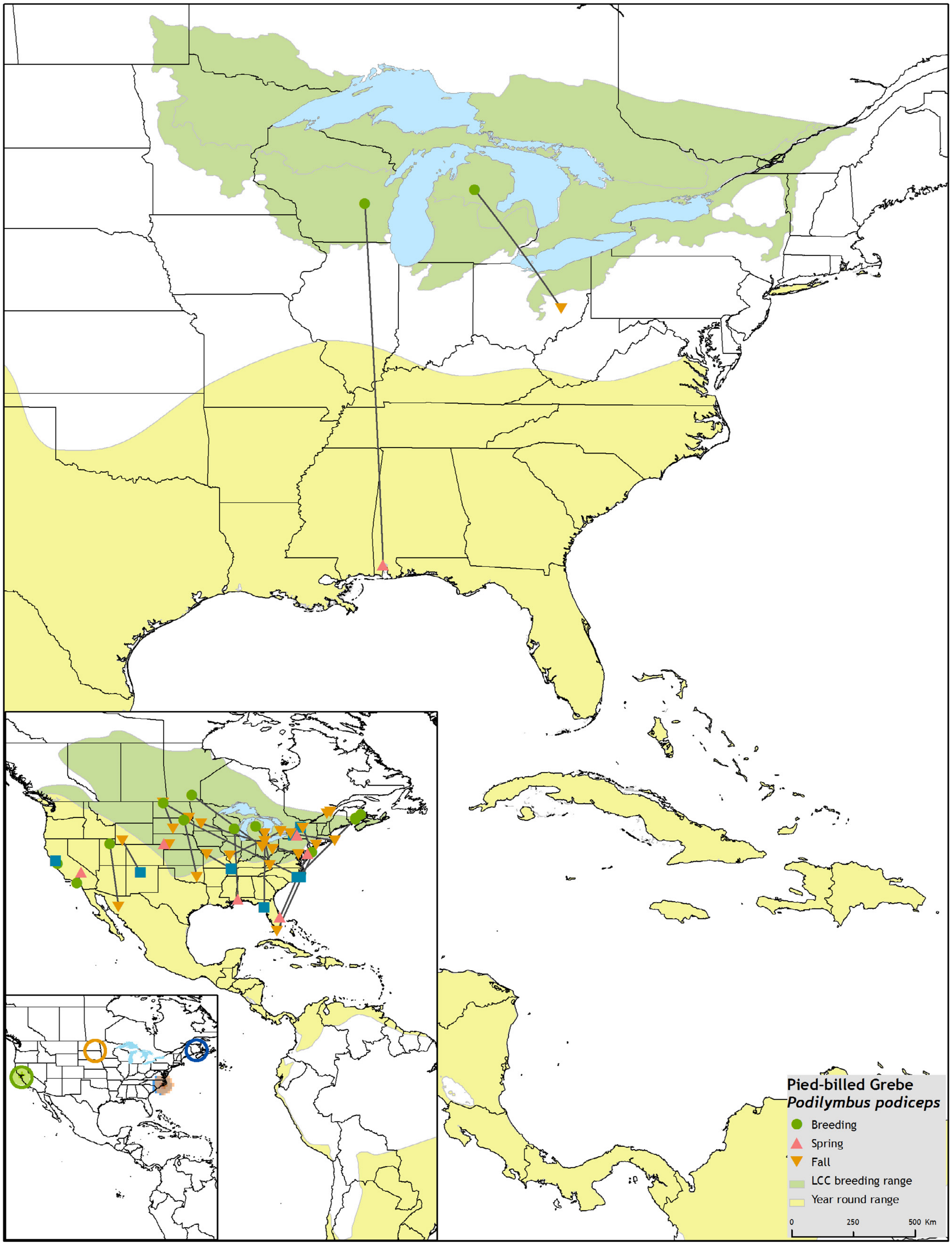


Figure 5.2. Pied-billed Grebe banding data from USGS Bird Banding Laboratory. The Upper Midwest Great Lakes LCC (UMGL) is shown in green in the main map and includes data from that region only. There were no breeding to stationary non-breeding encounters from the UMGL. Inset maps show data from the entire breeding range and concentrations of non-breeding encounters.

CLIMATE EXPOSURE

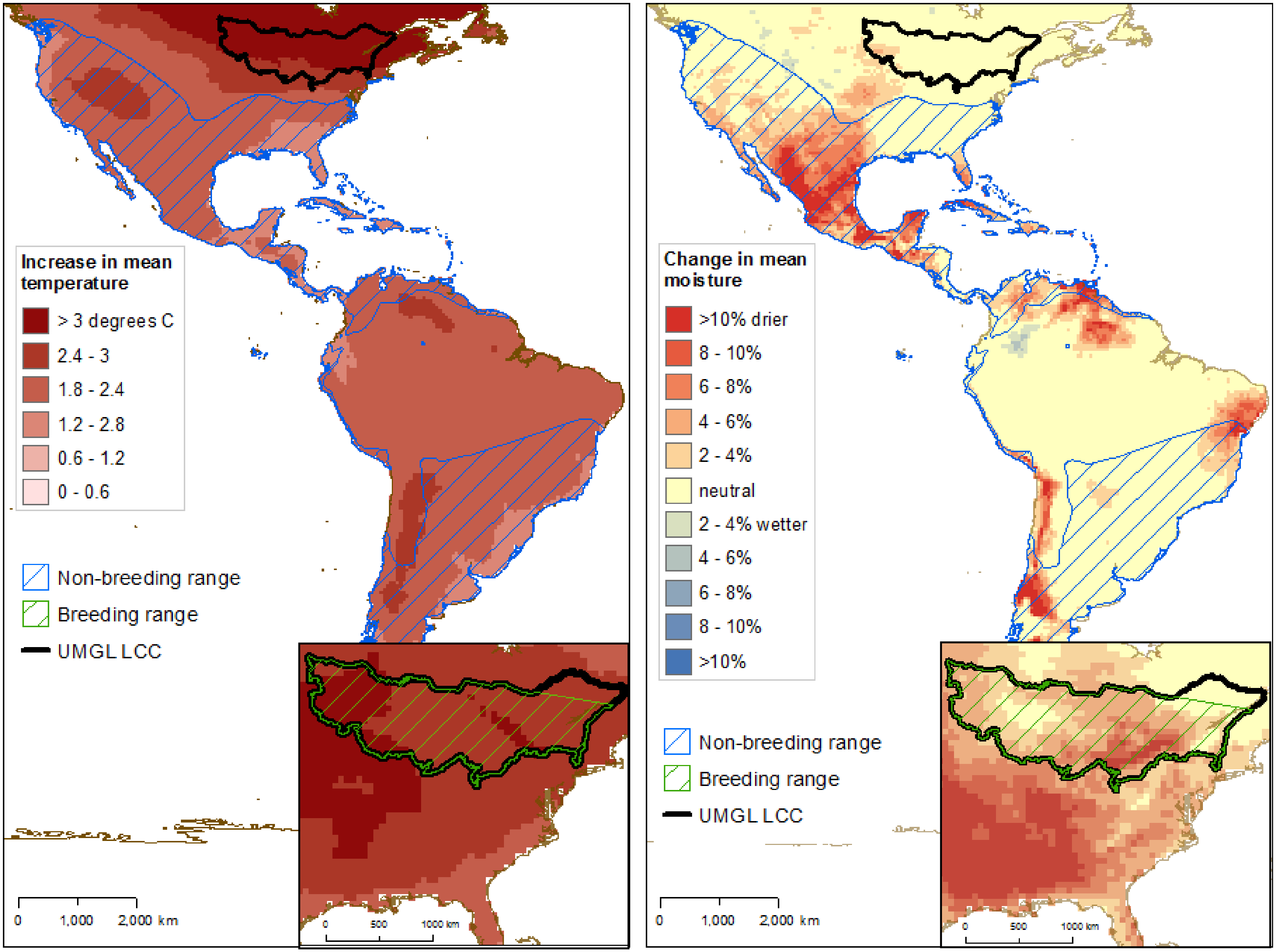


Figure 5.3. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Pied-billed Grebe's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

PIED-BILLED GREBE DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 3.0)
• Non-breeding PIF conservation	(score = 3.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 2.0) Non-migrant/resident and short-distance migrant (mean distance = 0 km)
• Breeding habitat niche specialization	(score = 4.5) Macro habitats freshwater wetlands and brackish wetlands; nesting micro habitat floating platform on the water (0 m high)
• Breeding diet niche specialization	(score = 3.5) Aquatic arthropods and fish; captured aquatically by diving
• Breeding site fidelity	(score = 4.0) May be high (assumed to return to same territory year after year)
• Non-breeding habitat niche specialization	(score = 4.0) Freshwater wetlands and brackish wetlands
• Non-breeding diet niche specialization	(score = 3.5) Fish and aquatic arthropods (more fish than during breeding)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 32.6° C
• Breeding precipitation range	(score = 1) 145 cm
• Non-breeding thermal range	(score = 0) 37.4° C
• Non-breeding precipitation range	(score = 2.0) 97 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.3% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0): 2.0° C increase N. America (score = 3.0): 2.0° C increase Mexico (score = 3.0): 2.0° C increase Caribbean (score = 2.0): 1.6° C increase C. America (score = 2.0): 1.8° C increase S. America (score = 3.0): 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 1.0): 3.1% drier N. America (score = 1.0): 2.9% drier Mexico (score = 4.0): 8.1% drier Caribbean (score = 3.0): 6.0% drier C. America (score = 1.0): 3.7% drier S. America (score = 0): 1.8% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.5) High vulnerability on freshwater wetlands due to drying and re-vegetation (Goulatowitsch et al. 2009, Karl et al. 2009, USDA 2012, USFS 2013); vulnerability of brackish wetlands is uncertain but may be very little because some freshwater wetlands may become brackish as water levels drop and evaporation increases or as marine influence encroaches inland
• Breeding biotic interaction vulnerability	(score = 4.0) Cold water prey will likely decrease in abundance due to decrease in oxygen, increased botulism in warmer waters is also a possibility (Heino et al. 2009, Karl et al. 2009, USDA 2012, Li et al. 2013, USFS 2013)
• Non-breeding habitat vulnerability	(score = 2.5) High vulnerability on freshwater wetlands (see above); vulnerability of brackish wetlands is uncertain but may be very little (see above)
• Non-breeding biotic interaction vulnerability	(score = 4.0) Cold water prey will likely decrease in abundance (see above), and increased botulism in warmer waters is also a possibility (see above)

5.2. Red-necked Grebe
(Podiceps grisegena)

photo by M Szczepanek

USFWS Region 3 status: common
AOU number: 0020
AOU abbreviation: RNGR

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.1	**3.2**	**3.2**	**0**	**0**	**4.0**	**3.8**	**3.3**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Red-necked Grebe was high, scoring 3.1 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability, mostly due to the grebe's high degree of habitat specialization during both summer and winter and to its high breeding site fidelity. Indirect effects of climate change also played a large role because of the high vulnerability of freshwater aquatic habitats. Unlike the Pied-billed Grebe, neither temperature nor moisture change on the non-breeding grounds are expected to have much effect on vulnerability. This is partly due to their large range of temperature tolerance in winter and partly due to climate models predicting very little moisture change on the Red-necked Grebe's winter range (< 1% change, Figure 5.5). In contrast, climate change on the UMGL breeding grounds are predicted to have a moderate effect on vulnerability. Drying of the breeding grounds is of particular concern given the Red-necked Grebe's reliance on aquatic habitats and fauna. We had very little connectivity information on Red-necked Grebes from banding data (Figure 5.4) and no information from the literature. Our limited knowledge of migratory connectivity could hinder our ability to predict vulnerability and conserve the species. However, because the Red-necked Grebe has a small winter range that is completely within the USA and Canada, researching migratory connectivity for this species may be more feasible than for others.

wetland habitat (photo by J van der Crabben)

MIGRATORY CONNECTIVITY

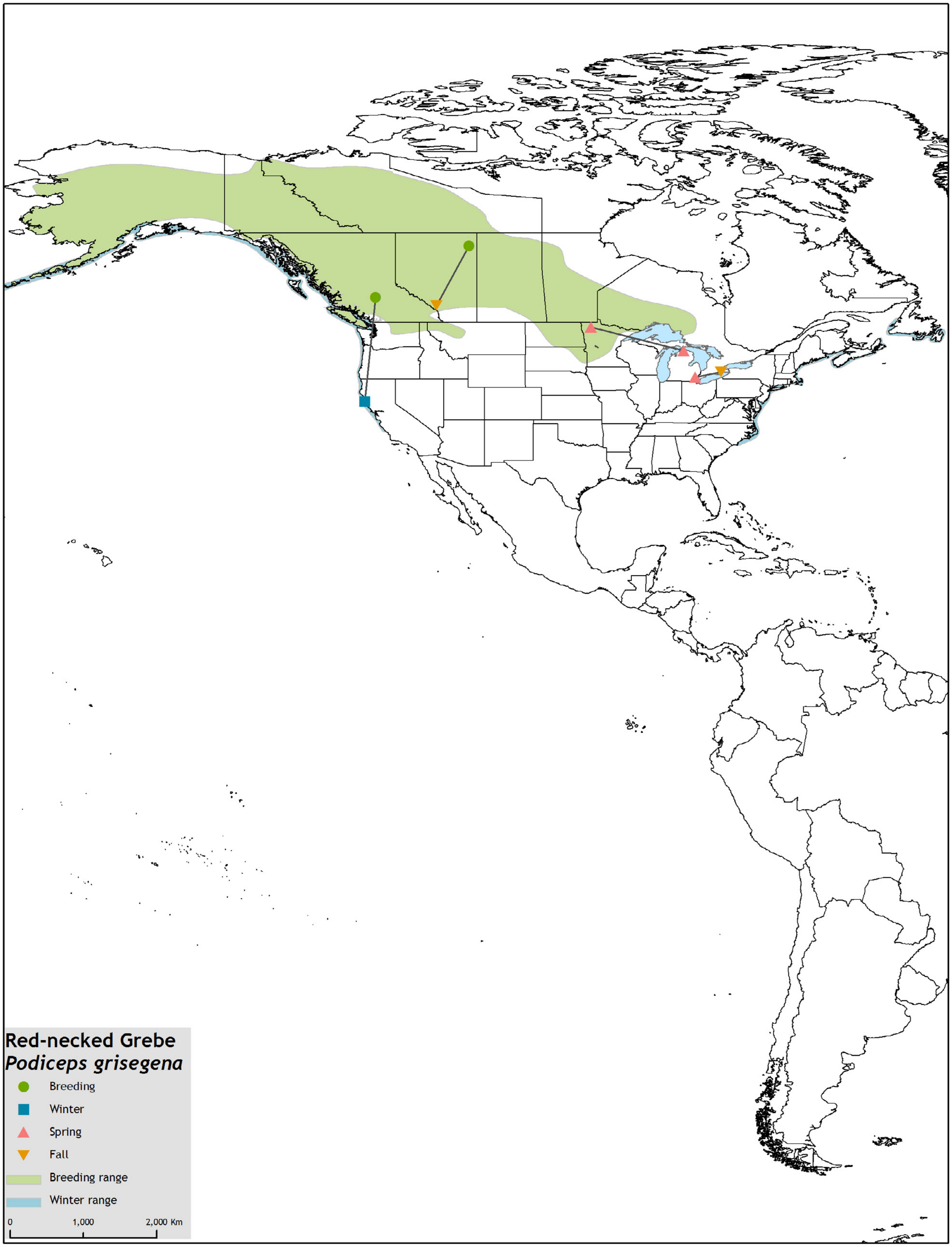


Figure 5.4. Red-necked Grebe banding data from USGS Bird Banding Laboratory. The entire breeding range is shown. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

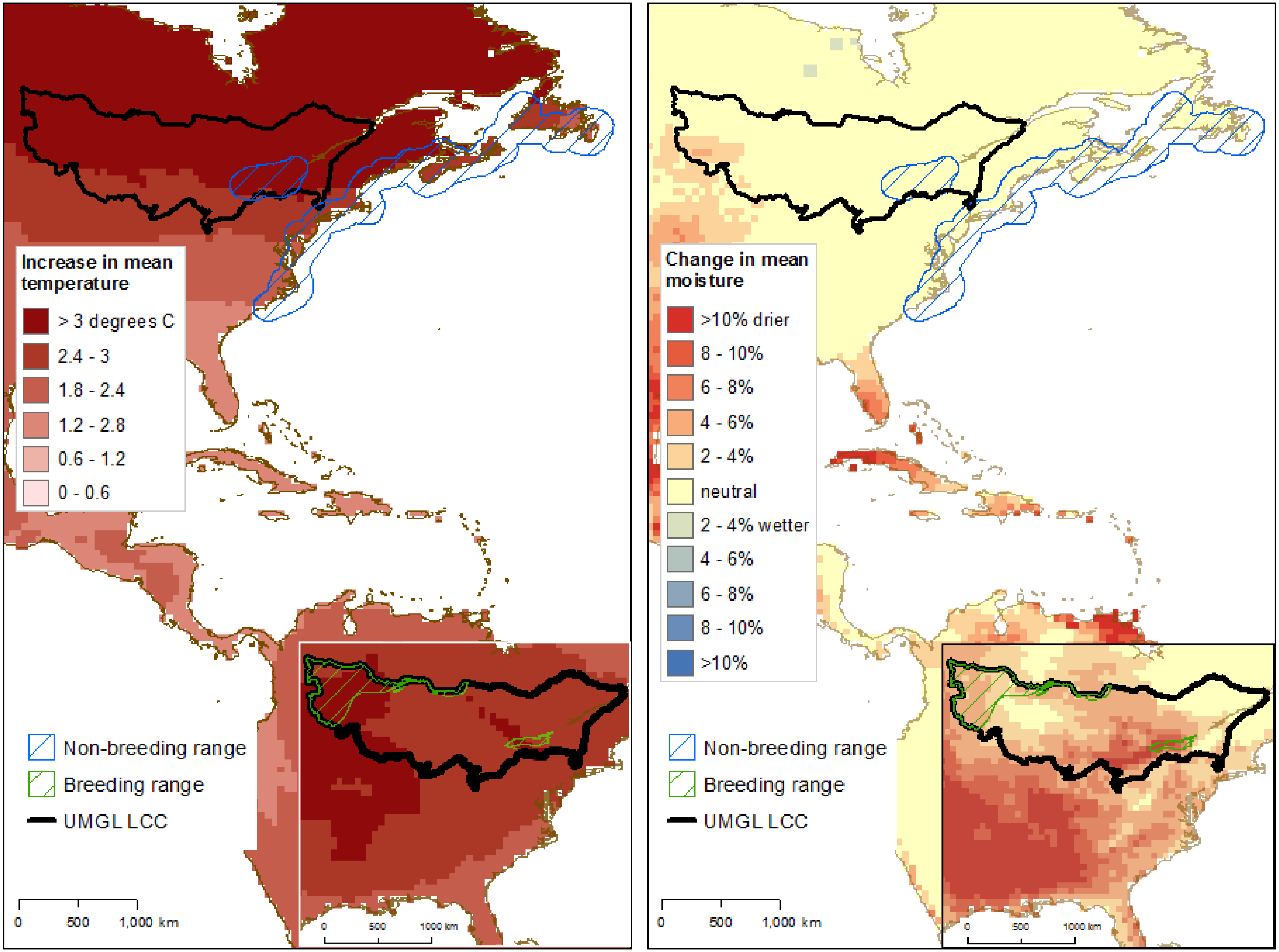


Figure 5.5. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Red-necked Grebe's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

RED-NECKED GREBE DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 3.0)
• Non-breeding PIF conservation	(score = 3.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 2.0) Short-distance migrant (mean distance = 990 km)
• Breeding habitat niche specialization	(score = 4.5) Macro habitats are freshwater wetlands and saltwater wetlands; nesting micro habitat is floating platforms on the water (0 m high)
• Breeding diet niche specialization	(score = 3.5) Aquatic arthropods and fish; captured aquatically by diving
• Breeding site fidelity	(score = 5.0) High (individuals known to return to same territory each year)
• Non-breeding habitat niche specialization	(score = 5.0) Marine
• Non-breeding diet niche specialization	(score = 4.0) Marine fish and marine invertebrates
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 15.3° C
• Breeding precipitation range	(score = 5.0) 25 cm
• Non-breeding thermal range	(score = 0) 26.6° C
• Non-breeding precipitation range	(score = 2.5) 91 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 5.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.3% drier
• Winter (Dec – Feb) non-breeding temperature	N. America (score = 4.0) 2.8° C increase
• Winter (Dec – Feb) non-breeding moisture	N. America (score = 0) < 1% change
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.5) High vulnerability on freshwater wetlands due to drying and re-vegetation (Goulatowitsch et al. 2009, Karl et al. 2009, USDA 2012, USFS 2013); very high vulnerability on saltwater wetlands due to sea level rise (IPCC 2014)
• Breeding biotic interaction vulnerability	(score = 4.0) Cold water prey highly likely to decrease in abundance due to decrease in oxygen, increased botulism in warmer waters is also a possibility (Heino et al. 2009, Karl et al. 2009, USDA 2012, Li et al. 2013, USFS 2013)
• Non-breeding habitat vulnerability	(score = 2.5) Vulnerability of nearshore marine habitats in general is uncertain, may depend on location and dependence on upwelling
• Non-breeding biotic interaction vulnerability	(score = 4.0) Uncertain, cold water environments may be highly vulnerable due to decrease in upwelling and decrease in prey; there may also be an increase in nearshore pollution such as red tides (Karl et al. 2009)

5.3. Green Heron
(Butorides virescens)

USFWS Region 3 status: common
AOU number: 2010
AOU abbreviation: GRHE

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.7	**2.0**	**1.0**	**0**	**2.4**	**3.3**	**3.1**	**3.0**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Green Heron was moderate, scoring 2.7 out of 5.0. Drying on the Mexican non-breeding grounds (Dec – Feb) was the largest contributor to vulnerability (climate exposure × climate sensitivity = 3.5, Figure 5.6). This high score was due in part to the Green Heron's high sensitivity to changes in precipitation during winter and in part to the very high moisture exposure in Mexico during winter. This drying is of particular concern given the species' reliance on aquatic habitats and fauna. The fairly strong breeding site fidelity contributed to a high adaptive capacity score (3.3), which also increased the total vulnerability. More work is needed, however, to verify site fidelity for this species. Winter diet is also poorly understood for this species. The Green Heron has a large non-breeding range, including N. America, Mexico, Caribbean, C. America, and S. America. We had very little connectivity information from their banding data (Figure 5.7) and no information from the literature. Thus, we maintained a broad approach to assessing vulnerability for the species which may hinder our ability to determine the best approach to conserving Green Herons. Information about migratory connectivity should be a research priority.

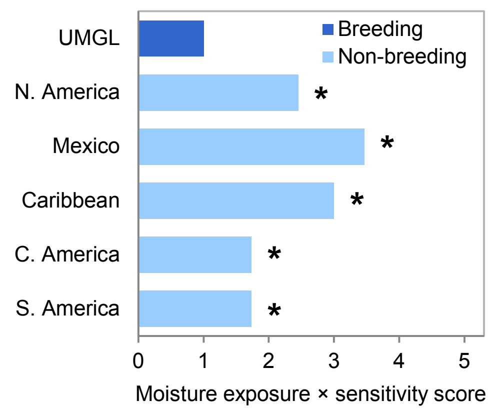


Figure 5.6. Green Heron subscores for moisture exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). Temperature results not shown as all non-breeding scores equaled zero. *Non-breeding score ≥ 20% greater than breeding.

Green Heron chicks at nest (photo by Agathman)

MIGRATORY CONNECTIVITY

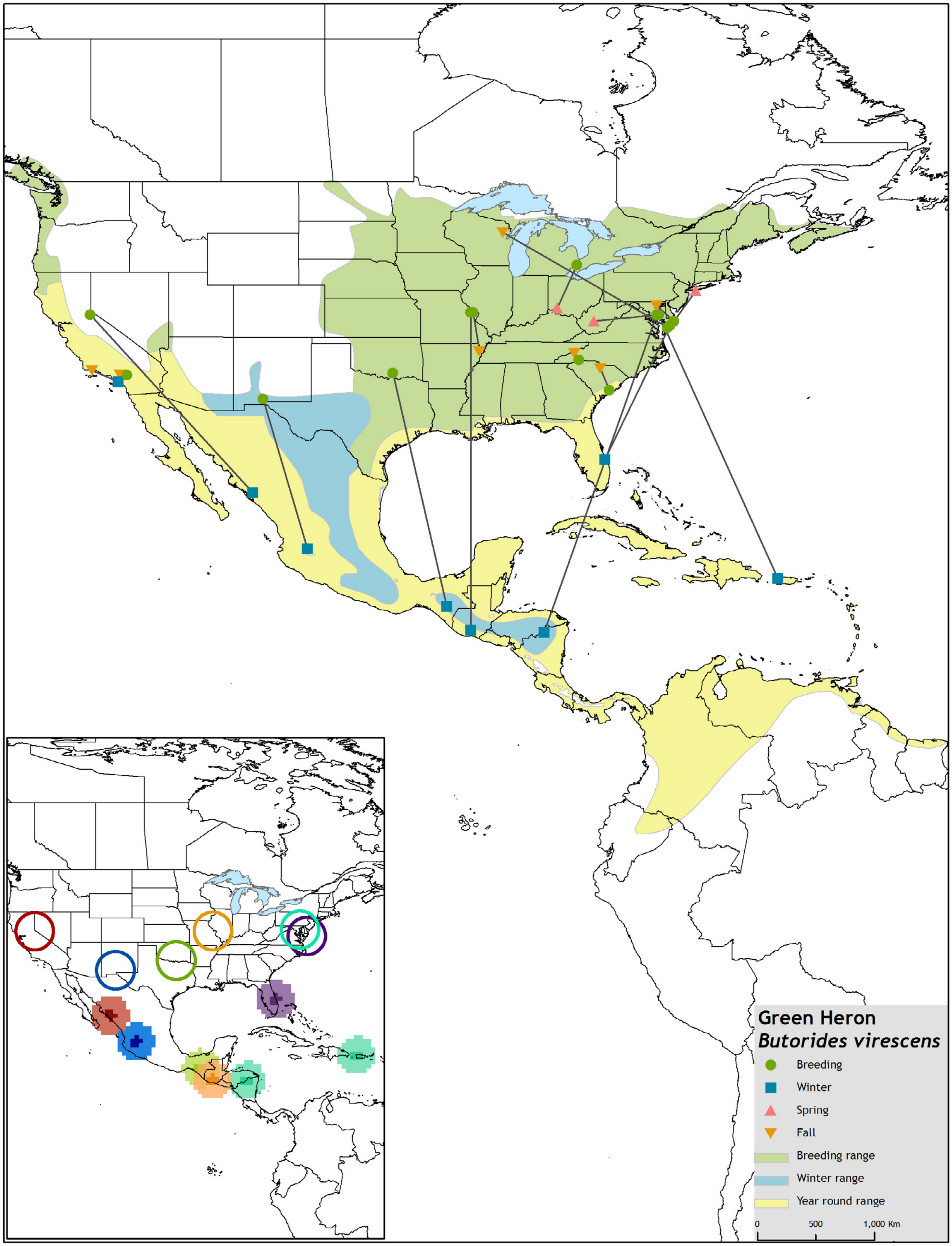


Figure 5.7. Green Heron banding data from USGS Bird Banding Laboratory. The entire breeding range is shown. There were no breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of non-breeding encounter data.

CLIMATE EXPOSURE

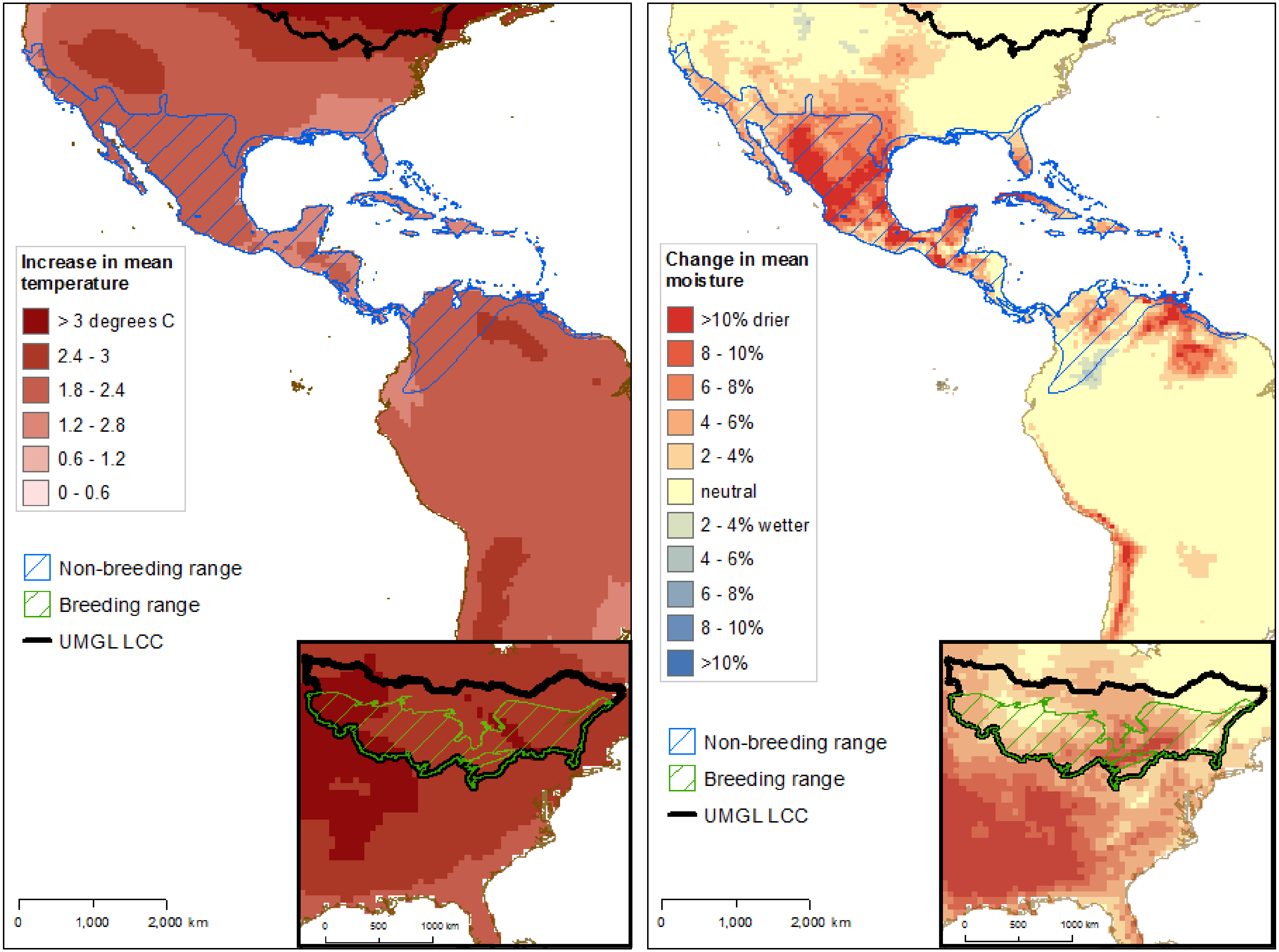


Figure 5.8. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Green Heron's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

GREEN HERON DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 2.3)
• Non-breeding PIF conservation	(score = 3.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant/resident, short-distance migrant, long-distance migrant (mean distance = 245 km)
• Breeding habitat niche specialization	(score = 3.5) Macro habitats wooded/shrubby wetlands and riparian areas; micro nest habitat trees and shrubs (3-6 m high)
• Breeding diet niche specialization	(score = 3.2) Fish, arthropods, and other invertebrates; captured aquatically by stalking
• Breeding site fidelity	(score = 4.0) May be high (assumed to return to same territory year after year)
• Non-breeding habitat niche specialization	(score = 3.0) Marine to brackish wetlands, freshwater wetlands, mangrove forests
• Non-breeding diet niche specialization	(score = unknown) No data
iii. Climate Sensitivity	
• Breeding thermal range	(score = 1.0) 17.4° C
• Breeding precipitation range	(score = 0.5) 148 cm
• Non-breeding thermal range	(score = 0) 22.5° C
• Non-breeding precipitation range	(score = 3.0) 82 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.7% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0): 2.0° C increase N. America (score = 3.0) 2.0° C increase Mexico (score = 3.0) 2.0° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.1° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.7% drier N. America (score = 2.0) 5.1% drier Mexico (score = 4.0) 8.1% drier Caribbean (score = 3.0) 6% drier C. America (score = 1.0) 3.8% drier S. America (score = 1.0) 2.6% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.3) High vulnerability on freshwater wetlands due to drying and re-vegetation (Goulatowitsch et al. 2009, Karl et al. 2009, USDA 2012, USFS 2013); riparian habitat vulnerability may depend on location (Perry et al. 2012, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 2.8) Cold water prey are highly likely to decrease in abundance due to decrease in oxygen, increased botulism in warmer waters is also possible (Heino et al. 2009, Karl et al. 2009, USDA 2012, Li et al. 2013, USFS 2013); other prey items may be less likely to change
• Non-breeding habitat vulnerability	(score = 3.3) Vulnerability of brackish wetlands is uncertain but may be very little as freshwater wetlands may become brackish due to increased evaporation or seawater encroachment; high vulnerability on freshwater wetlands due to drying and re-vegetation (see above); mangrove forests are very highly vulnerable due to sea level rise and increased frequency of storm surges (Gilman et al. 2008)
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.4. Black-crowned Night-Heron
(Nycticorax nycticorax)

USFWS Region 3 status: conservation concern
AOU number: 2020
AOU abbreviation: BCNH

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.4	**0**	**1.4**	**0**	**1.4**	**2.9**	**2.9**	**3.3**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Black-crowned Night-Heron was moderate, scoring 2.4 out of 5.0. The background risk category was the largest contributor to vulnerability, suggesting that factors other than climate change may be a priority for the species. Although Black-crowned Night-Herons use aquatic habitats, they are extremely versatile during both breeding and non-breeding periods in terms of habitat use and diet. Although, diet specific to the non-breeding season remains largely unknown and was a limiting factor in our analysis. Temperature change is not expected to have much effect on vulnerability (neither breeding nor non-breeding) because Black-crowned Night-Herons are relatively insensitive to temperature change throughout the annual cycle. Moisture change, however, is expected to have a small to moderate effect with the greatest impact occurring on the Caribbean non-breeding grounds (Figure 5.9). We had 114 breeding to non-breeding banding locations from the UMGL (Figure 5.10). The majority of winter locations were in the Caribbean and UMGL, suggesting some individuals migrate to the Caribbean while others remain relatively local. A few birds form the UMGL also migrated to other areas, including the Atlantic coast, Mississippi River, Florida, the Gulf Coast, and C. America, suggesting some connectivity with these regions as well. The data did not support connectivity with the southwestern USA, Mexico, or S. America. Thus, we excluded these regions from our vulnerability analysis. No information on migratory connectivity has been published in the literature for this species, illustrating the importance of banding data. Further research will greatly improve conservation efforts for the species.

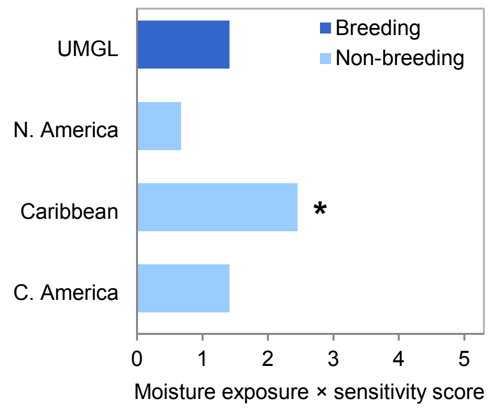


Figure 5.9. Black-crowned Night-Heron subscores for moisture exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). Temperature results not shown as all scores equaled zero. *Non-breeding score ≥ 20% greater than breeding.

Black-crowned Night-Herons have an extremely versatile diet (photo by A Carpentier)

MIGRATORY CONNECTIVITY

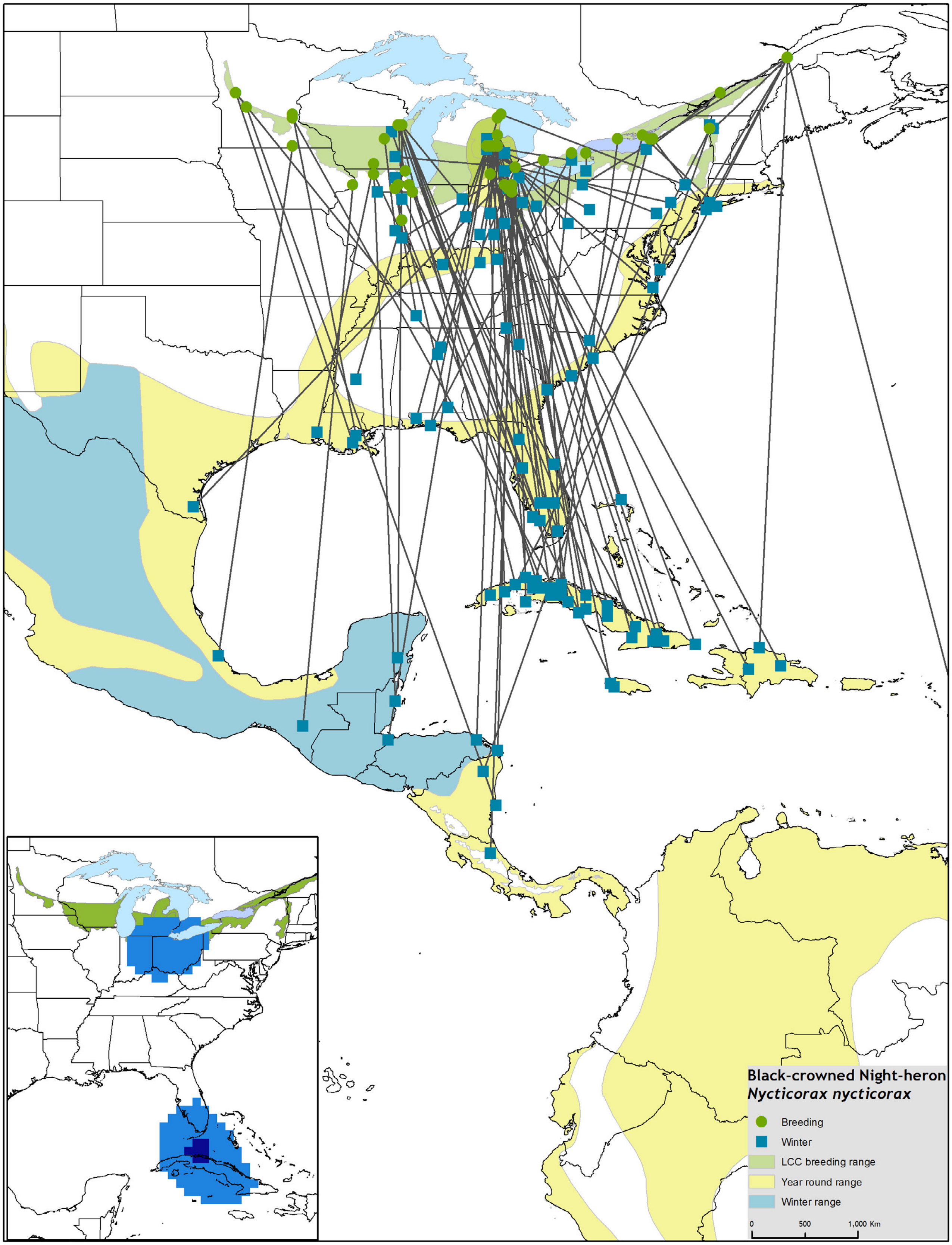


Figure 5.10. Black-crowned Night-Heron banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were 114 breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of non-breeding data originating from the UMGL.

CLIMATE EXPOSURE

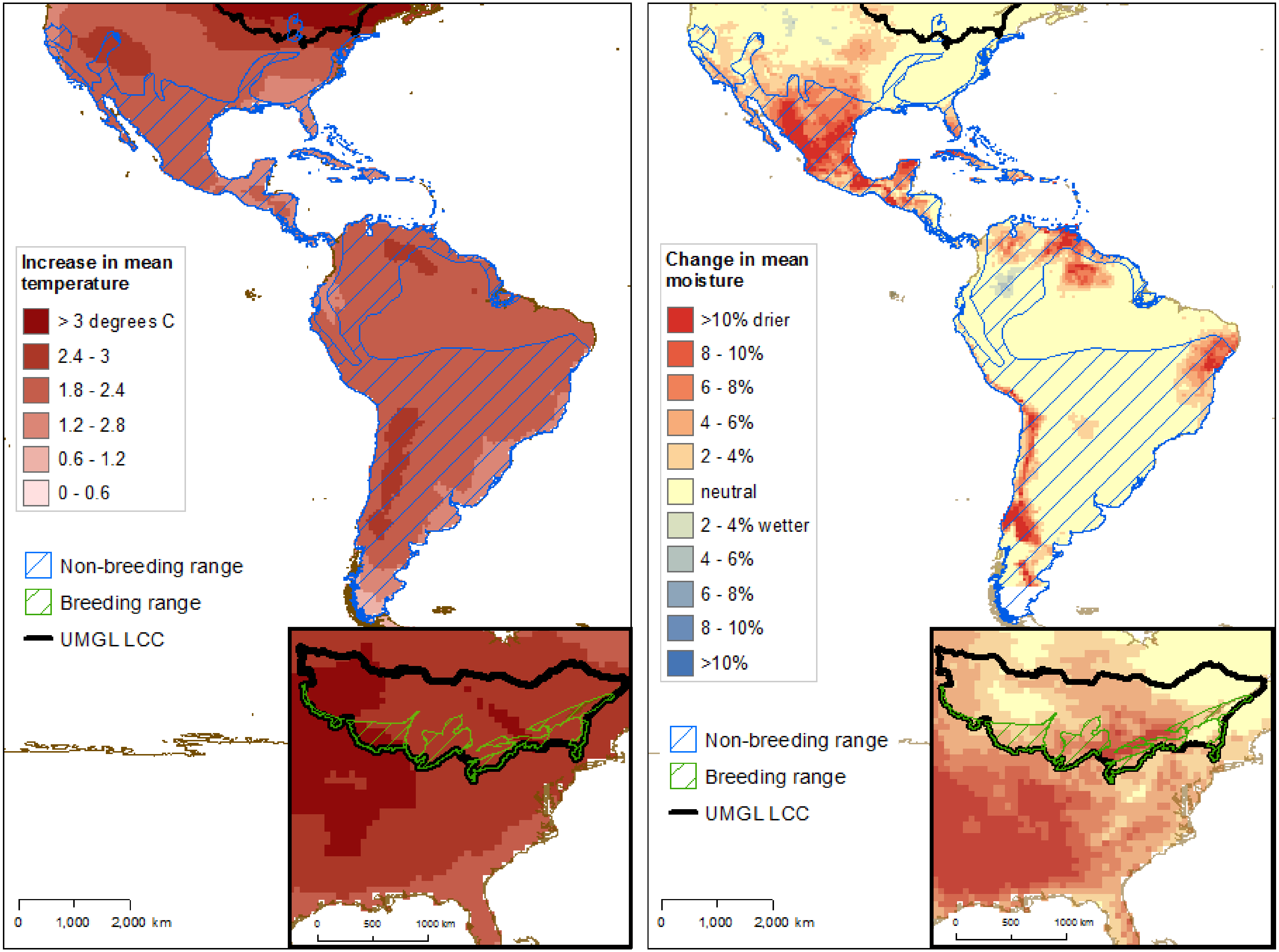


Figure 5.11. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Black-crowned Night-Heron's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

BLACK-CROWNED NIGHT-HERON DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 3.0)
• Non-breeding PIF conservation	(score = 3.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) non-migrant/resident, short-distance migrant, long-distance migrant (mean distance = 612 km)
• Breeding habitat niche specialization	(score = 2.3) Macro habitats wooded/shrubby wetlands and riparian areas; micro nest habitats trees and shrubs (5-10 m high)
• Breeding diet niche specialization	(score = 2.2) Fish, arthropods and other invertebrates, amphibians and reptiles, small mammals, birds, eggs, carrion, plant material, and garbage; captured aquatically by stalking
• Breeding site fidelity	(score = 4.0) May be high (assumed to return to same territory each year)
• Non-breeding habitat niche specialization	(score = 3.0) Marine to brackish wetlands, freshwater wetlands, and mangrove forests
• Non-breeding diet niche specialization	(score = unknown) No data
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 33.4° C
• Breeding precipitation range	(score = 1.0) 133 cm
• Non-breeding thermal range	(score = 0) 32.0° C
• Non-breeding precipitation range	(score = 2.0) 114 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.2% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9 increase N. America (score = 3.0) 2.2 increase Caribbean (score = 2.0) 1.6 increase C. America (score = 2.0) 1.8 increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 1.0) 3.0% drier N. America (score = 1.0) 1.8% drier Caribbean (score = 3.0) 6.0% drier C. America (score = 1.0) 3.8% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.3) High vulnerability on freshwater wetlands due to drying and re-vegetation (Goulatowitsch et al. 2009, Karl et al. 2009, USDA 2012, USFS 2013); riparian habitat vulnerability may depend on location (Perry et al. 2012, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 2.1) Cold water prey are highly likely to decrease in abundance due to decrease in oxygen, increased botulism in warmer waters is also a possibility (Heino et al. 2009, Karl et al. 2009, USDA 2012, Li et al. 2013, USFS 2013); other prey items may be less likely to change
• Non-breeding habitat vulnerability	(score = 3.3 Vulnerability of brackish wetlands is uncertain but may be very little as freshwater wetlands may become brackish due to increased evaporation or seawater encroachment; high vulnerability on freshwater wetlands due to drying and re-vegetation (see above); mangrove forests are very highly vulnerable due to sea level rise and increased frequency of storm surges (Gilman et al. 2008)
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.5. American Kestrel
(Falco sparverius)


Photo by G Hume

USFWS Region 3 status: common
AOU number: 3600
AOU abbreviation: AMKE

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.1	**0**	**1.4**	**0**	**1.4**	**2.8**	**1.2**	**3.6**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for American Kestrel was moderate, scoring 2.1 out of 5.0. The background risk category was the largest contributor to vulnerability, suggesting that factors other than climate change may be a priority for the species. Temperature and moisture change were not expected to have much effect on vulnerability (neither breeding nor non-breeding) because American Kestrels were relatively insensitive to change throughout the annual cycle. We had 125 breeding to non-breeding banding locations from the UMGL region (Figure 5.12). All winter locations were in the USA, with most concentrated in the southeast and northeast. This suggests UMGL populations are relatively short-distance migrants, wintering in the USA. Research by Hobson et al. (2009) using stable isotopes corroborates this conclusion. They found that kestrels breeding in the north-central region of the USA and southeastern Canada wintered in the southeastern USA, namely S. Carolina and Tennessee. We did not find any data to support connectivity with Mexico, the Caribbean, C. America, or S. America. For this reason, we excluded these regions from our vulnerability analysis. The USGS banding data added important information to existing research. As with the USFWS Region 3 status , our analysis suggests that this species is not currently at risk.


Juvenile American Kestrel (photo by S Hillebrand)

MIGRATORY CONNECTIVITY

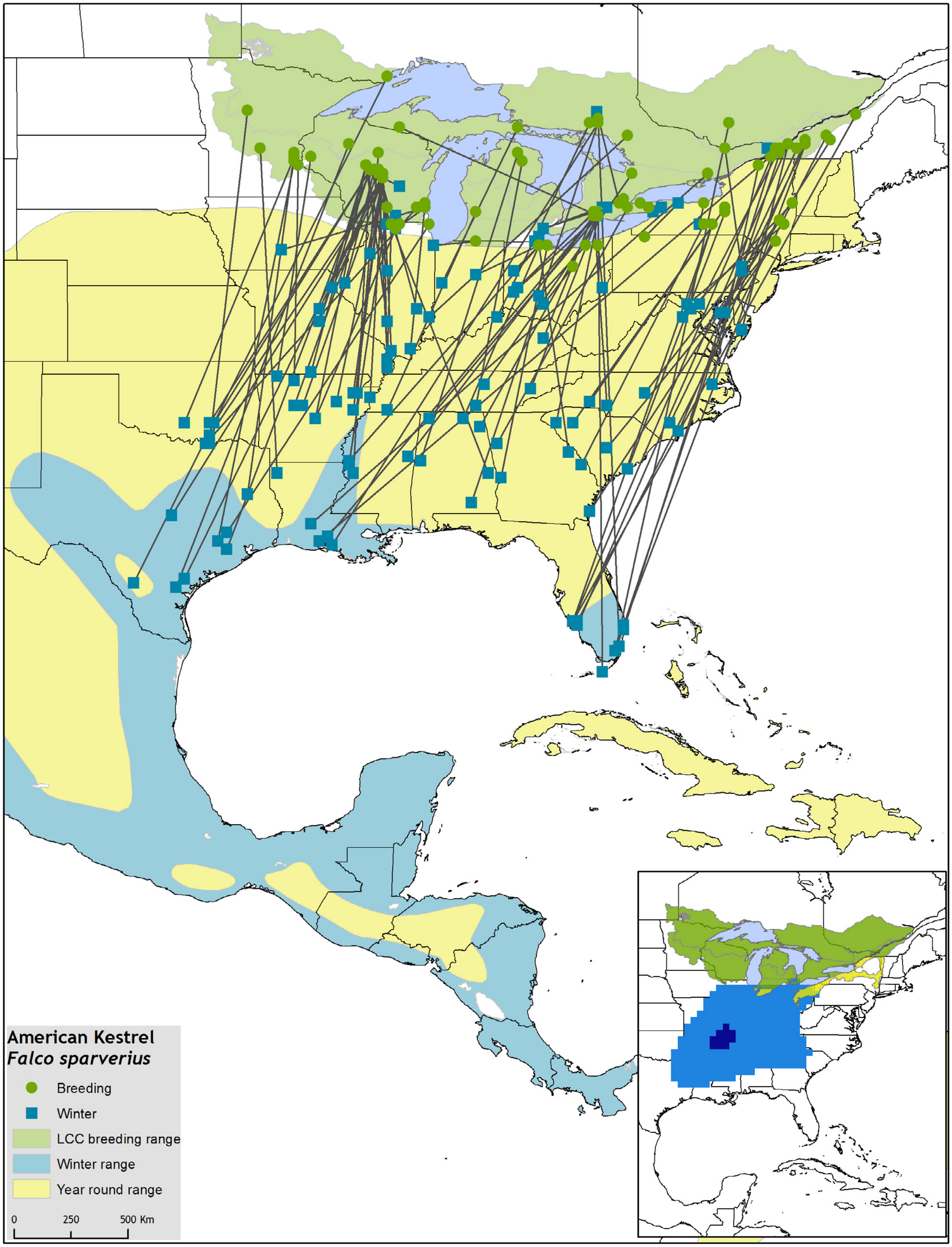


Figure 5.12. American Kestrel banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were 125 breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentration of non-breeding data originating from the UMGL.

CLIMATE EXPOSURE

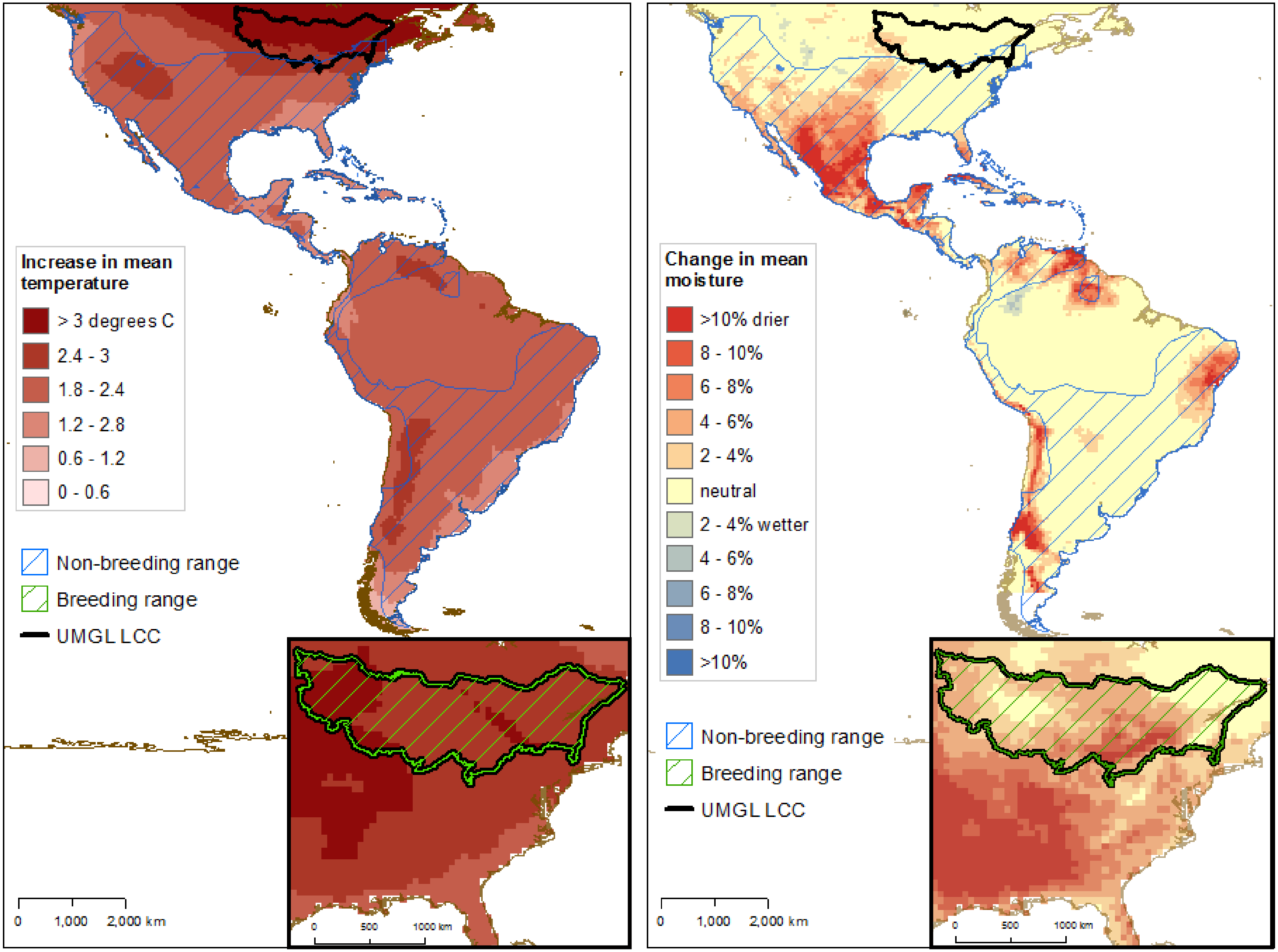


Figure 5.13. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the American Kestrel's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

AMERICAN KESTREL DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 3.6)
• Non-breeding PIF conservation	(score = 2.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant/resident, short-distance migrant, and long-distance migrant (mean distance = 1072 km)
• Breeding habitat niche specialization	(score = 1.2) Macro habitats grassland, desert, agriculture/pasture, urban, woodland (open with at least some trees); nesting micro habitat cavity (4-25 m high); can be natural or secondary cavity or nest box
• Breeding diet niche specialization	(score = 3.2) Arthropods, small mammals, and other small vertebrates like reptiles; captured by hovering and pouncing on prey in open areas using perches
• Breeding site fidelity	(score = 5.0) Very high (return to same territory year after year)
• Non-breeding habitat niche specialization	(score = 1.0) Grassland, desert, agriculture/pasture, urban/parks, woodland
• Non-breeding diet niche specialization	(score = 3.2) Not well studied but probably similar to breeding period (proportions may vary depending on what is available)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 33.4° C
• Breeding precipitation range	(score = 1.0) 123 cm
• Non-breeding thermal range	(score = 0) 37.8° C
• Non-breeding precipitation range	(score = 2.0) 97 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9 increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.0% drier
• Winter (Dec – Feb) non-breeding temperature	N. America (score = 3.0) 2.2 increase
• Winter (Dec – Feb) non-breeding moisture	N. America (score = 1.0) 2.4% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.0) Very little vulnerability of grasslands although specific components may change or disappears (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); we considered deserts as moderately vulnerable, particularly in the southwestern United States where woodlands and non-native grasses may take over (Bachelet et al. 2001, USDA 2012, but see Gonzalez et al. 2010); no vulnerability of agricultural and urban areas
• Breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in general and small vertebrates like reptiles largely unknown, but there may be some for native species (Chown et al. 2007); very little vulnerability of small mammals, which may even increase in abundance (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013); cavities are another necessary resource but there is no reason to think they will decrease in number
• Non-breeding habitat vulnerability	(score = 1.0) Very little vulnerability of grasslands although specific components may change or disappear, particularly in wet prairies (see above); very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (see above); we considered deserts as moderately vulnerable (see above); no vulnerability of agricultural and urban areas
• Non-breeding biotic interaction vulnerability	(score = 1.3) Vulnerability of arthropods in general and small vertebrates like reptiles are largely unknown (see above); very little vulnerability of small mammals (see above)

5.6. Peregrine Falcon
(Falco peregrinus)

USFWS Region 3 status: conservation concern
AOU number: 3560
AOU abbreviation: PEFA

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.1	**0**	**2.4**	**0**	**0**	**3.1**	**1.8**	**3.1**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Peregrine Falcon was moderate, scoring 2.1 out of 5.0. The background risk and adaptive capacity categories were the largest contributors to vulnerability, suggesting that both climate change and non-climate change related factors are important. Peregrine Falcons are flexible in the type of habitat that they use. However, they are fairly specialized in their diet (avian prey exclusively). This, combined with their tendency to return to the same breeding site year after year, increased their score in the adaptive capacity category. Temperature change was not expected to have much effect on vulnerability (neither breeding nor non-breeding) because Peregrine Falcons are relatively insensitive to temperature change throughout the annual cycle. Moisture change, however, is expected to have a low to moderate effect, depending on location and season (Figure 5.14). We had 165 breeding to non-breeding banding locations from the UMGL region (Figure 5.15). Most winter locations were in the USA, followed by the Caribbean, S. America, and C. America. This suggests most UMGL populations are relatively short-distance migrants and winter in the USA, though some likely go further south. We did not find any data to support connectivity with Mexico or southwestern S. America, and we excluded these regions from our vulnerability analysis. We found limited information on migratory connectivity in the literature: satellite data from across the USA showed weak connectivity throughout the Peregrine Falcon's non-breeding range (Fuller et al. 1998). However, we found no data specific to the UMGL region. Thus, the USGS banding data are some of the first on this important topic. Further research will greatly improve conservation efforts for the species.

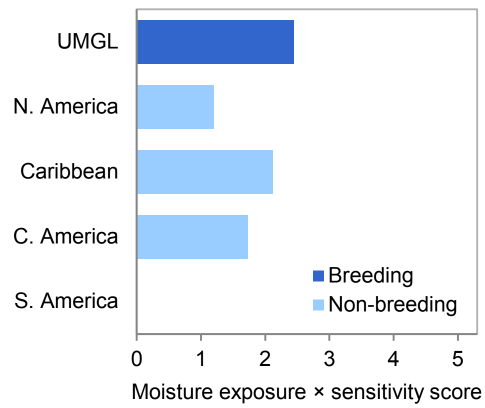


Figure 5.14. Peregrine Falcon subscores for moisture exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). Temperature results not shown as all scores equaled zero.

Peregrine Falcons need cliffs for nesting (photo by K Cole)

MIGRATORY CONNECTIVITY

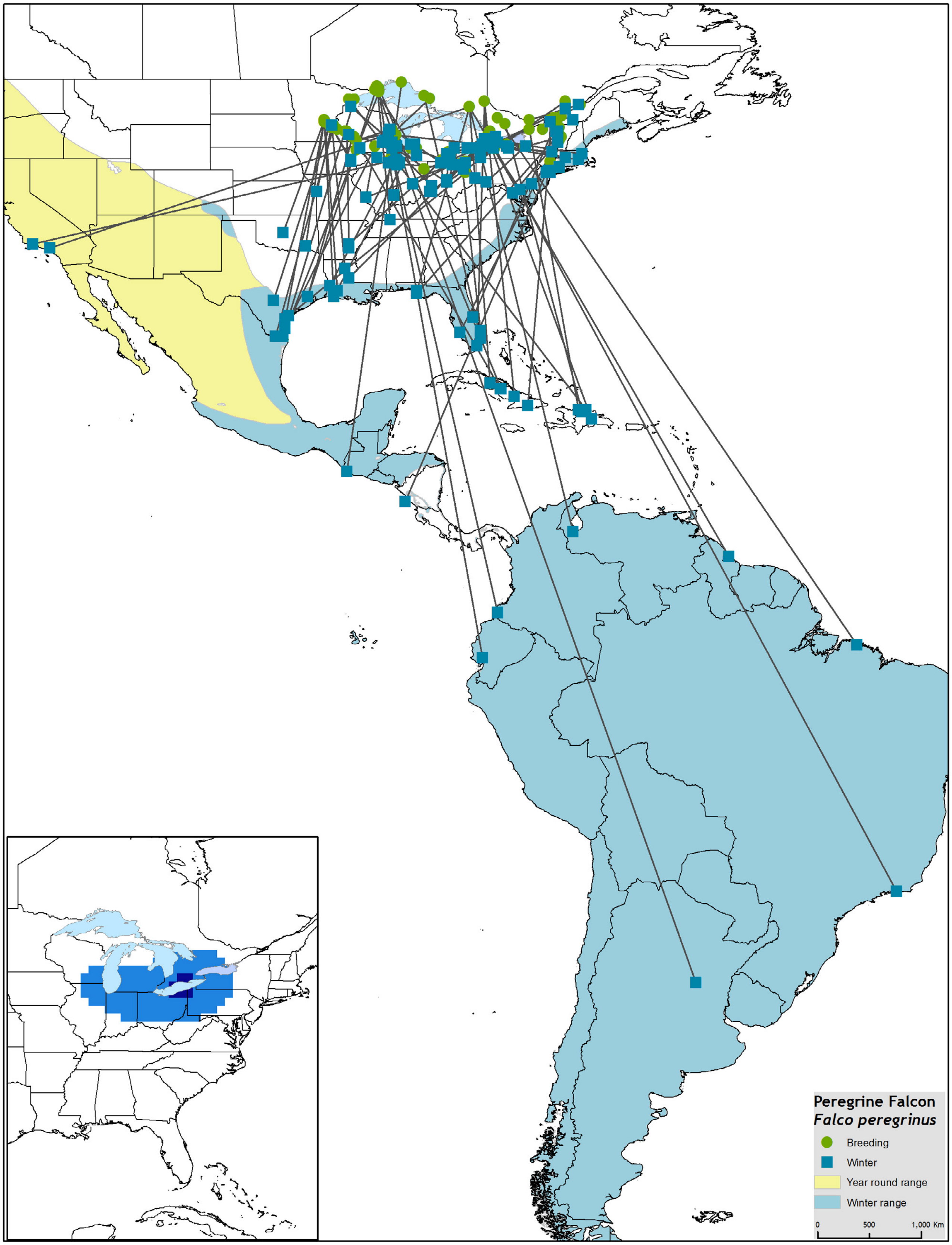


Figure 5.15. Peregrine Falcon banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were 165 breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentration of non-breeding data originating from the UMGL.

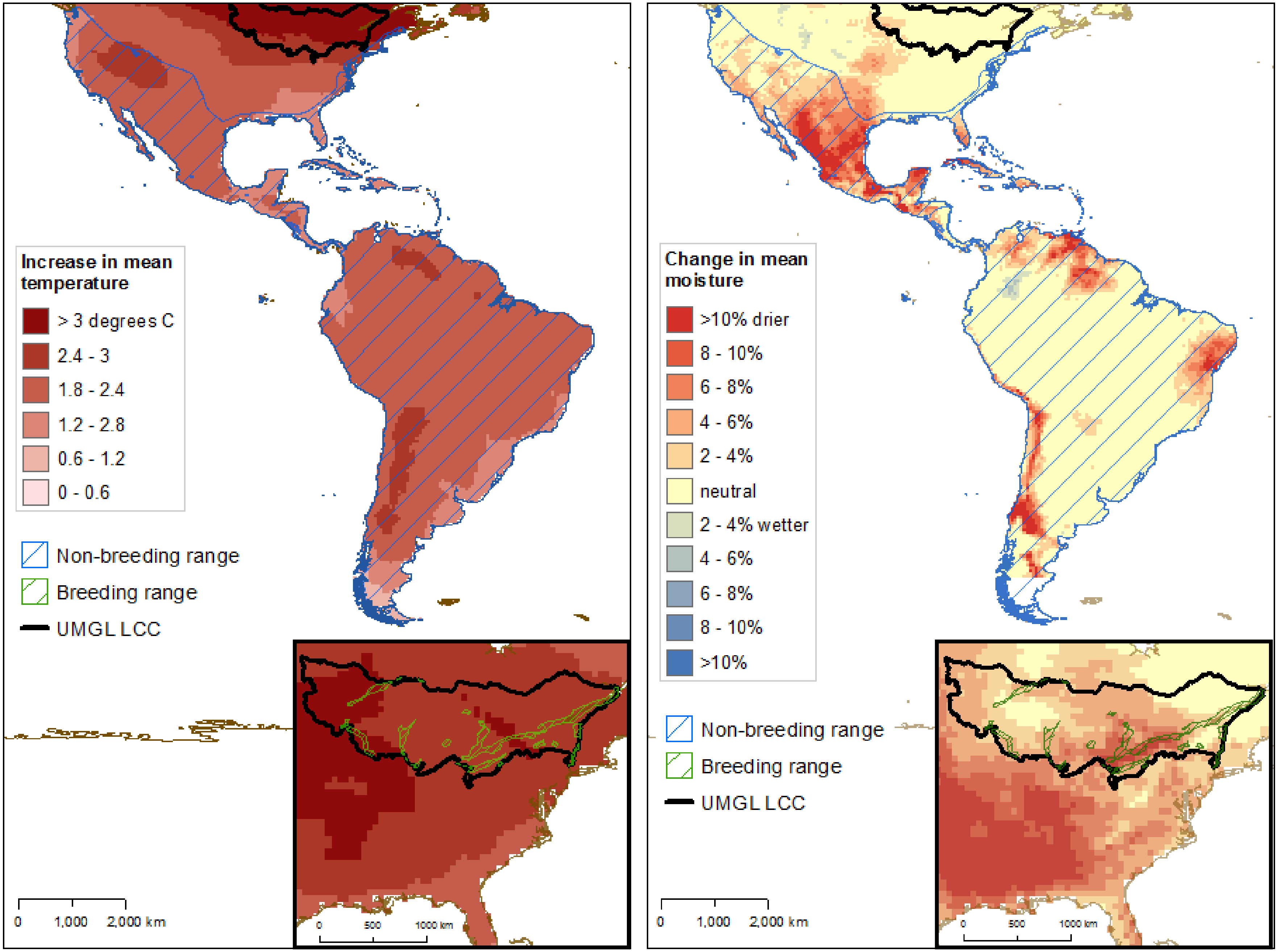


Figure 5.16. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Peregrine Falcon's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

PEREGRINE FALCON DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 3.1)
• Non-breeding PIF conservation	(score = 2.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant, short-distance migrant, long-distance migrant (mean distance = 1592 km)
• Breeding habitat niche specialization	(score = 1.7) Macro habitats coasts, grassland, tundra, shrub, wetland, desert, urban (generally open country); micro nesting habitat cliffs and buildings (10-100 m high)
• Breeding diet niche specialization	(score = 3.9) Birds; taken through aerial pursuit in open areas using perches
• Breeding site fidelity	(score = 5.0) High (not much detailed study, however)
• Non-breeding habitat niche specialization	(score = 1.0) Coasts, grassland, shrub, wetland, desert, mangrove forests, agriculture/pasture, urban
• Non-breeding diet niche specialization	(score = 3.9) Birds
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 32.6° C
• Breeding precipitation range	(score = 3.0) 65 cm
• Non-breeding thermal range	(score = 0) 44.9° C
• Non-breeding precipitation range	(score = 1.5) 120 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0): 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0): 5.3% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.1° C increase N. America (score = 3.0) 2.1° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 2.7) 2.1° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 0) 1.4% drier N. America (score = 1) 3.7% drier Caribbean (score = 3.0) 6.0% drier C. America (score = 2.0) 5.1% drier S. America (score = 0) 0.9% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.9) All sources agree tundra habitat is very highly vulnerable (Bachelet et al. 2001, Gonzalez et al. 2010); high vulnerability of coastal areas due to sea-level rise, and hurricanes (IPCC 2014, Karl et al. 2009); high vulnerability of wetlands due to drying and sea level rise (Goulatowitsch et al. 2009, Karl et al. 2009, USDA 2012, USFS 2013); shrublands may be moderately vulnerable due to woodland encroachment (USDA 2012, USFS 2013); we considered deserts moderately vulnerable, particularly in the southwest USA due to woodland and non-native grass encroachment (Bachelet et al. 2001, USDA 2012, but see Gonzalez et al. 2010); very little vulnerability of grasslands although specific components may change or disappear (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); no vulnerability of urban areas
• Breeding biotic interaction vulnerability	(score = 1.0) Though specific bird taxa may be vulnerable to climate change, Peregrine Falcons take a wide variety of species and are probably buffered from changes in avian communities
• Non-breeding habitat vulnerability	(score = 2.3) High vulnerability of coasts (see above); high vulnerability of wetlands (see above); very high vulnerability of mangrove forests due to sea level rise and storm surges (Gilman et al. 2008); shrublands may be moderately vulnerable (see above); moderate vulnerability of deserts (see above); very little vulnerability of grasslands (see above); no vulnerability of agricultural or urban areas
• Non-breeding biotic interaction vulnerability	(score = 1.0) see above

5.7. Killdeer
(Charadrius vociferus)

USFWS Region 3 status: common
AOU number: 2730
AOU abbreviation: KILL

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
1.7	**0**	**2.4**	**0**	**2.0**	**2.9**	**1.3**	**1.7**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Killdeer was low, scoring 1.7 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability, largely due to high breeding site fidelity and, to a lesser extent, to a highly specialized diet during the breeding season. However, we found no information on non-breeding diet. Temperature change was not expected to have much effect on vulnerability during breeding nor non-breeding because Killdeer were relatively insensitive to temperature change throughout the annual cycle. Moisture change was expected to have a moderate to high effect, with the greatest impact in Mexico during the non-breeding season (Figure 5.17). There were eight breeding to non-breeding banding locations from the UMGL region, all to N. America (Figure 5.18). Because the data are sparse and there was no published information, we were not able to measure migratory connectivity. Thus, we maintained a broad approach to vulnerability analysis for the species. Although we found total vulnerability to be low as did the USFWS, lack of information about MC for this species may hinder our ability manage them year-round.

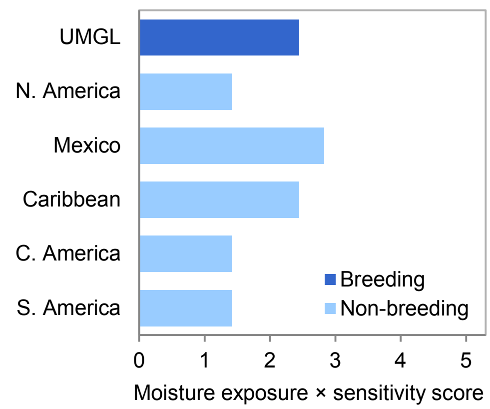


Figure 5.17. Killdeer subscores for moisture exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). Temperature results not shown as all scores equaled zero.

Killdeer with chick (photo by N Tox)

MIGRATORY CONNECTIVITY

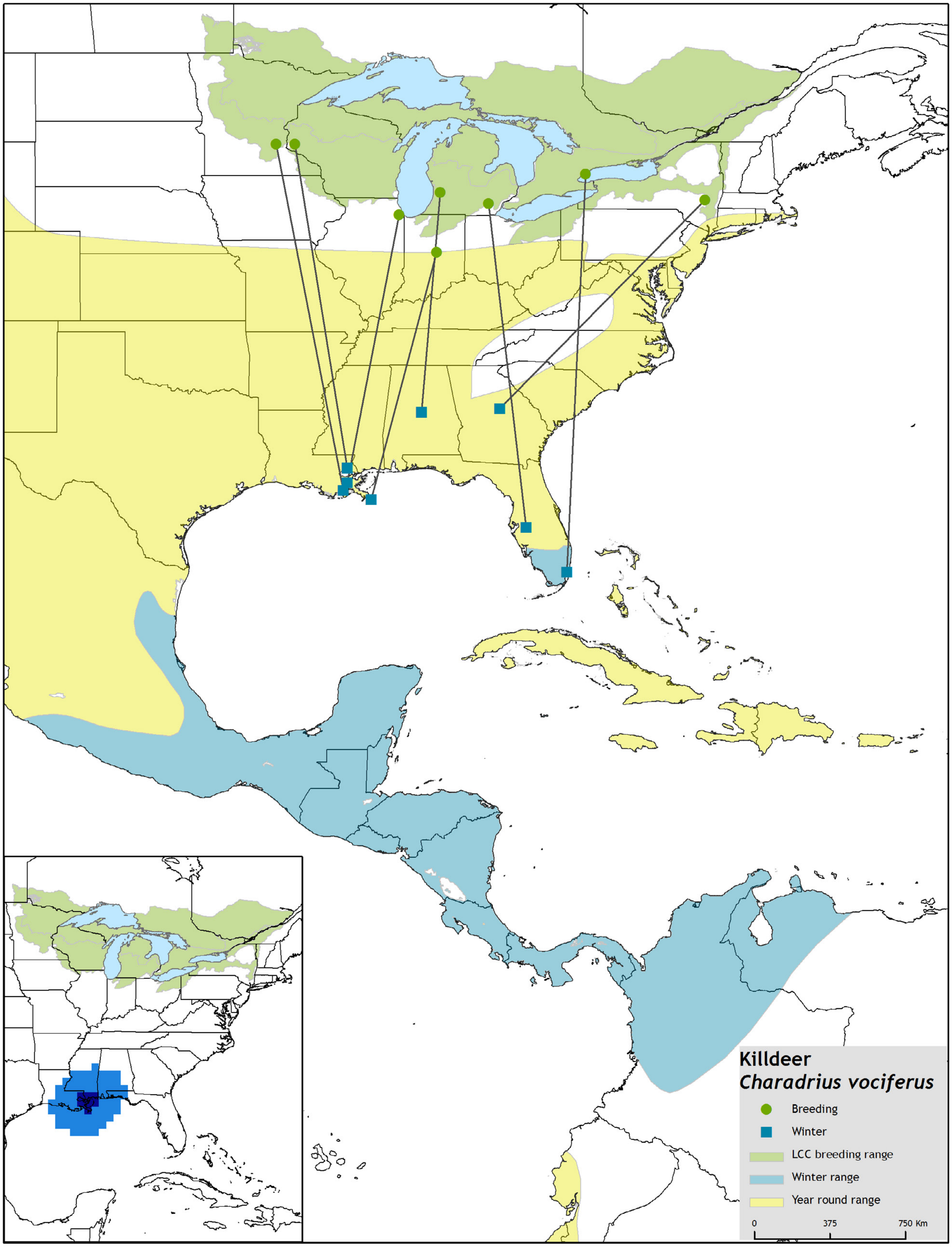


Figure 5.18. Killdeer banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were eight breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentration of non-breeding data originating from the UMGL.

CLIMATE EXPOSURE

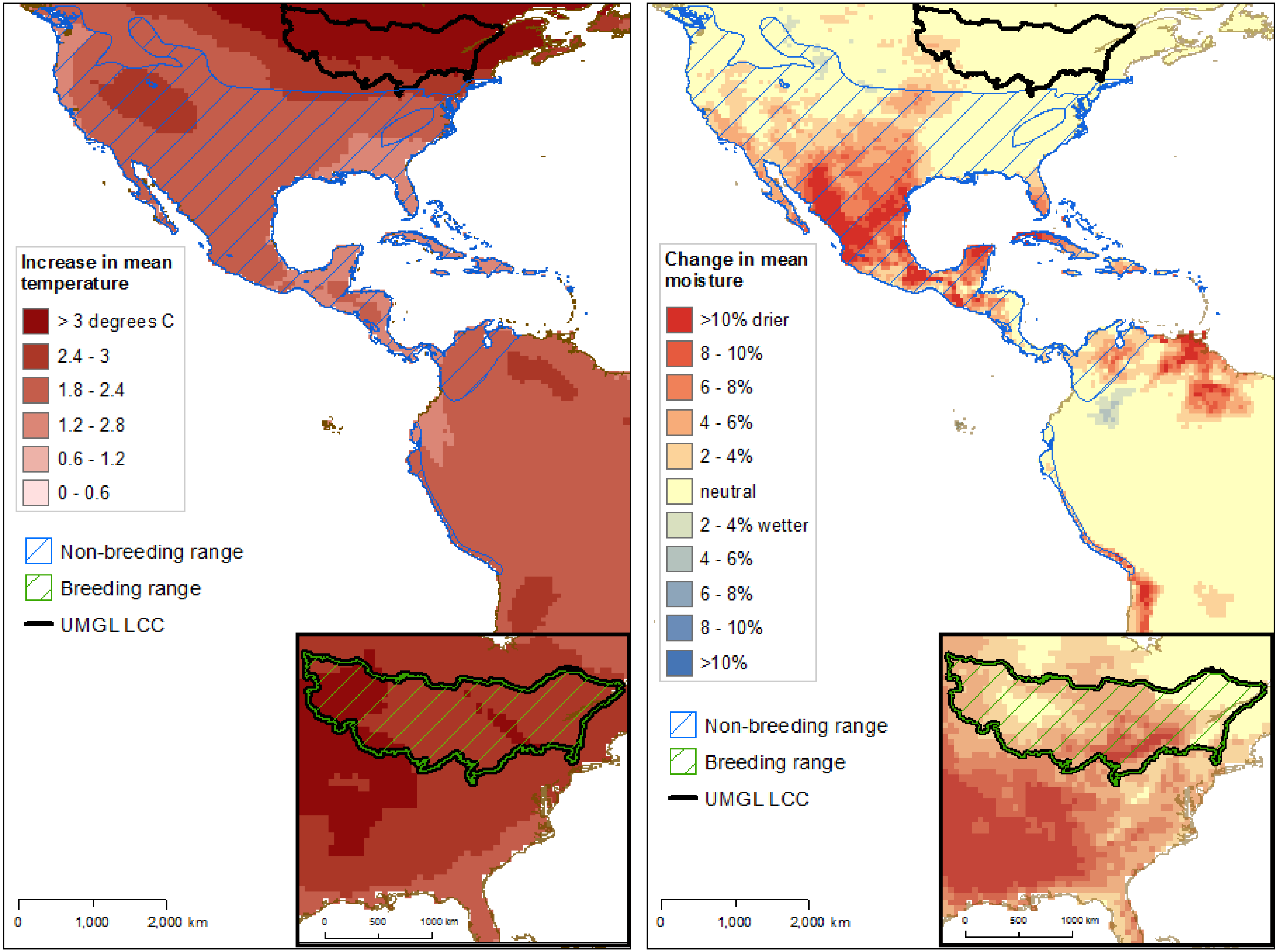
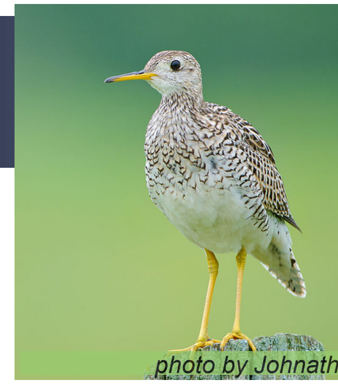


Figure 5.19. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Killdeer's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

KILLDEER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 1.0) breeding = 16,500,000 km2; non-breeding = 28,800,000 km2
• Threats (PIF)	(score = 3.0) breeding score = 3.0; non-breeding score = 3.0
• Breeding PIF conservation	(score = 2.5)
• Non-breeding PIF conservation	(score = 2.8)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant, short-distance migrant, long-distance migrant (mean distance = 1003 km)
• Breeding habitat niche specialization	(score = 2.1) Macro habitats riparian, agriculture/pasture, urban/parks, coasts, wetland and lake shores (with gravel, sand, mudflat, or bare ground); nesting micro habitat open or sparsely vegetated ground (0 m high)
• Breeding diet niche specialization	(score = 3.5) Arthropods (other inverts also taken); captured on the ground by gleaning
• Breeding site fidelity	(score = 5.0) Very high (known to have considerable fidelity between years)
• Non-breeding habitat niche specialization	(score = 1.0) Riparian, agriculture/pasture, urban/parks, coasts, wetland and lake shores (with gravel, sand, mudflat, or bare ground)
• Non-breeding diet niche specialization	(score = unknown) No data
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 23.9° C
• Breeding precipitation range	(score = 3.0) 69 cm
• Non-breeding thermal range	(score = 0) 36.7° C
• Non-breeding precipitation range	(score = 2.0) 101 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.0% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.0° C increase N. America (score = 3.0) 2.1° C increase Mexico (score = 3.0) 2.0° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.5% drier N. America (score = 1.0) 2.9% drier Mexico (score = 4.0) 8.1% drier Caribbean (score = 3.0) 6.3% drier C. America (score = 1.0) 3.7% drier S. America (score = 1.0) 3.1% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 0.9) Riparian habitat vulnerability may depend on location (Perry et al. 2012, USFS 2013); although coastal habitat is highly vulnerable in general, shorelines used by Killdeer may be less vulnerable; wetland and lake shorelines are probably less vulnerable also as long as lakes do not disappear entirely; no vulnerability of agricultural and urban areas
• Breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in general is largely unknown, though native species may be vulnerable (Chown et al. 2007); however, Killdeer take a wide variety of species
• Non-breeding habitat vulnerability	(score = 0.9) Riparian habitat vulnerability may depend on location (see above); coastal shorelines less vulnerable (see above); wetland and lake shorelines less vulnerable (see above); no vulnerability of agricultural and urban areas
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.8. Upland Sandpiper
(Bartramia longicauda)



USFWS Region 3 status: conservation concern
AOU number: 2610
AOU abbreviation: UPSA

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.4	**2.0**	**3.2**	**3.2**	**0**	**4.3**	**1.3**	**2.0**

(maximum score of 5 for all columns)

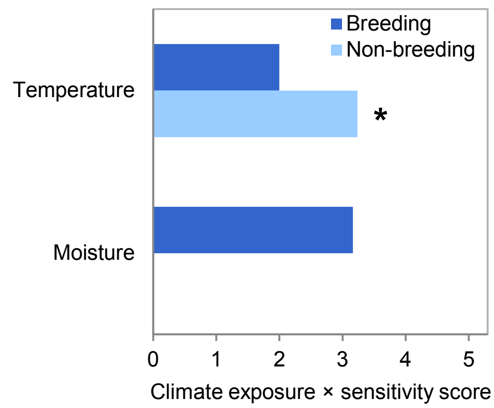


Figure 5.20. Upland Sandpiper subscores for climate exposure × sensitivity, breeding (UMGL, Jun – Aug) and non-breeding regions (S. America, Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

SUMMARY

Total vulnerability for Upland Sandpiper was moderate, scoring 2.4 out of 5.0. The adaptive capacity category was by far the largest contributor to vulnerability, largely due to a combination of extremely long-distance migration, highly specialized habitat requirements during breeding and non-breeding seasons, and high breeding site fidelity. Although Upland Sandpipers are so specialized, the grassland habitat that they require was not predicted to be heavily affected by climate change during the breeding season. Thus, the subscore for indirect effects is low and reduced total vulnerability. Our knowledge of indirect effects, however, is incomplete due to the lack of information about vulnerability of the pampas grasslands used during winter. More data are needed on this topic for a complete picture of Upland Sandpiper vulnerability. Non-breeding diet was another information gap for the species and should be an area of priority for research. Drying on the UMGL breeding grounds and temperature increases in S. America were both predicted to have high effects on vulnerability (Figure 5.20). This was partly due a very high sensitivity to moisture change during summer. We had very little connectivity information on Upland Sandpipers from banding data (Figure 5.21) and no information from the literature. Thus, our knowledge of possible migratory connectivity was very limited, which could hinder our ability to predict vulnerability and conserve the species comprehensively. However, because the Upland Sandpiper has a fairly small winter range, researching its migratory connectivity may be more feasible than for other species.

Upland Sandpiper standing vigil
© 2009 Brad Moon

MIGRATORY CONNECTIVITY

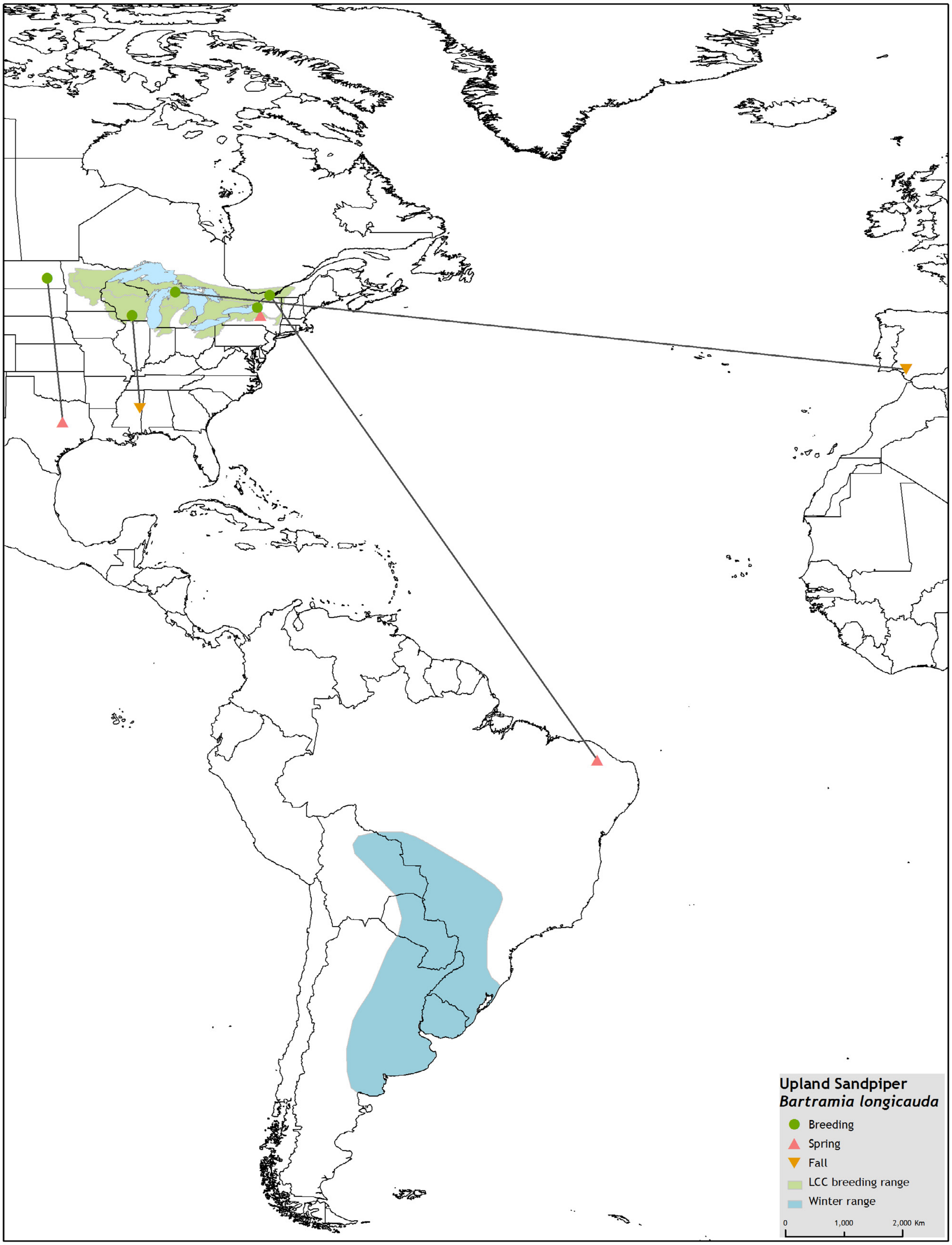


Figure 5.21. Upland Sandpiper banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green. There were no breeding to stationary non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

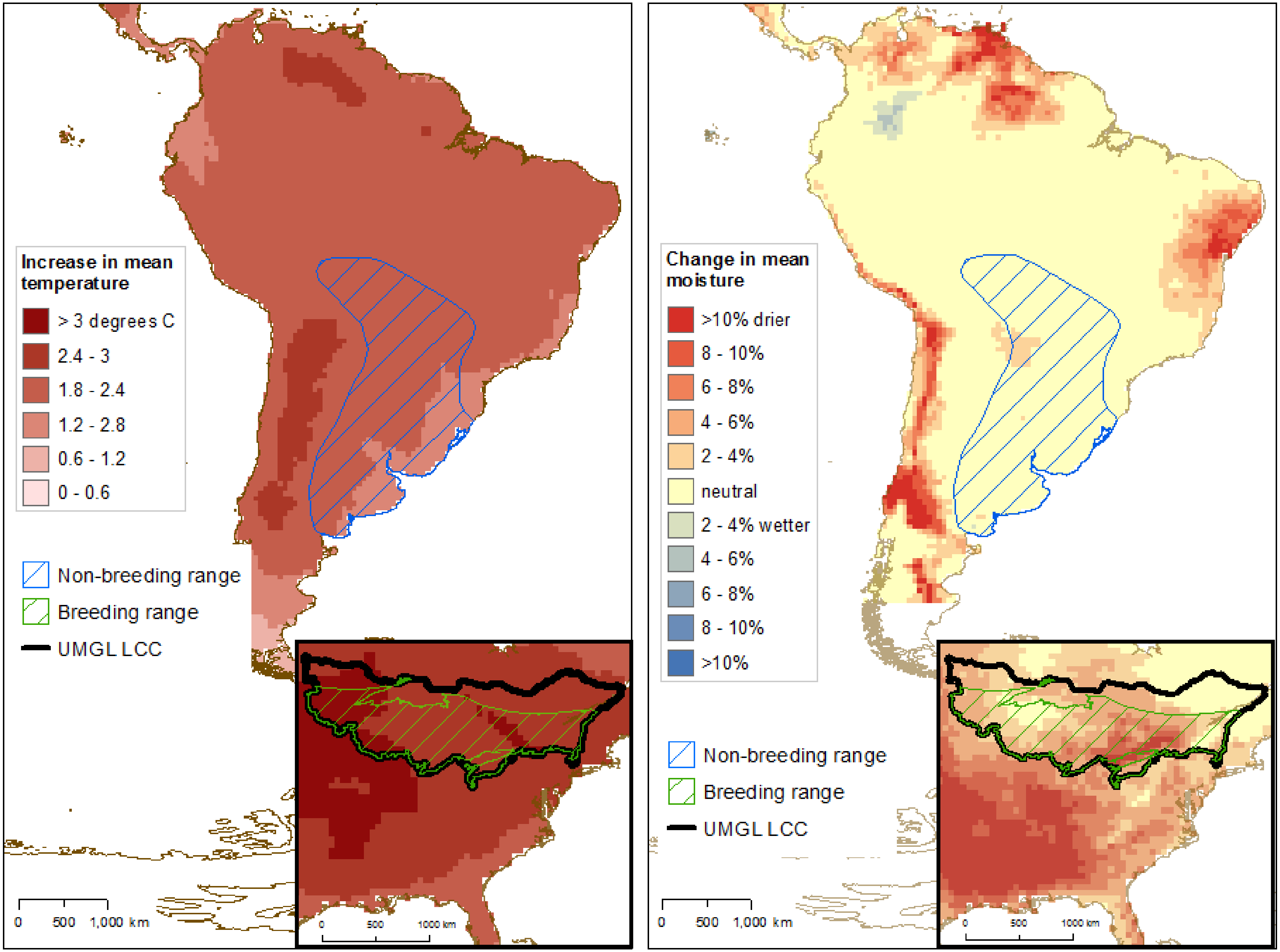


Figure 5.22. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Upland Sandpiper's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

UPLAND SANDPIPER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 (95% CI = 0, 0)
• Range size	(score = 1.0) breeding = 10,500,000 km2; non-breeding = 8,900,000 km2
• Threats (PIF)	(score = 4.0) breeding = score 2.0; non-breeding score = 4.0
• Breeding PIF conservation	(score 3.0)
• Non-breeding PIF conservation	(score 3.3)

ii. Adaptive Capacity	
• Migration strategy	(score = 5.0) long-distance migrant (mean distance = 8849 km)
• Breeding habitat niche specialization	(score = 4.7) Macro habitat prairies (especially native prairies, though agricultural fields may also be used); nesting micro habitat ground with tall, thick, grass (0 m high)
• Breeding diet niche specialization	(score = 3.2) Arthropods, other invertebrates, and grain seeds; captured on the ground by gleaning
• Breeding site fidelity	(score = 4.0) Medium high (pairs often return each year, but colony sites only moderately consistent even if the habitat remains unchanged)
• Non-breeding habitat niche specialization	(score = 4.5) Grasslands (pampas)
• Non-breeding diet niche specialization	(score = unknown) No data

iii. Climate Sensitivity	
• Breeding thermal range	(score = 1.0) 19.6° C
• Breeding precipitation range	(score = 5.0) 25 cm
• Non-breeding thermal range	(score = 3.5) 8.2° C
• Non-breeding precipitation range	(score = 3.0) 67 cm

iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.7% drier
• Winter (Dec – Feb) non-breeding temperature	S. America (score= 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	S. America (score = 0) 0.4% drier

v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.0) Very little vulnerability of grasslands although specific components may change or disappear, particularly in wet prairies (Goulatowitsch et al. 2009, USDA 2012, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 1.8) Upland Sandpipers make only one nesting attempt, even if the first attempt is destroyed; thus, the timing of arthropod phenology may be critical to successful nesting, which led us to categorized their arthropod diet as moderate to highly vulnerable; phenology of grain seeds, however, is not expected to affect vulnerability
• Non-breeding habitat vulnerability	(score = 1.0) Not much information is available on the vulnerability of pampas grasslands due to climate change
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.9. Caspian Tern
(Hydroprogne caspia)

USFWS Region 3 status: conservation concern
AOU number: 0640
AOU abbreviation: CATE

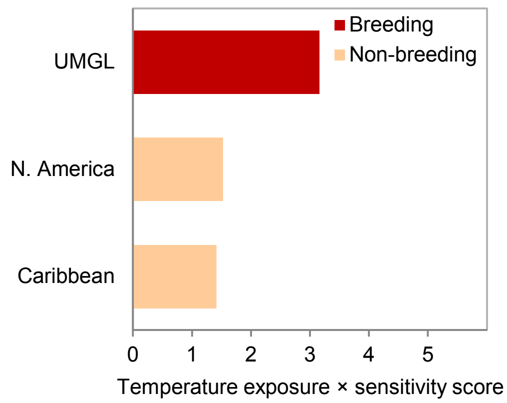
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.2	3.2	2.8	1.4	2.8	3.5	3.9	2.8

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Caspian Tern was high, scoring 3.2 out of 5.0. The indirect effects category was the largest contributor to vulnerability due to the high vulnerability of the aquatic habitat and aquatic prey (particularly cold freshwater prey) that the species requires throughout the year. Unfortunately, we have no data on diet during the non-breeding season, which limited our assessment of both indirect effects and adaptive capacity. The adaptive capacity category also had a high subscore, mostly due to the Caspian Tern's highly specialized habitat requirements during the breeding season and its high breeding site fidelity. Temperature increases on the UMGL breeding grounds were predicted to have a large effect on vulnerability, while drying on the Caribbean non-breeding grounds was also predicted to have a large effect (Figure 5.23). This was due to a large increase in temperature predicted for the UMGL region and due to the Caspian Tern's high sensitivity to moisture change during winter. Thus, it appears that temperature change on the breeding grounds and moisture change on the non-breeding grounds may work synergistically to increase the Caspian Tern's vulnerability. We had 266 breeding to non-breeding banding encounters from the UMGL region (Figure 5.24a). We built a capture-recapture model that accounted for spatial variation in encounter probability and quantified Caspian Tern migratory connectivity from the UMGL region (Figure 5.24b from Cohen et al. 2014). We found very tight connectivity between the UMGL and the southeastern USA and Caribbean (94 ± 3% probability of wintering in those regions). Terns were less likely to winter in Mexico or C. America (2 ± 2% probability) or in northern S. America (4 ± 3% probability). Thus, we restricted our vulnerability analysis to climate from the southeastern USA and Caribbean.



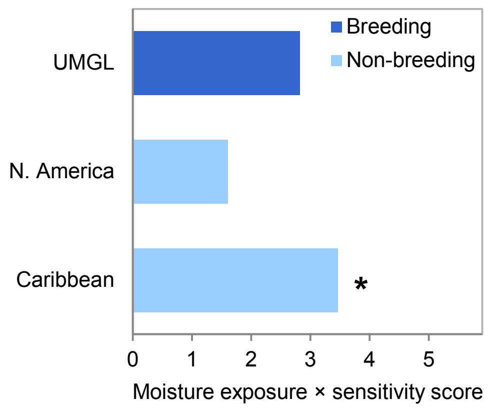


Figure 5.23. Caspian Tern subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

(A) (B)

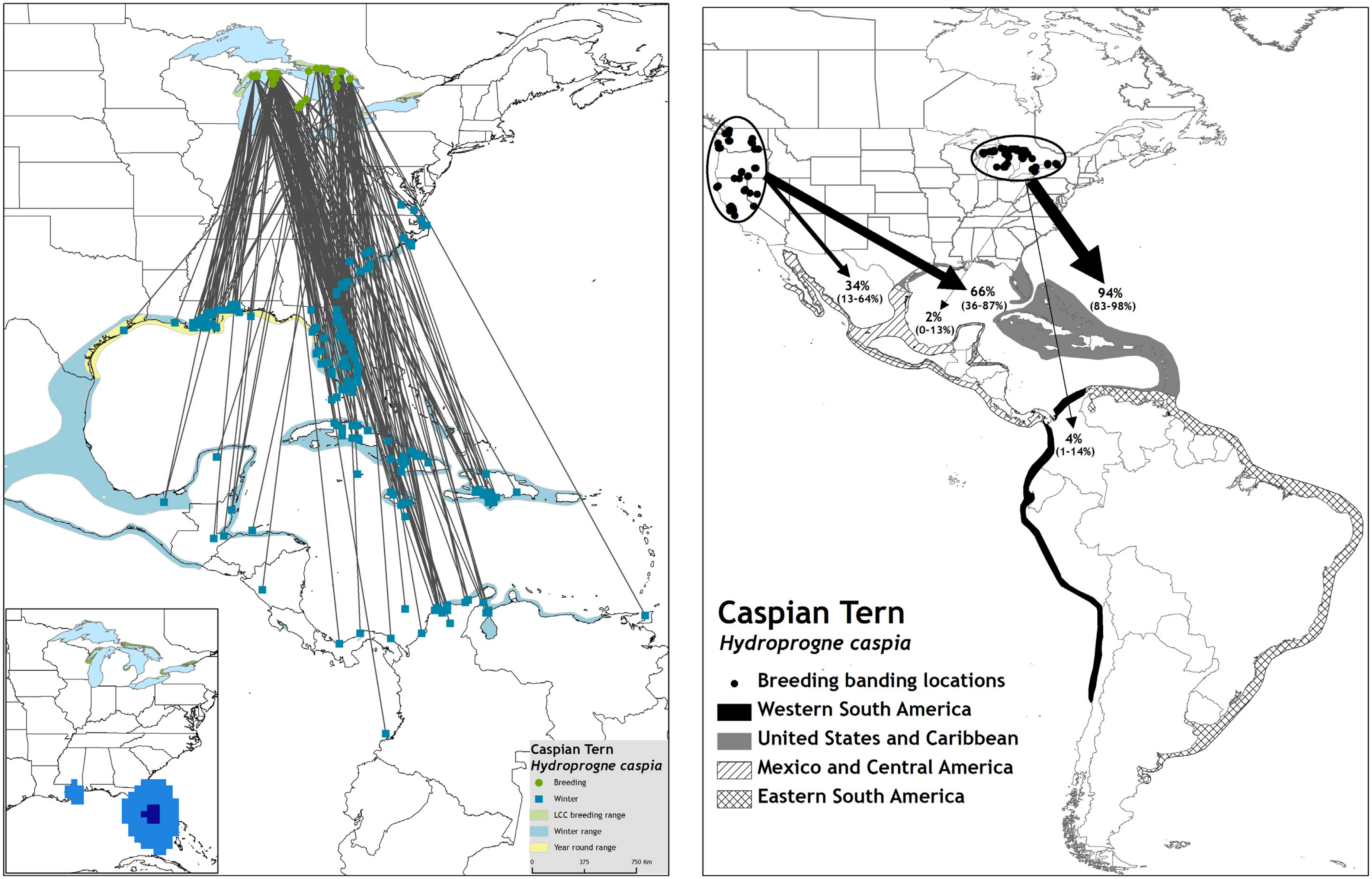


Figure 5.24. (A) Caspian Tern banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were 266 breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of non-breeding data originating from the UMGL. (B) Capture-recapture model results for Caspian Tern. Breeding source populations were UMGL and northwest USA. There was a very high degree of connectivity between UMGL populations and the southeast USA and Caribbean.

CLIMATE EXPOSURE

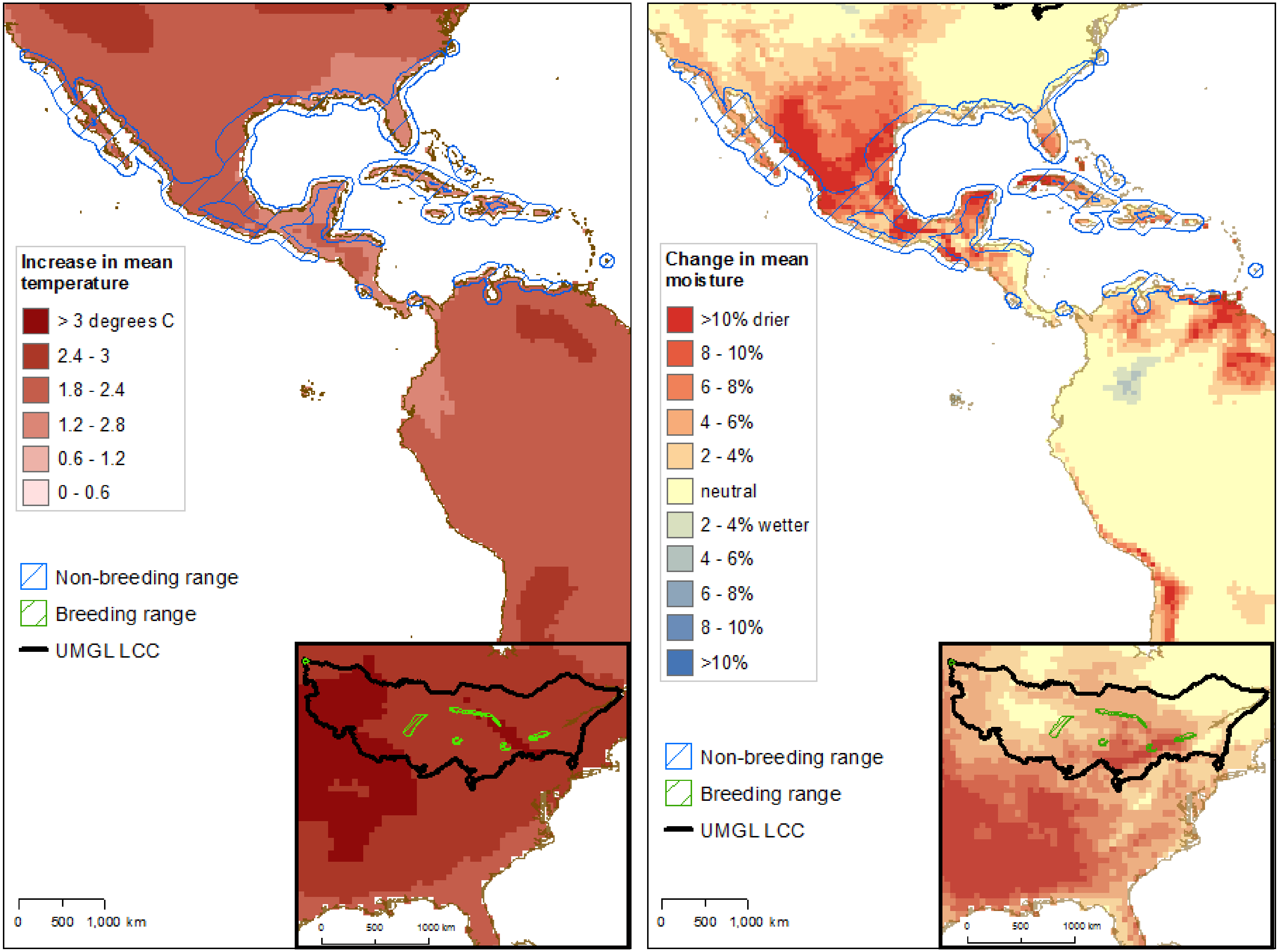


Figure 5.25. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Caspian Tern's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

CASPIAN TERN DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 2.8)
• Non-breeding PIF conservation	(score = 2.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant, short-distance migrant, long-distance migrant (mean distance = 2531 km)
• Breeding habitat niche specialization	(score = 3.9) Macro habitats coasts, freshwater wetlands, and saltwater wetlands; nesting micro habitat ground with sparse vegetation (0 m high)
• Breeding diet niche specialization	(score = 3.5) Fish and aquatic arthropods; captured aquatically by plunge diving
• Breeding site fidelity	(score = 4.0) High (maintains stable colonies unless hit by heavy failure, after which colonies can move en masse)
• Non-breeding habitat niche specialization	(score = 3.0) Coasts, saltwater wetlands, and freshwater wetlands
• Non-breeding diet niche specialization	(score = unknown) No data
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.5) 12.1° C
• Breeding precipitation range	(score = 4.0) 36 cm
• Non-breeding thermal range	(score = 1.0) 17.7° C
• Non-breeding precipitation range	(score = 4.0) 45 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.8% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.7° C increase N. America (score = 2.0) 1.8° C increase Caribbean (score = 2.0) 1.6° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.4% drier N. America (score = 1.0) 3.1% drier Caribbean (score = 3.0) 6.2% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.3) High vulnerability on coasts due to sea-level rise, and hurricanes (IPCC 2014, Karl et al. 2009); high vulnerability on freshwater wetlands due to drying and re-vegetation (Goulatowitsch et al. 2009, Karl et al. 2009, USDA 2012, USFS 2013); very high vulnerability on saltwater wetlands due to sea level rise (IPCC 2014)
• Breeding biotic interaction vulnerability	(score = 4.0) Moderate to very high vulnerability of aquatic prey, depending on whether it's a cold-water or warm-water species (Heino et al. 2009, Karl et al. 2009, Li et al. 2013, USFS 2013); as wetlands dry out, island colonies may become accessible to terrestrial nest predators
• Non-breeding habitat vulnerability	(score = 3.5) Vulnerability of near shore coastal habitat is uncertain, may depend on location and dependence on upwelling; very high vulnerability on saltwater wetlands (see above); high vulnerability on freshwater wetlands (see above)
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.10. Black Tern
(Chlidonias niger)

photo by D Daniels

USFWS Region 3 status: conservation concern
AOU number: 0770
AOU abbreviation: BLTE

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.3	**2.8**	**3.0**	**3.5**	**2.4**	**4.1**	**3.6**	**2.8**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Black Tern was high, scoring 3.3 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability, due to the Black Tern's very specialized year-round requirement of freshwater wetland habitat. This may be of particular concern given the high vulnerability of wetland habitats worldwide. Background risk scored less than most climate-change related categories, indicating that climate change may be a priority for this species. Temperature increases on the Mexican and S. American non-breeding breeding grounds (Dec – Feb) were predicted to have large effects on vulnerability, while drying on the UMGL breeding grounds and the Mexican non-breeding grounds were predicted to have large effects (Figure 5.26). Consequently, it appears that climate change during breeding and non-breeding periods may work synergistically to increase the Black Tern's vulnerability. We had just two breeding to non-breeding banding locations from the UMGL (Figure 5.27) and no information from the literature. For this reason, we included all possible non-breeding regions in our vulnerability analysis. Because our knowledge of possible migratory connectivity was very limited, which could hinder our ability to predict vulnerability and conserve the species comprehensively. This area should be a research priority. Nevertheless, in agreement with the USFWS status we found the species to be highly vulnerable.

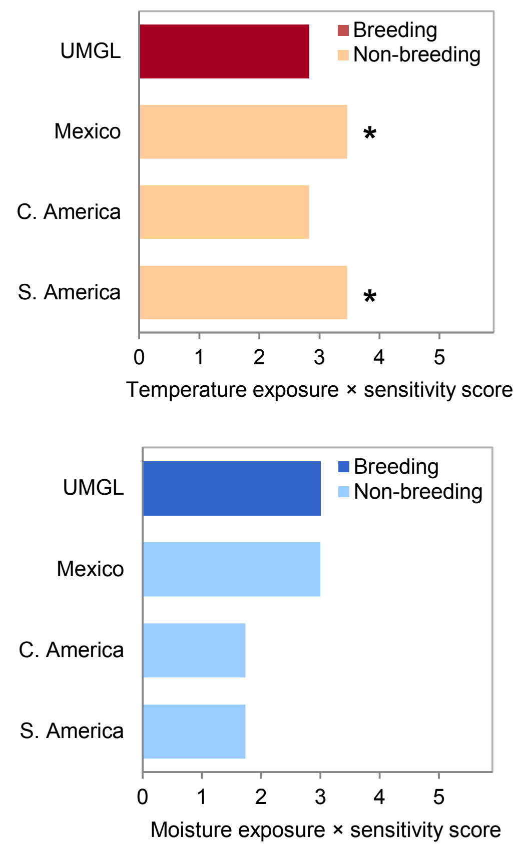


Figure 5.26. Black Tern subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

Black Tern at nest

MIGRATORY CONNECTIVITY

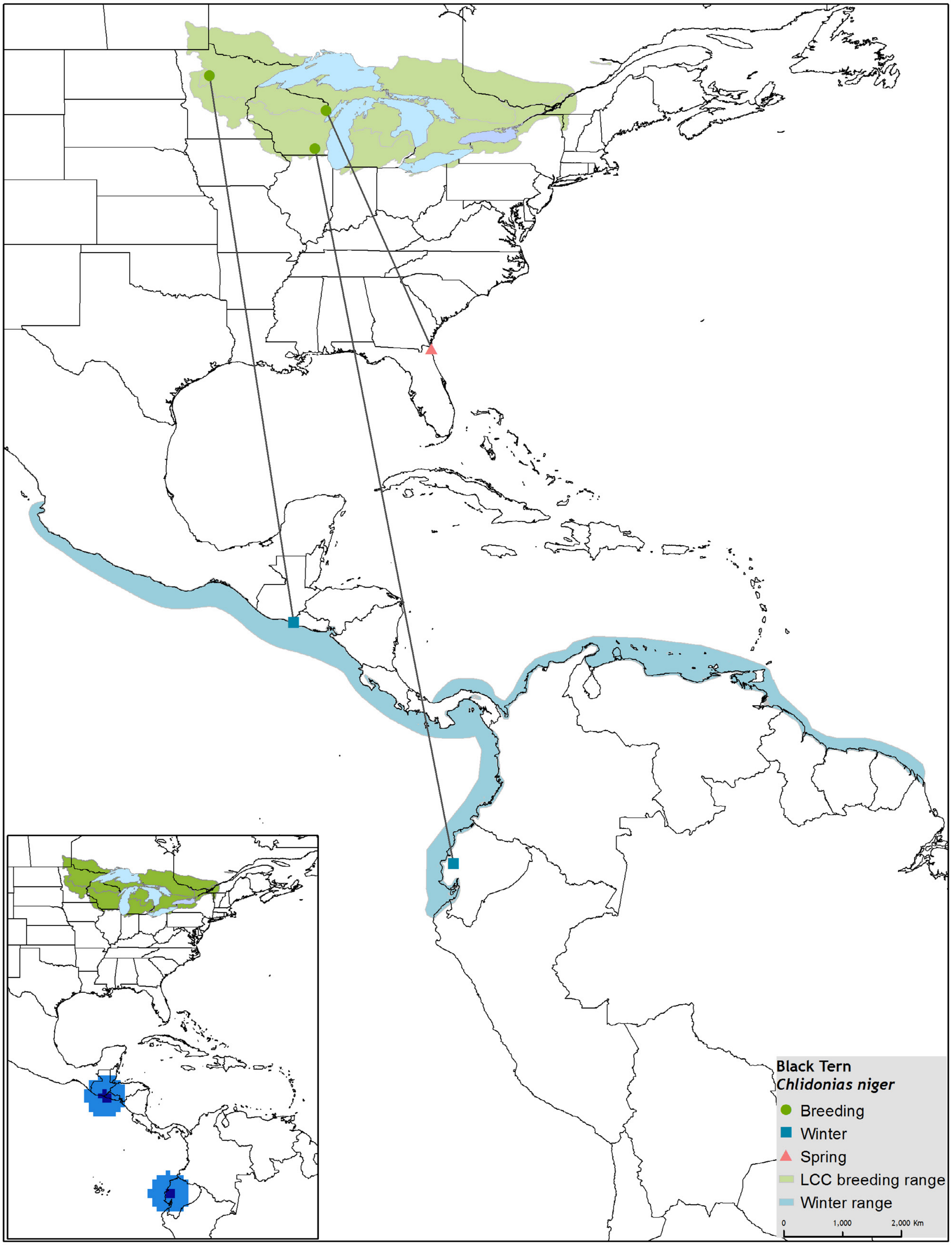


Figure 5.27. Black Tern banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were just two breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of non-breeding data originating from the UMGL.

CLIMATE EXPOSURE

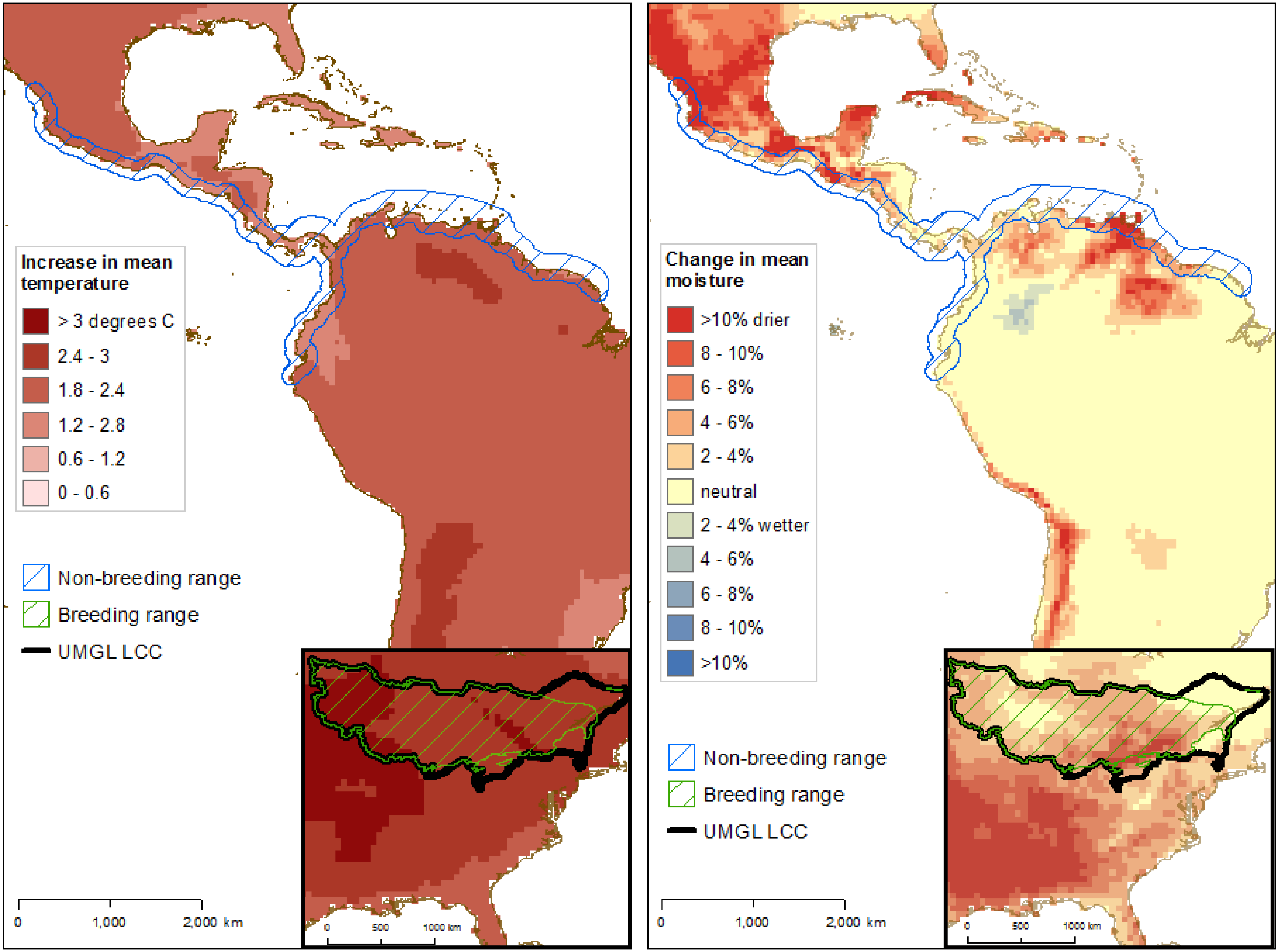


Figure 5.28. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Black Tern's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

BLACK TERN DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 2.8)
• Non-breeding PIF conservation	(score = 2.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 4403 km)
• Breeding habitat niche specialization	(score = 5.0) Macro habitat freshwater wetland; nesting micro habitat floating platform (0 m high)
• Breeding diet niche specialization	(score = 3.5) Aquatic arthropods and fish; captured by hawking and plucking from water surface
• Breeding site fidelity	(score = 3.0) Some (colonies ephemeral, also adults shift within single season)
• Non-breeding habitat niche specialization	(score = 5.0) Marine (nearshore and offshore)
• Non-breeding diet niche specialization	(score = 3.9) Small marine fish, marine invertebrates, and plankton
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 14.1° C
• Breeding precipitation range	(score = 4.5) 31 km
• Non-breeding thermal range	(score = 4.0) 5.1° C
• Non-breeding precipitation range	(score = 3.0) 82 km
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.4% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase Mexico (score = 3.0) 1.9° C increase C. America (score = 2.0) 1.7° C increase S. America (score = 3.0) 1.9° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.1% drier Mexico (score = 3.0) 7.0% drier C. America (score = 1.0) 3.8% drier S. America (score = 1.0) 3.1% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.0) High vulnerability on freshwater wetlands due to drying and re-vegetation (Karl et al. 2009, Goulatowitsch et al. 2009, USDA 2012, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 4.0) Moderate to very high vulnerability of aquatic prey, depending on whether it's a cold-water species or warm-water (Heino et al. 2009, Karl et al. 2009, Li et al. 2013, USFS 2013)
• Non-breeding habitat vulnerability	(score = 2.5) Vulnerability of marine habitats in general is uncertain, may depend on location and dependence on upwelling
• Non-breeding biotic interaction vulnerability	(score = 4.0) Uncertain, cold water environments may be highly vulnerable due to decrease in upwelling and decrease in prey; there may also be an increase in nearshore pollution such as red tides (Karl et al. 2009)

5.11. Common Tern
(Sterna hirundo)


photo by J Joseph

USFWS Region 3 status: conservation concern
AOU number: 0700
AOU abbreviation: COTE

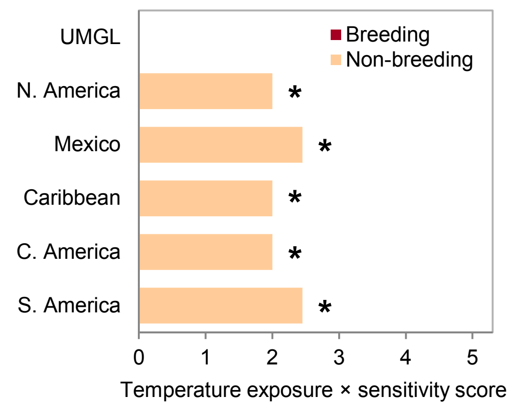
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.9	**0**	**1.7**	**2.4**	**1.4**	**3.9**	**3.6**	**2.8**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Common Tern was moderate, scoring 2.9 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability, due to their long migration distance, high degree of habitat specialization during breeding and non-breeding periods, and high breeding site fidelity. The contribution of the indirect effects category was also high, mostly due to the high vulnerability of aquatic prey and habitats, particularly salt water wetlands. Neither temperature nor moisture change on the UMGL breeding grounds (Jun – Aug) were predicted to have much effect on vulnerability. On the non-breeding grounds (Dec – Feb), however, they were predicted to have small to moderate effects, particularly in Mexico and S. America (for temperature) and the Caribbean (for moisture; Figure 5.29). Thus, it appears that climate change on the breeding and non-breeding grounds may work synergistically to moderately increase Common Tern vulnerability. We had 279 breeding to non-breeding encounters from the UMGL region (Figure 5.30a). We built a capture-recapture model that accounted for spatial variation in encounter probability and quantified Common Tern migratory connectivity (Figure 5.30b from Cohen et al. 2014). We found weak connectivity between the UMGL and non-breeding locations: 25 ± 9% probability of wintering in N. America and the Caribbean, 37 ±8% probability of wintering in Mexico and C. America, 26 ± 7% probability of wintering in western S. America, and 11 ± 5% probability of wintering in eastern S. America. Because of this weak connectivity, we included all regions in our vulnerability analysis.



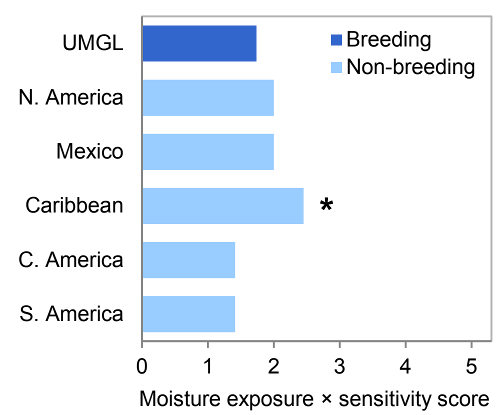


Figure 5.29. Common Tern subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

(A) (B)

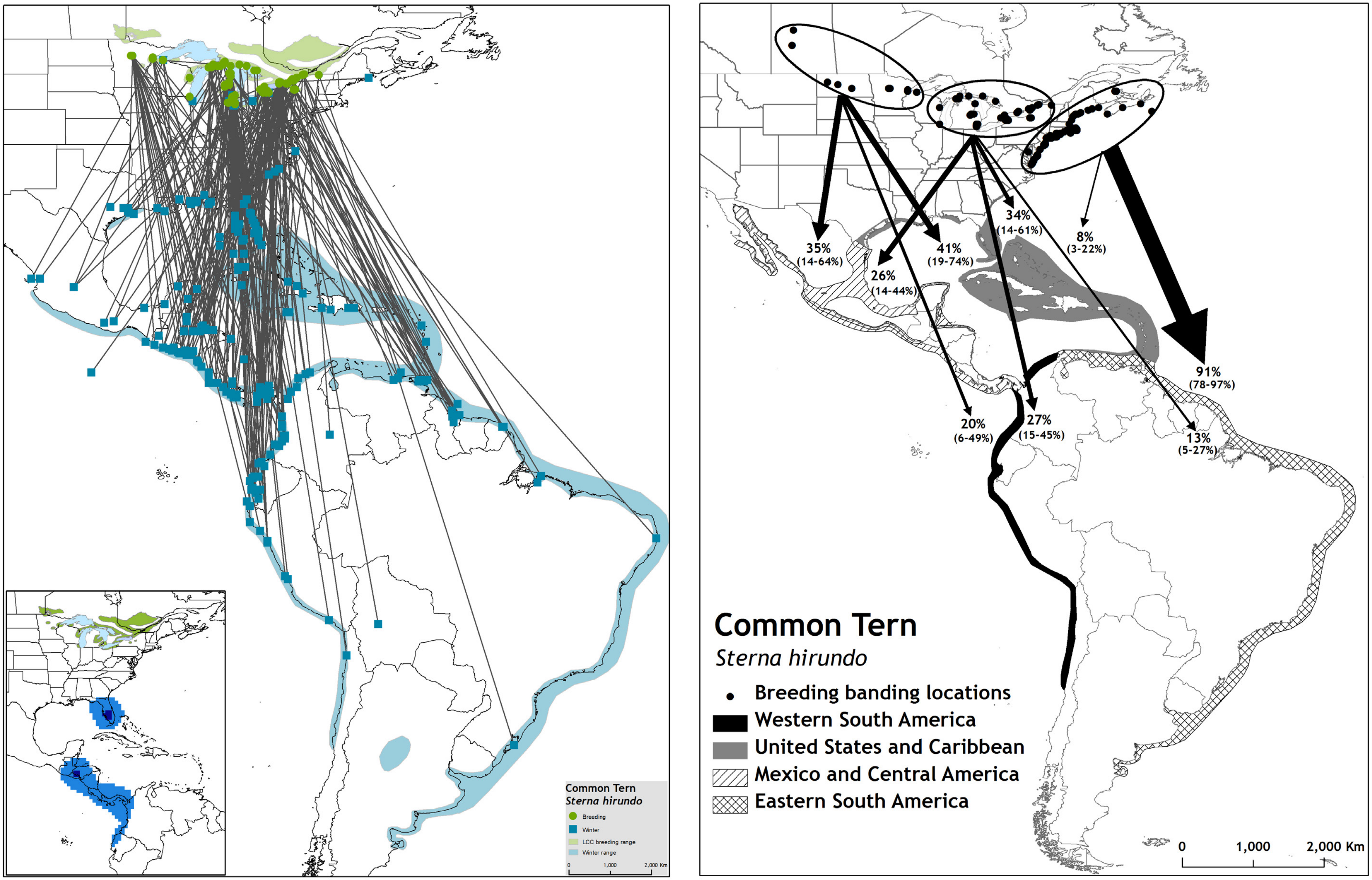


Figure 5.30. (A) Common Tern banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were 279 breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of non-breeding data originating from the UMGL. (B) Capture-recapture model results for Common Tern. Breeding source populations were Northeast USA, UMGL, and west USA/Canada. There was weak connectivity between UMGL populations and the southeast USA/Caribbean as well as Mexico/C. America and western S. America. Connectivity between UMGL and eastern S. America was even weaker.

CLIMATE EXPOSURE

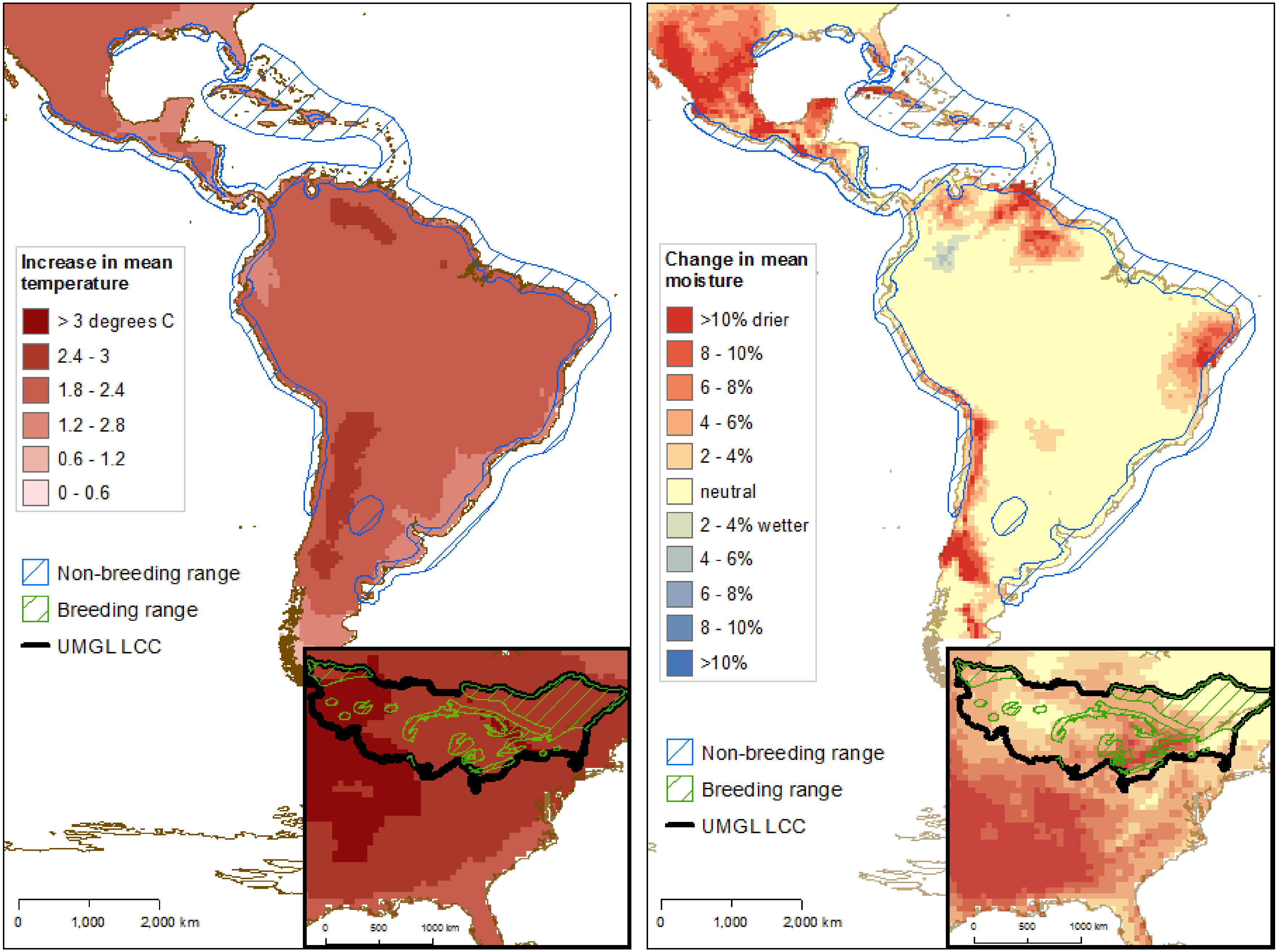


Figure 5.31. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Common Tern's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

COMMON TERN DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 2.8)
• Non-breeding PIF conservation	(score = 2.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 5947 km)
• Breeding habitat niche specialization	(score = 4.5) Macro habitats coasts and freshwater wetlands; nesting micro habitat ground with sparse vegetation (0 m high)
• Breeding diet niche specialization	(score = 3.7) Fish (some small invertebrates may also be taken); captured aquatically by plunge diving
• Breeding site fidelity	(score = 4.0) Medium high (colonies mostly stable unless hit by heavy failure at which point they can move en masse)
• Non-breeding habitat niche specialization	(score = 4.0) Coasts and saltwater wetlands
• Non-breeding diet niche specialization	(score = 3.2) Fish, insects, and other invertebrates
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 21.5° C
• Breeding precipitation range	(score = 3.0) 64 cm
• Non-breeding thermal range	(score = 2.0) 15.6° C
• Non-breeding precipitation range	(score = 2.0) 107 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.8° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 3.8% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase N. America (score = 2.0) 1.7° C increase Mexico (score = 3.0) 1.9° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.7° C increase S. America (score = 3.0) 1.9° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 1.0) 2.7% drier N. America (score = 2.0) 4.2% drier Mexico (score = 2.0) 5.5% drier Caribbean (score = 3.0) 6.0% drier C. America (score = 1.0) 3.1% drier S. America (score = 1.0) 2.1% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.0) High vulnerability on coasts due to sea-level rise, and hurricanes (IPCC 2014, Karl et al. 2009); high vulnerability on freshwater wetlands due to drying and re-vegetation (Karl et al. 2009, Goulatowitsch et al. 2009, USDA 2012, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 4.0) Cold water prey are highly likely to decrease in abundance due to decrease in oxygen, increased botulism in warmer waters is also a possibility (Heino et al. 2009, Karl et al. 2009, Li et al. 2013, USDA 2012, USFS 2013); in addition, as wetlands dry out, islands with nest colonies may become accessible to terrestrial nest predators
• Non-breeding habitat vulnerability	(score = 3.3) Very high vulnerability on saltwater wetlands due to sea level rise (IPCC 2014); vulnerability of near shore coastal habitat is uncertain, may depend on location and dependence on upwelling
• Non-breeding biotic interaction vulnerability	(score = 3.0) Uncertain, cold water environments may be highly vulnerable due to decrease in upwelling and decrease in prey, while warm waters may remain stable; there may be increase in nearshore pollution such as red tides (Karl et al. 2009)

5.12. Forster's Tern
(Sterna forsteri)

USFWS Region 3 status: common
AOU number: 0690
AOU abbreviation: FOTE

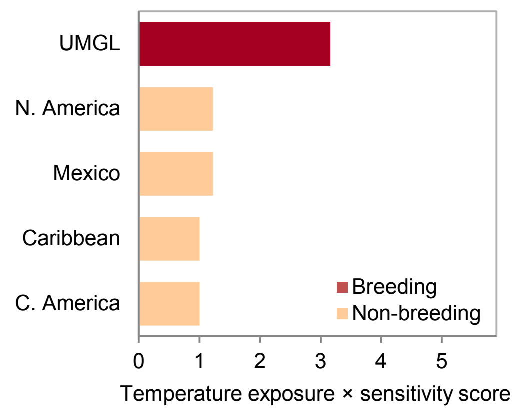
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.3	3.2	2.8	1.2	2.8	3.5	4.2	3.0

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Forster's Tern was high, scoring 3.3 out of 5.0. The indirect effects category was the largest contributor to vulnerability due to very high vulnerability of wetlands throughout their range as well as high vulnerability of cold-water aquatic prey. Wetland vulnerability was further exacerbated by the tern's year-round reliance on this habitat. Unfortunately, we have no data on diet during the non-breeding season and our assessments of both indirect effects and adaptive capacity were limited in this regard. More data are needed for a complete understanding of vulnerability. Another very large contributor to vulnerability was drying of the Mexican non-breeding grounds, followed by drying of the Caribbean non-breeding grounds (Figure 5.32). Temperature increases on the UMGL breeding grounds are also predicted to have large effects on vulnerability (Figure 4.32). As a result, Forster's Terns had increased vulnerability throughout the year—affected by temperature change during the breeding season and by moisture change during the non-breeding season. We had 31 breeding to non-breeding encounters originating from the UMGL (Figure 5.33) and no information from the literature. Because of the paucity of data, we maintained a broad approach including all of the non-breeding range in our analysis. Lack of information on migratory connectivity may hinder our ability to determine the best approach to conserving Forster's Terns, and it should be a research priority.



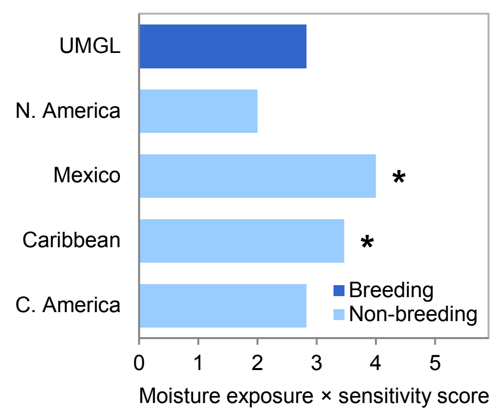


Figure 5.32. Forster's Tern subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

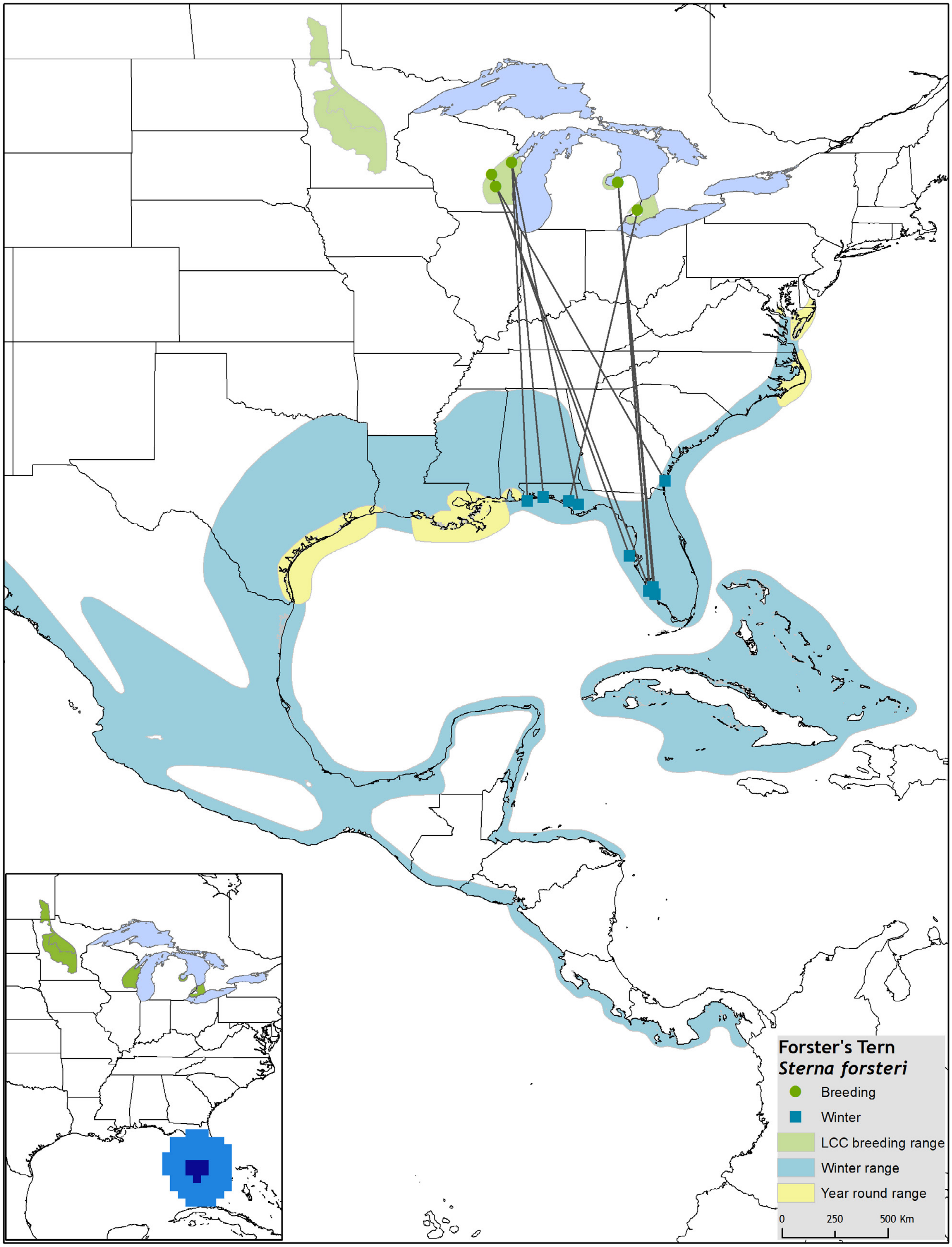


Figure 5.33. Forster's Tern banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were 31 breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of non-breeding data originating from the UMGL.

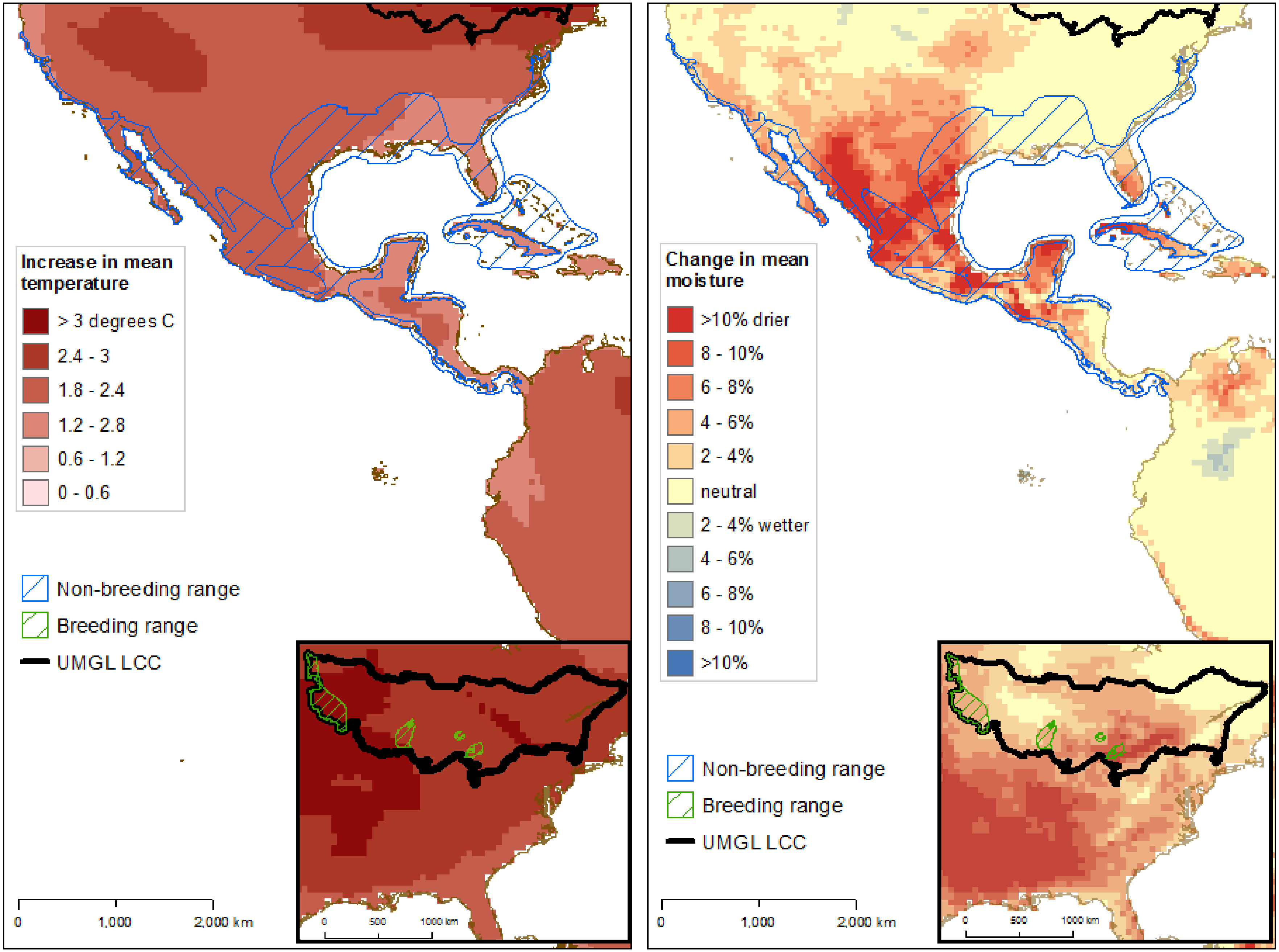


Figure 5.34. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Forster's Tern non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

FORSTER'S TERN DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 3.0)
• Non-breeding PIF conservation	(score = 2.8)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Short-distance migrant, long-distance migrant (mean distance = 1856 km)
• Breeding habitat niche specialization	(score = 4.0) Macro habitats freshwater wetlands, saltwater wetlands; nesting micro habitat ground or floating platform (0 m high)
• Breeding diet niche specialization	(score = 3.5) Fish and aquatic arthropods; captured aquatically by plunge diving
• Breeding site fidelity	(score = 3.0) Some (colonies can shift quickly from year to year)
• Non-breeding habitat niche specialization	(score = 4.0) Saltwater wetlands, freshwater wetlands, lakes
• Non-breeding diet niche specialization	(score = unknown) No data
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 13.2° C
• Breeding precipitation range	(score = 4.0) 34 km
• Non-breeding thermal range	(score = 0.5) 20.2° C
• Non-breeding precipitation range	(score = 4.0) 44 km
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 5.0) 3.1° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.2% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0): 1.9° C increase N. America (score = 3.0): 1.8° C increase Mexico (score = 3.0): 2.0° C increase Caribbean (score = 2.0): 1.6° C increase C. America (score = 2.0): 1.7° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0): 5.6% drier N. America (score = 1.0): 3.1% drier Mexico (score = 4.0): 8.1% drier Caribbean (score = 3.0): 7.8% drier C. America (score = 2.0): 4.0% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.5) High vulnerability on freshwater wetlands due to drying and re-vegetation (Karl et al. 2009, Goulatowitsch et al. 2009, USDA 2012, USFS 2013); very high vulnerability on saltwater wetlands due to sea level rise (IPCC 2014)
• Breeding biotic interaction vulnerability	(score = 4.0) Moderate to very high vulnerability of aquatic prey, depending on whether it's a cold-water species or warm-water (Heino et al. 2009, Karl et al. 2009, Li et al. 2013, USDA 2013); as wetlands dry out, islands with nest colonies may become accessible to terrestrial nest predators
• Non-breeding habitat vulnerability	(score = 4.0) Very high vulnerability on saltwater wetlands (see above); high vulnerability on freshwater wetlands (see above)
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.13. Yellow-billed Cuckoo *(Coccyzus americanus)*

USFWS Region 3 status: common
AOU number: 3870
AOU abbreviation: YBCU

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.3	**2.8**	**2.8**	**2.4**	**0.7**	**3.6**	**1.5**	**2.1**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Yellow-billed Cuckoo was moderate, scoring 2.3 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability, due to the Yellow-billed Cuckoo's long-distance migration, fairly high habitat specialization (particularly during the non-breeding season), and specialized breeding diet on large insects and small vertebrates. Temperature increases throughout the year and drying on the UMGL breeding grounds were predicted to have moderate effects on vulnerability (Figure 5.35). Moisture is not expected to change much by 2050 in S. America, and drying during the non-breeding season did not have much effect on vulnerability (Figure 5.35). Indirect effects of climate change also did not have much effect on vulnerability, partly because one of their preferred foods, large toxic caterpillar pests like the tent caterpillar, is expected to increase in abundance with climate change (Percy et al. 2002).During the non-breeding season, Yellow-billed Cuckoos can be found across most of S. America, but we had just one breeding to non-breeding encounter from the UMGL (Figure 5.36) and no information from the literature. For these reasons, we were unable to deduce possible migratory connectivity with the UMGL, and we included all of the non-breeding range in our vulnerability analysis. This species is considered common and not vulnerable in the UMGL. Western populations are under serious threat probably due to loss of breeding habitat. However, our assessment of non-breeding vulnerability may not be very accurate because of the large area included. Given that some populations of this species are declining, increased information about migratory connectivity should be a research priority.

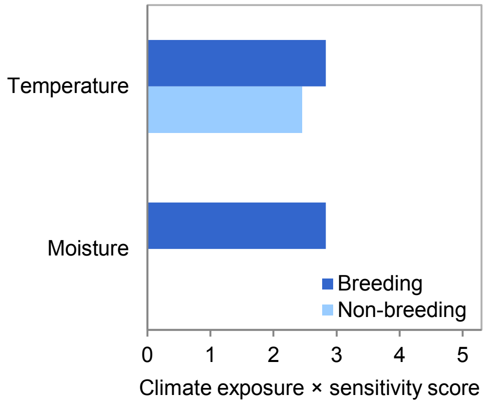


Figure 5.35. Yellow-billed Cuckoo subscores for climate exposure × sensitivity, breeding (UMGL, Jun – Aug) and non-breeding regions (S. America, Dec – Feb).

Yellow-billed Cuckoos are sit-and-wait predators (photo by S Ramirez)

MIGRATORY CONNECTIVITY

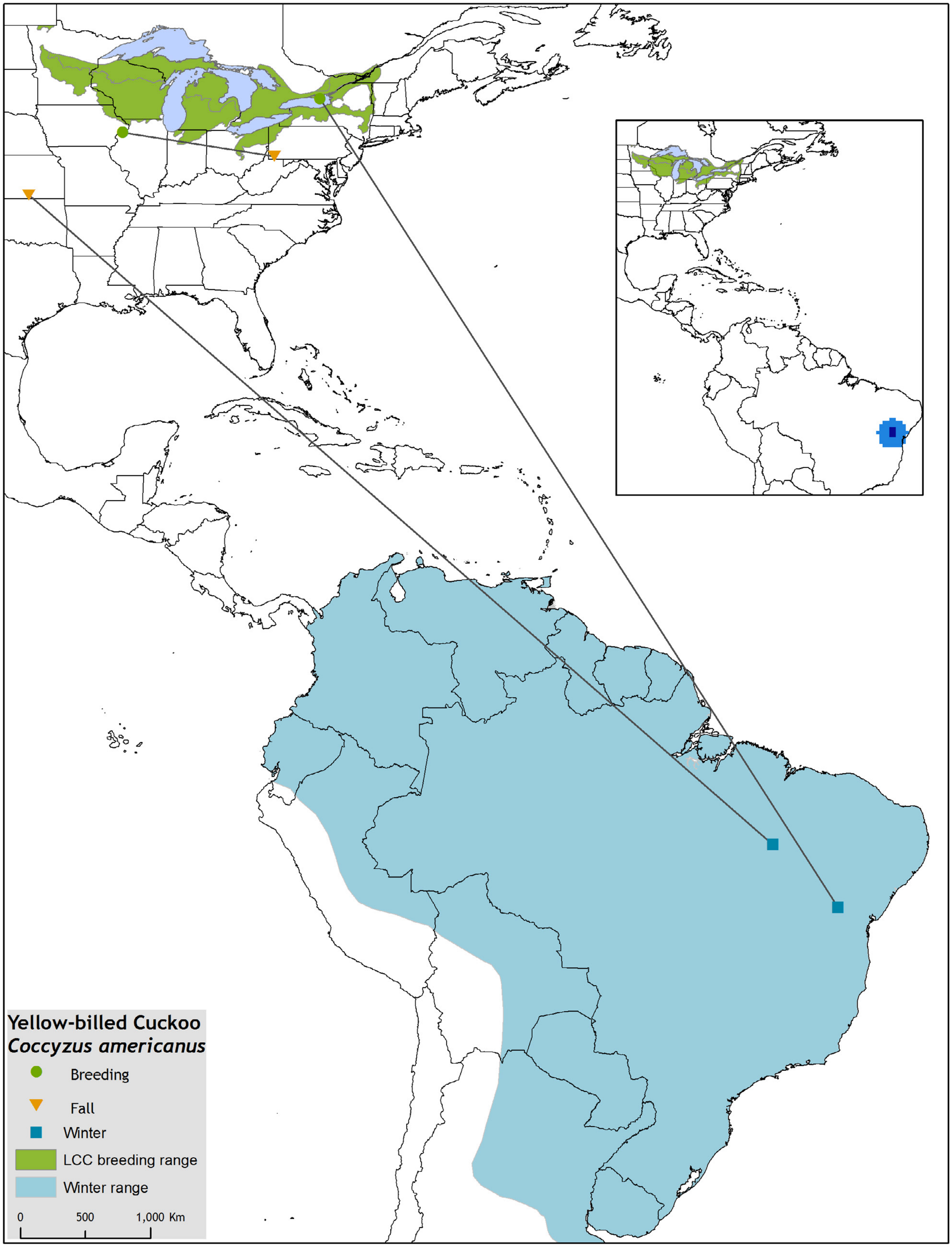


Figure 5.36. Yellow-billed Cuckoo banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There was just one breeding to stationary non-breeding encounter from the UMGL. Inset map shows concentration of non-breeding data originating from the UMGL.

CLIMATE EXPOSURE

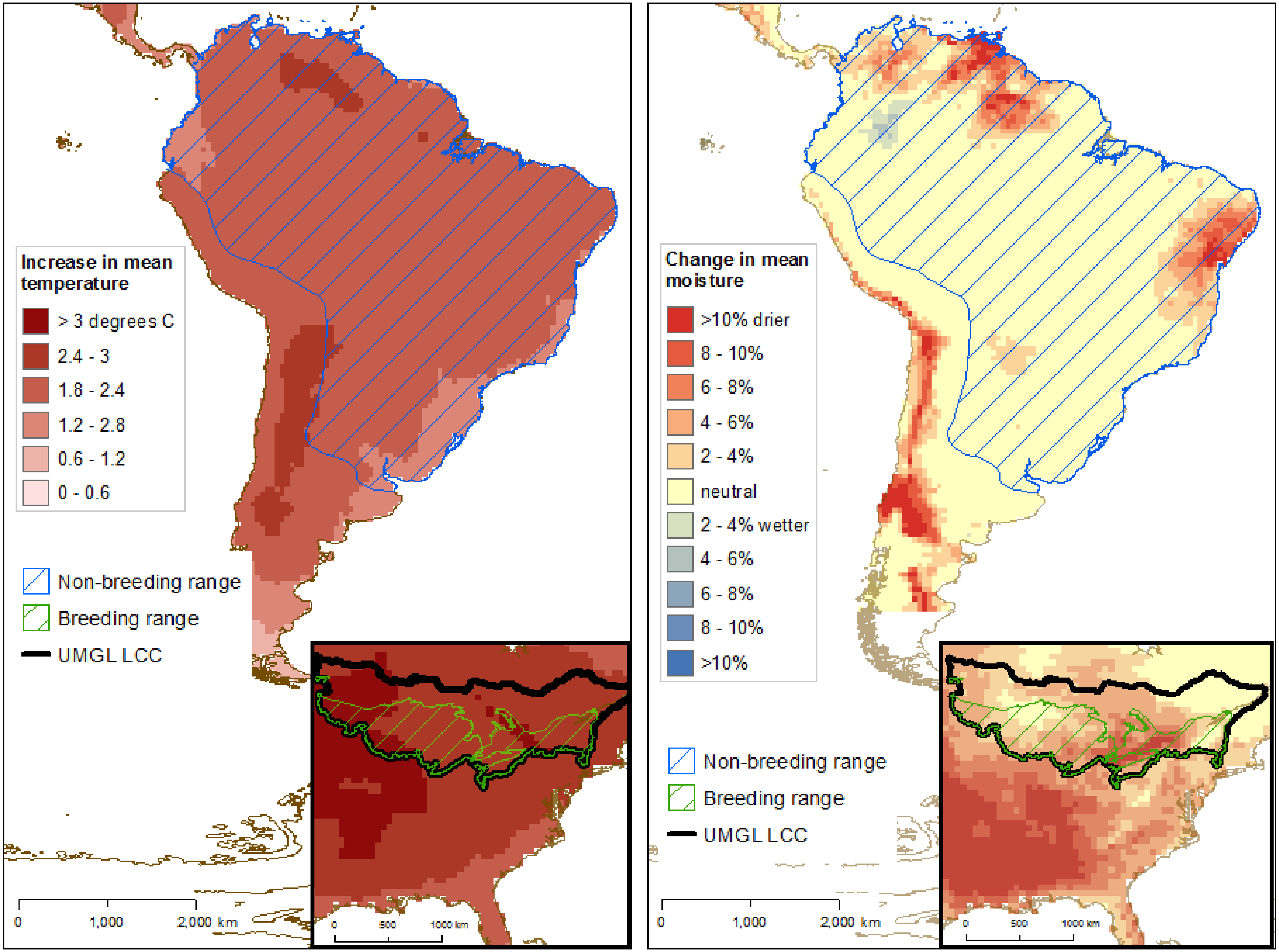


Figure 5.37. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Yellow-billed Cuckoo's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

YELLOW-BILLED CUCKOO DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 (95% CI = 0, 0.01)
• Range size	(score = 2.0) breeding = 5,267,573 km2; non-breeding = 3,514,098 km2
• Threats (PIF)	(score = 3.4) breeding score = 3.4; non-breeding score = 3.0
• Breeding PIF conservation	(score = 2.6)
• Non-breeding PIF conservation	(score = 3.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 4987 km)
• Breeding habitat niche specialization	(score = 3.7) Macro habitats woodlands, riparian; nesting micro habitat trees with thick cover (1-2.5 m high)
• Breeding diet niche specialization	(score = 4.2) Large insects (including toxic pest caterpillars), small vertebrates; captured by gleaning foliage in the woodland canopy layer
• Breeding site fidelity	(score = 3.0) Perhaps some (but very little information available)
• Non-breeding habitat niche specialization	(score = 4.0) Scrub/second-growth forest and gallery forest
• Non-breeding diet niche specialization	(score = 2.7) Large insects (including toxic pest caterpillars), small vertebrates, fruit, and seeds
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 13.4° C
• Breeding precipitation range	(score = 4.0) 52 cm
• Non-breeding thermal range	(score = 2.0) 14.8° C
• Non-breeding precipitation range	(score = 2.0) 114 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.8% drier
• Winter (Dec – Feb) non-breeding temperature	S. America (score = 3.0) 2.1° C increase
• Winter (Dec – Feb) non-breeding moisture	S. America (score = 0) 1.2% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.8) Very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); riparian habitat vulnerability may depend on location with western riparian habitat highly vulnerable (Perry et al. 2012, USFS 2013) and eastern riparian habitat less vulnerable
• Breeding biotic interaction vulnerability	(score = 1.7) Preferred food of large toxic pest caterpillars expected to increase with climate change (Percy et al. 2002); vulnerability of small vertebrates may depend on taxa (no information on reptiles and amphibians in general, but small mammals are predicted to be resilient, Johnston et al. 2012); however, if small mammals increase in abundance, there may be more nest predation
• Non-breeding habitat vulnerability	(score = 1.5) Very little vulnerability of dry tropical forest as these habitats may increase in area (Khatun et al. 2013); vulnerability of primary tropical forest may depend on location and exact forest type –stable in most areas partly because of high heat tolerance (Gonzalez et al. 2010, Mahi et al. 2008, and Huntingford et al. 2013) but Brazil and eastern Amazon may be exception (Freeley et al. 2010, Gonzalez et al. 2010)
• Non-breeding biotic interaction vulnerability	(score = 1.1) Preferred food of large toxic pest caterpillars expected to increase with climate change (Percy et al. 2002); vulnerability of small vertebrates may depend on taxa (see above); masting of fruits and seeds may be resilient (mean temperature is not expected to affect mast frequency, though annual variability probably will, Kelley et al. 2012)

5.14. Black-billed Cuckoo
(Coccyzus erythropthalmus)

USFWS Region 3 status: conservation concern
AOU number: 3880
AOU abbreviation: BBCU

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.5	**2.8**	**3.0**	**2.4**	**0**	**3.9**	**1.5**	**2.7**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Black-billed Cuckoo was moderate, scoring 2.5 out of 5.0. The adaptive capacity category was the largest contributor, due to the Cuckoo's long-distance migration, specialized habitat during the breeding season, and breeding diet specialized exclusively on large insects. Temperature increases throughout the year and drying on the UMGL breeding grounds were predicted to have moderate effects on vulnerability (Figure 5.38). Moisture is not expected to change much by 2050 in S. America. Consequently, drying during the non-breeding season did not have much effect on vulnerability (Figure 5.38). Indirect effects of climate change also did not have much effect, partly because one of their preferred foods, large toxic caterpillar pests like the tent caterpillar, is expected to increase in abundance with climate change (Percy et al. 2002). During the non-breeding season, Black-billed Cuckoos can be found across large regions of northwestern S. America. We had very little connectivity information from banding data (Figure 5.39), however, and no information from the literature. Therefore, we were unable to measure migratory connectivity from the UMGL, and we included all of the non-breeding range in our vulnerability analysis. Because Black-billed Cuckoos have a fairly limited non-breeding range, however, gaps in migratory connectivity might not limit our ability to determine the best approach for conservation. Their smaller range could make investigation of this subject more feasible and easier to interpret, making them a good candidate for the research.

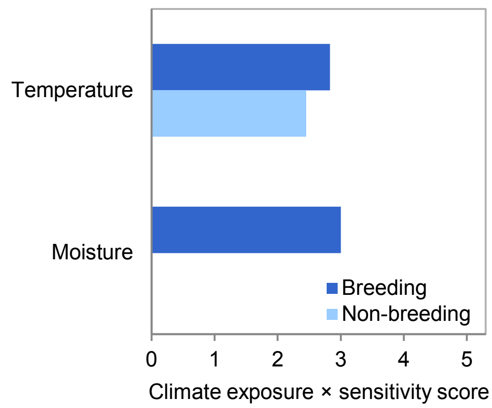


Figure 5.38. Black-billed Cuckoo subscores for climate exposure × sensitivity, breeding (UMGL, Jun – Aug) and non-breeding regions (S. America, Dec – Feb).

Eastern tent caterpillars are a preferred food of cuckoos © 2009 Charles Stephen

MIGRATORY CONNECTIVITY

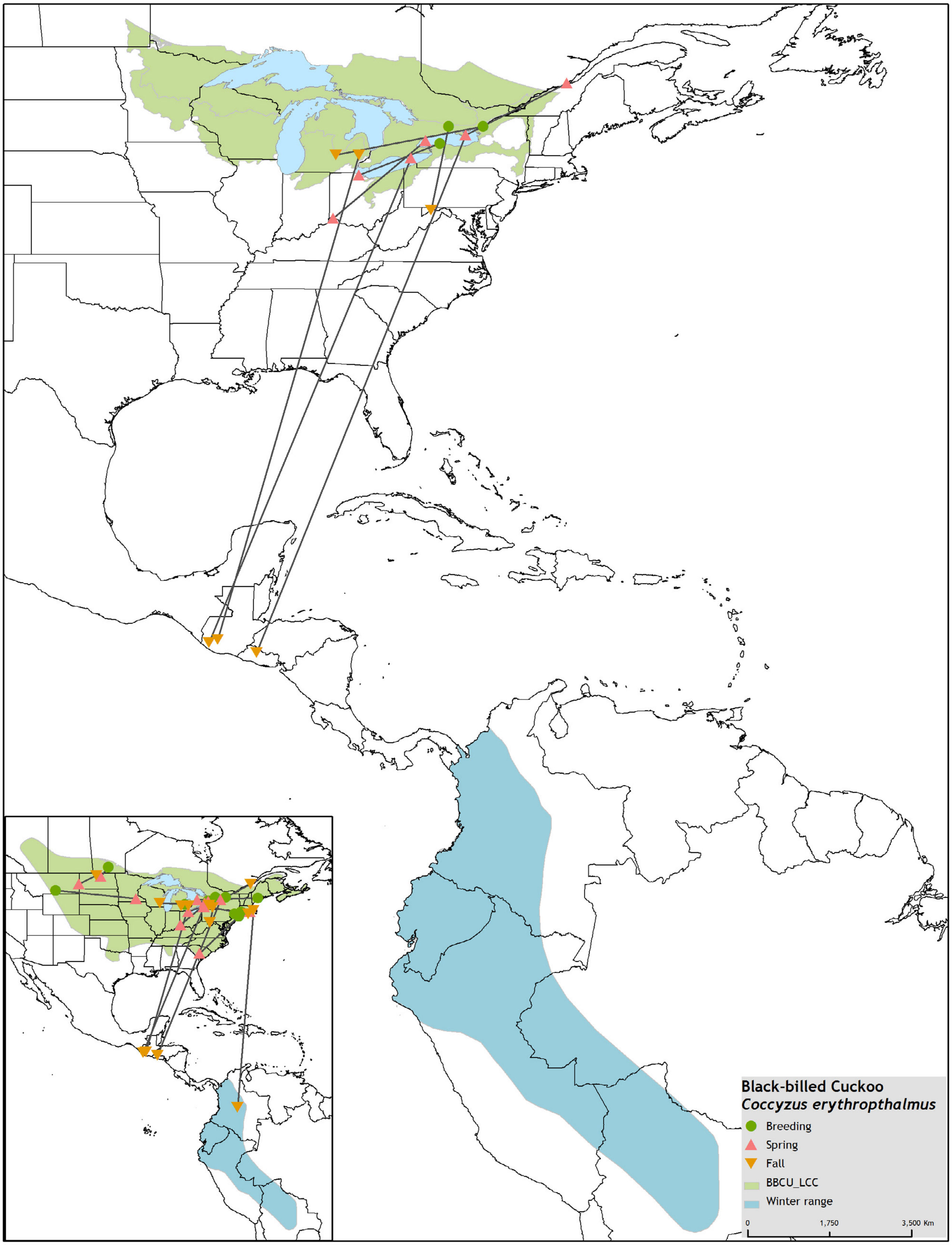


Figure 5.39. Black-billed Cuckoo banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were no breeding to stationary non-breeding encounters originating from the UMGL. Inset map shows data from the entire breeding range.

CLIMATE EXPOSURE

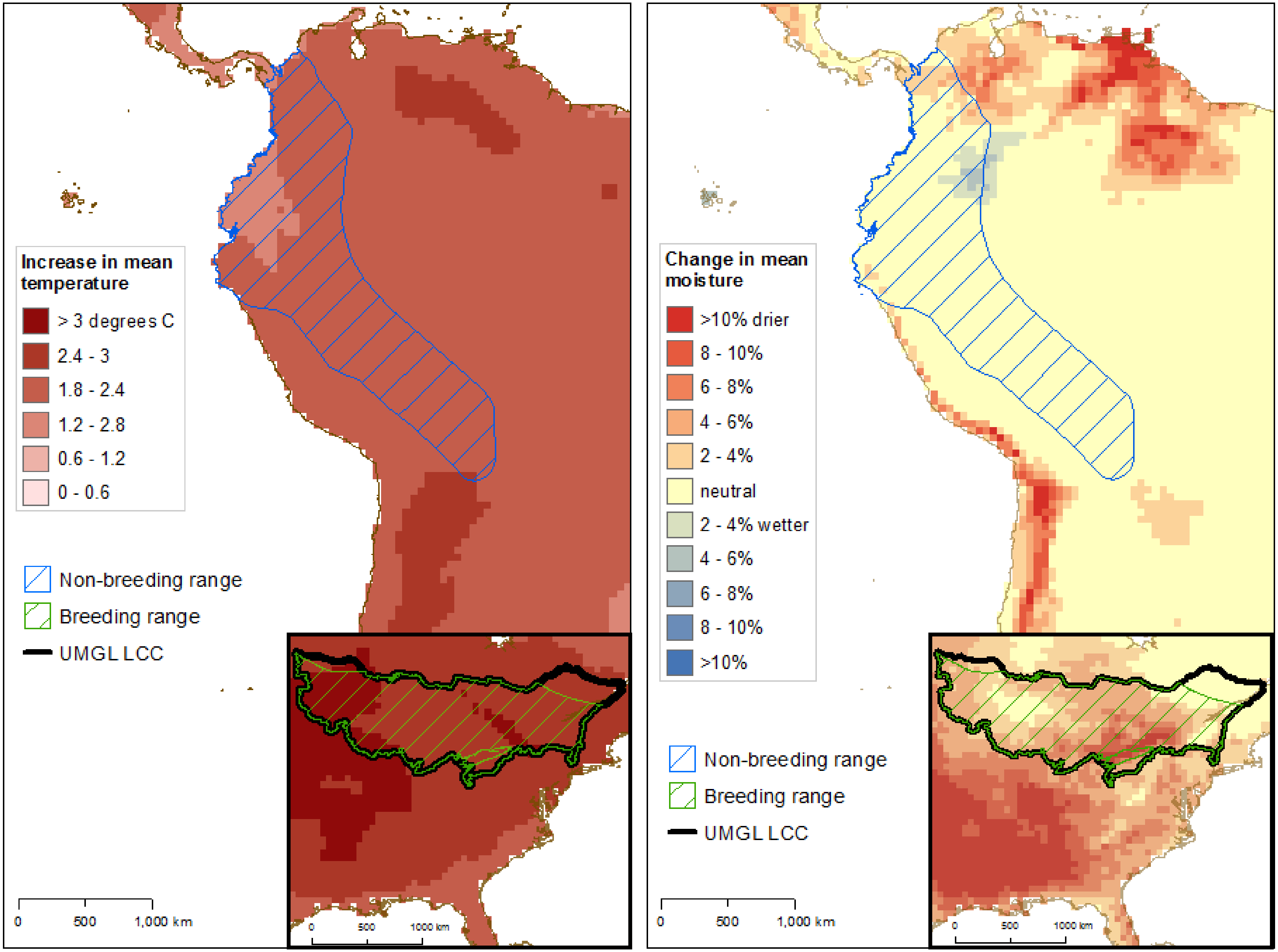


Figure 5.40. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Black-billed Cuckoo's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

BLACK-BILLED CUCKOO DATA

i. Background Risk	
• Quasi-extinction risk	(score = 3.0) 0.11 (95% CI = 0.01, 0.64)
• Range size	(score = 2.0) breeding = 4,934,488 km2; non-breeding = 2,301,267 km2
• Threats (PIF)	(score = 3.1) breeding score = 3.1; non-breeding score = 3.0
• Breeding PIF conservation	(score = 3.9)
• Non-breeding PIF conservation	(score = 3.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 5430 km)
• Breeding habitat niche specialization	(score = 4.0) Macro habitats deciduous and mixed forest, riparian; nesting micro habitat trees with thick cover (0.5-2 m high)
• Breeding diet niche specialization	(score = 4.5) Large insects (including toxic pest caterpillars); captured by gleaning foliage in the forest canopy layer
• Breeding site fidelity	(score = 3.0) Perhaps some (but very little information available)
• Non-breeding habitat niche specialization	(score = 3.0) Tropical woodland and arid forest, scrub, humid tropical forest
• Non-breeding diet niche specialization	(score = 3.2) Large insects (including toxic pest caterpillars), fruit, seeds
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 14.1° C
• Breeding precipitation range	(score = 4.5) 30 cm
• Non-breeding thermal range	(score = 2.0) 13.4° C
• Non-breeding precipitation range	(score = 2.0) 101 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.4% drier
• Winter (Dec – Feb) non-breeding temperature	S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	S. America (score = 0) 0.1% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.8) Some vulnerability of deciduous forest, particularly in the southern USA (USFS 2013), though may expand range in the north (USFS 2013); riparian habitat vulnerability may depend on location with western riparian habitat highly vulnerable (Perry et al. 2012, USFS 2013) and eastern riparian habitat less vulnerable
• Breeding biotic interaction vulnerability	(score = 2.0) preferred food of large toxic pest caterpillars expected to increase with climate change (Percy et al. 2002)
• Non-breeding habitat vulnerability	(score = 1.0) Very little vulnerability of dry tropical forest as these habitats may increase in area (Khatun et al. 2013); vulnerability of broadleaf tropical forest may depend on location and exact forest type –lowland forests may be stable partly because of high heat tolerance (Gonzalez et al. 2010, Mahi et al. 2008, and Huntingford et al. 2013); information on montane forests, including the Andes, is mixed (highly vulnerable according to Gonzalez et al. 2010, but stable according to Tovar et al. 2013)
• Non-breeding biotic interaction vulnerability	(score = 1.2) preferred food of large toxic pest caterpillars expected to increase with climate change (Percy et al. 2002); masting of fruits and seeds may be resilient (mean temperature is not expected to affect mast frequency, though annual variability probably will, Kelley et al. 2012)

5.15. Short-eared Owl
(Asio flammeus)


photo by D Sanches

USFWS Region 3 status: conservation concern
AOU number: 3670
AOU abbreviation: SEOW

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.1	**0**	**1.7**	**0**	**1.4**	**2.9**	**1.7**	**3.0**

(maximum score of 5 for all columns)

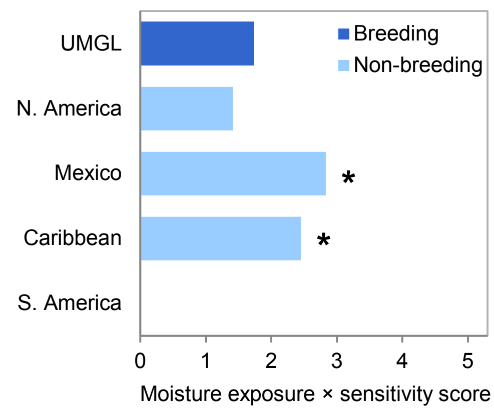


Figure 5.41. Short-eared Owl subscores for moisture exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). Temperature results not shown as all scores equaled zero. *Non-breeding score ≥ 20% greater than breeding.

SUMMARY

Total vulnerability for Short-eared Owl was moderate, scoring 2.1 out of 5.0. The background risk category was the largest contributor to vulnerability, suggesting that factors other than climate change may be a priority for the species. However, the adaptive capacity category was a close second, and Short-eared Owls may be limited in their flexibility and capacity to respond to climate change. This was driven by the owl's diet, which is specialized year-round on small mammals. Fortunately, there's evidence that small mammals will remain stable or may even increase in abundance under climate change (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013). Neither temperature change on the UMGL breeding grounds nor on the non-breeding grounds were predicted to have much effect on vulnerability, mostly because Short-eared Owls are particularly insensitive to temperature change throughout the annual cycle. We predicted that Short-eared Owls will be more affected by decreased moisture on the Mexican and Caribbean non-breeding grounds (Figure 5.41). We had very little connectivity information from Short-eared Owl banding data (Figure 5.42) and no information from the literature. For this reason, we were unable to measure migratory connectivity and we maintained a broad approach to analyzing vulnerability. This may hinder our ability to determine the best approach to conserving Short-eared Owls, and migratory connectivity should be a research priority.


Short-eared Owl hunting (photo by S Garvie)

MIGRATORY CONNECTIVITY

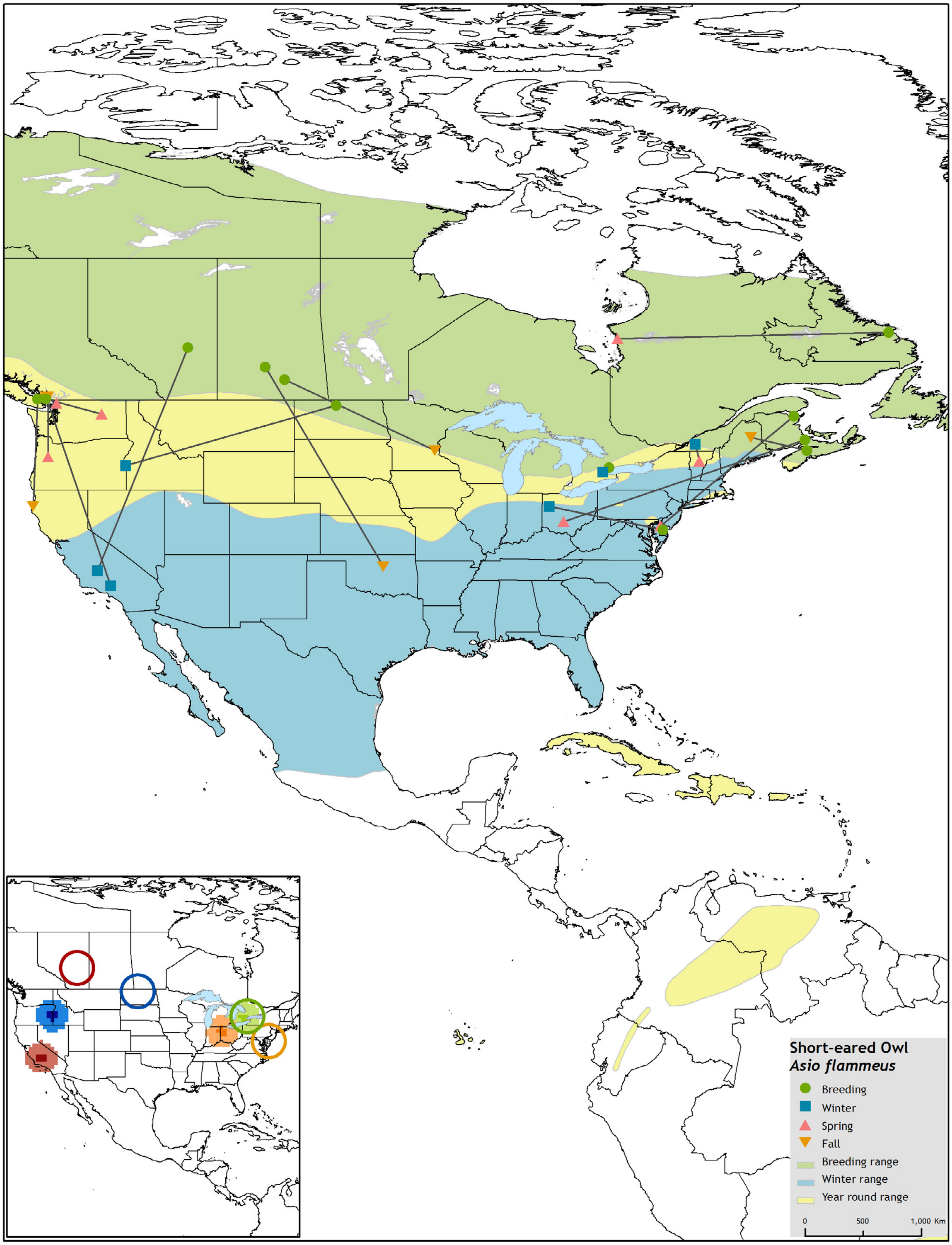


Figure 5.42. Short-eared Owl banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green in the main map. There were no breeding to stationary non-breeding encounters origination from the UMGL. Inset map shows concentrations of non-breeding data originating from four different breeding regions.

CLIMATE EXPOSURE

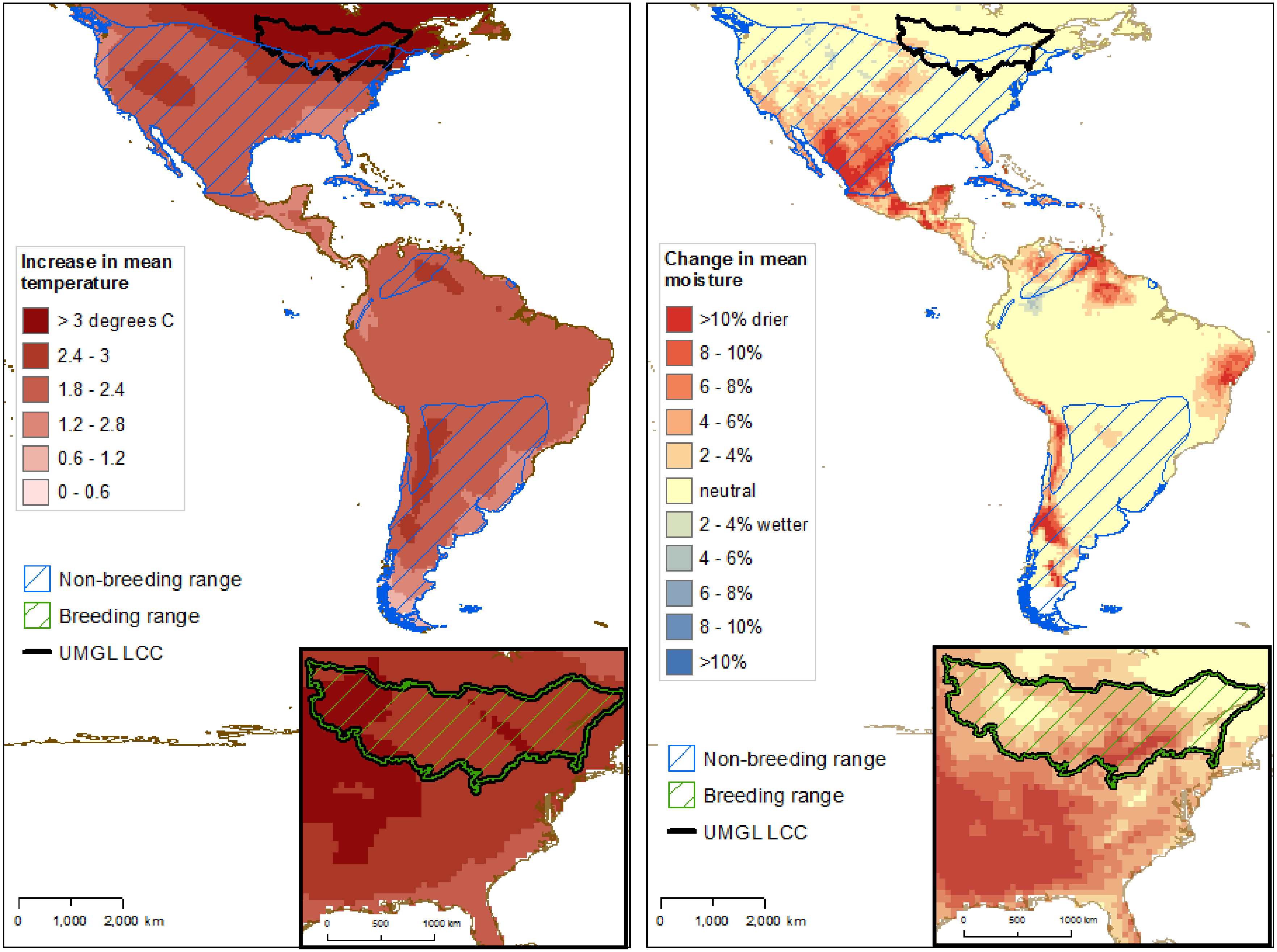


Figure 5.43. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Short-eared Owl's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

SHORT-EARED OWL DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 3.0)
• Non-breeding PIF conservation	(score = 3.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 2.0) Non-migrant, short-distance migrant (mean distance = 1130 km)
• Breeding habitat niche specialization	(score = 2.7) Macro habitat grassland (including prairie and marsh), tundra, shrub (including shrub steppe), agriculture; nesting micro habitat ground with grass and thatch (0 m high)
• Breeding diet niche specialization	(score = 4.2) Small mammals; captured by flying low over open areas
• Breeding site fidelity	(score = 3.0) Some (possibly shift locations depending on prey abundance)
• Non-breeding habitat niche specialization	(score = 1.0) Grassland (including prairie), shrub steppe, agriculture, freshwater wetland, saltwater wetland
• Non-breeding diet niche specialization	(score = 4.2) Small mammals
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 29.0° C
• Breeding precipitation range	(score = 1.5) 119 cm
• Non-breeding thermal range	(score = 0) 36.1° C
• Non-breeding precipitation range	(score = 2.0) 93 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.8% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.1° C increase N. America (score = 3.0) 2.2° C increase Mexico (score = 3.0) 2.1° C increase Caribbean (score = 2.0) 1.6° C increase S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 1.0) 4.0% drier N. America (score = 1.0) 2.2% drier Mexico (score = 4.0) 8.7% drier Caribbean (score = 3.0) 6.2% drier S. America (score = 0) 1.4% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.3) Very little vulnerability of grasslands although specific components may change or disappear, particularly in wet prairies (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); all sources agree that tundra habitat is very highly vulnerable (Bachelet et al. 2001, Gonzalez et al. 2010); overall, shrublands may be moderately vulnerable as woodland habitat encroaches on them (USDA 2012, USFS 2013); zero vulnerability of agricultural areas
• Breeding biotic interaction vulnerability	(score = 1.0) Very little vulnerability of small mammals, which may even increase in abundance (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 2.6) Very little vulnerability of grasslands (see above); high vulnerability of shrub steppe due to encroachment from woodland habitat and from fire and invasive grasses (USDA 2012); high vulnerability on freshwater wetlands (Karl et al. 2009, Goulatowitsch et al. 2009, USDA 2012, USFS 2013); very high vulnerability on saltwater wetlands due to sea level rise (IPCC 2014, Karl et al. 2009); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 1.0) Very little vulnerability of small mammals (see above)

5.16. Northern Saw-whet Owl
(Aegolius acadicus)

USFWS Region 3 status: conservation concern
AOU number: 3720
AOU abbreviation: NSWO

VULNERABILITY SCORES

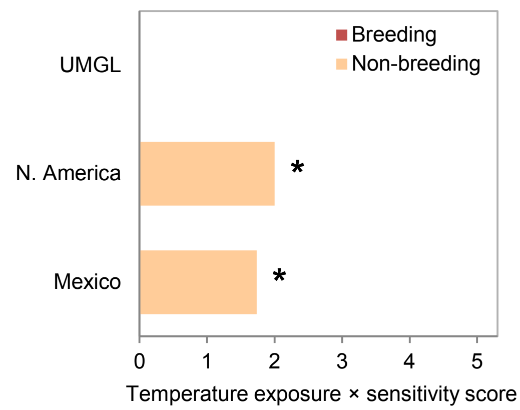
Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.2	**0**	**2.6**	**2.0**	**0**	**3.0**	**1.7**	**2.8**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Northern Saw-whet Owl was moderate, scoring 2.2 out of 5.0. Moisture change on the Mexican non-breeding grounds was the largest contributor to vulnerability. Climate change variables during other times of the year had negligible to moderate impacts (Figure 5.44). The adaptive capacity category was the second largest contributor to the vulnerability score, mostly driven by the owl's reliance on small mammals for its diet. Fortunately, there's evidence that small mammals will remain stable or may even increase in abundance under climate change (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013). We had many locations from migration to stationary non-breeding for Northern Saw-whet Owls, but just six breeding to stationary non-breeding encounters from the UMGL (Figure 5.45). In addition, we found no information on migratory connectivity in the literature. Thus, we were unable to deduce possible migratory connectivity, and we maintained a broad approach to analyzing vulnerability. This may hinder our ability to determine the best approach to conserving Northern Saw-whet Owls, and migratory connectivity should be a research priority.

Northern Saw-whet Owlets



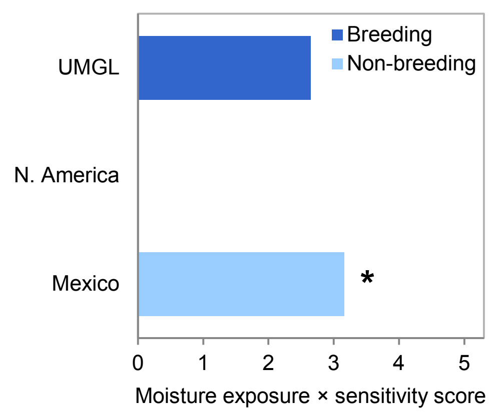


Figure 5.44. Northern Saw-whet Owl subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

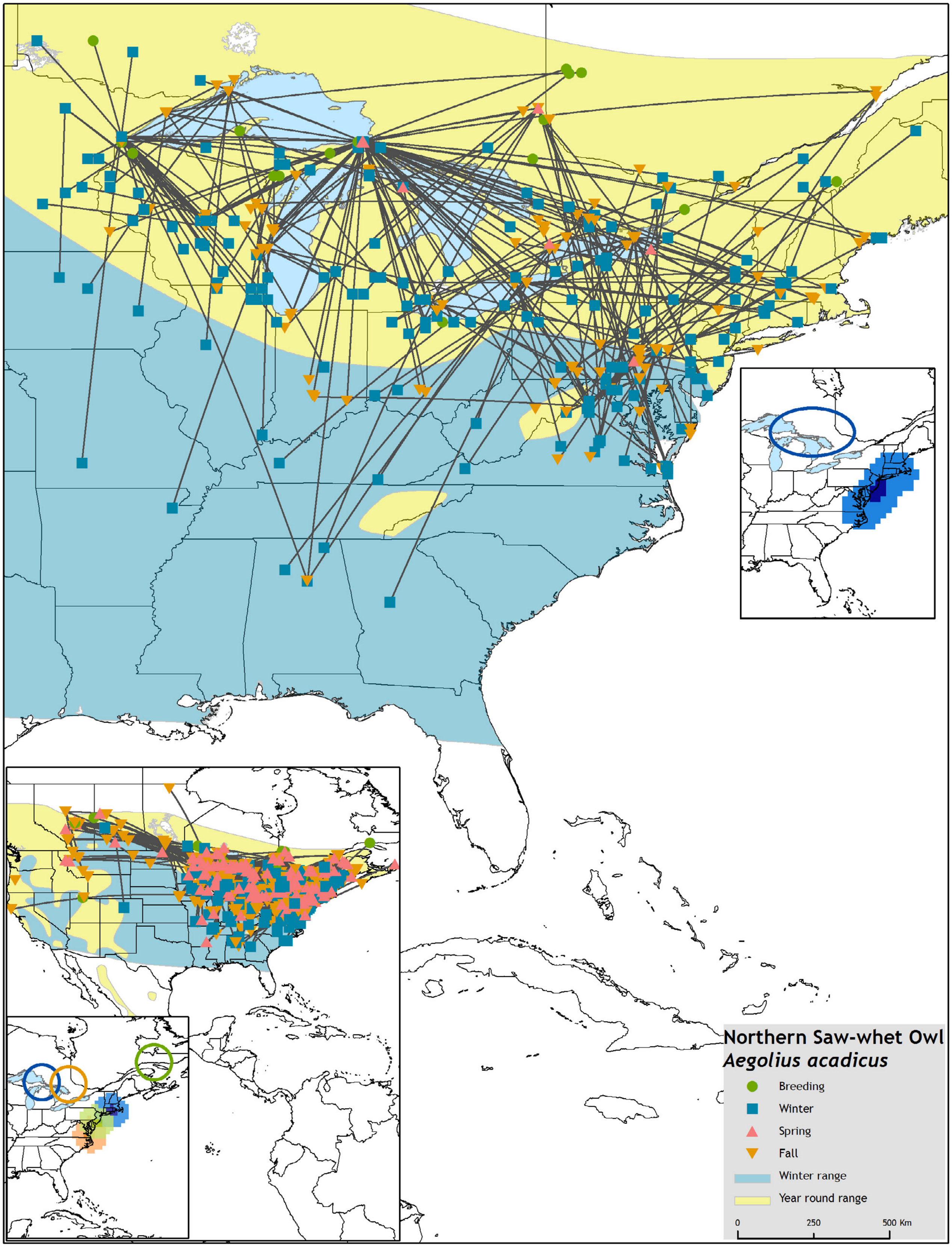


Figure 5.45. Northern Saw-whet Owl banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in yellow. There were just six breeding to stationary non-breeding encounters from the UMGL. Upper right inset map shows concentrations of non-breeding data originating from UMGL. Lower left inset map shows concentrations of non-breeding data originating from three different breeding regions.

CLIMATE EXPOSURE

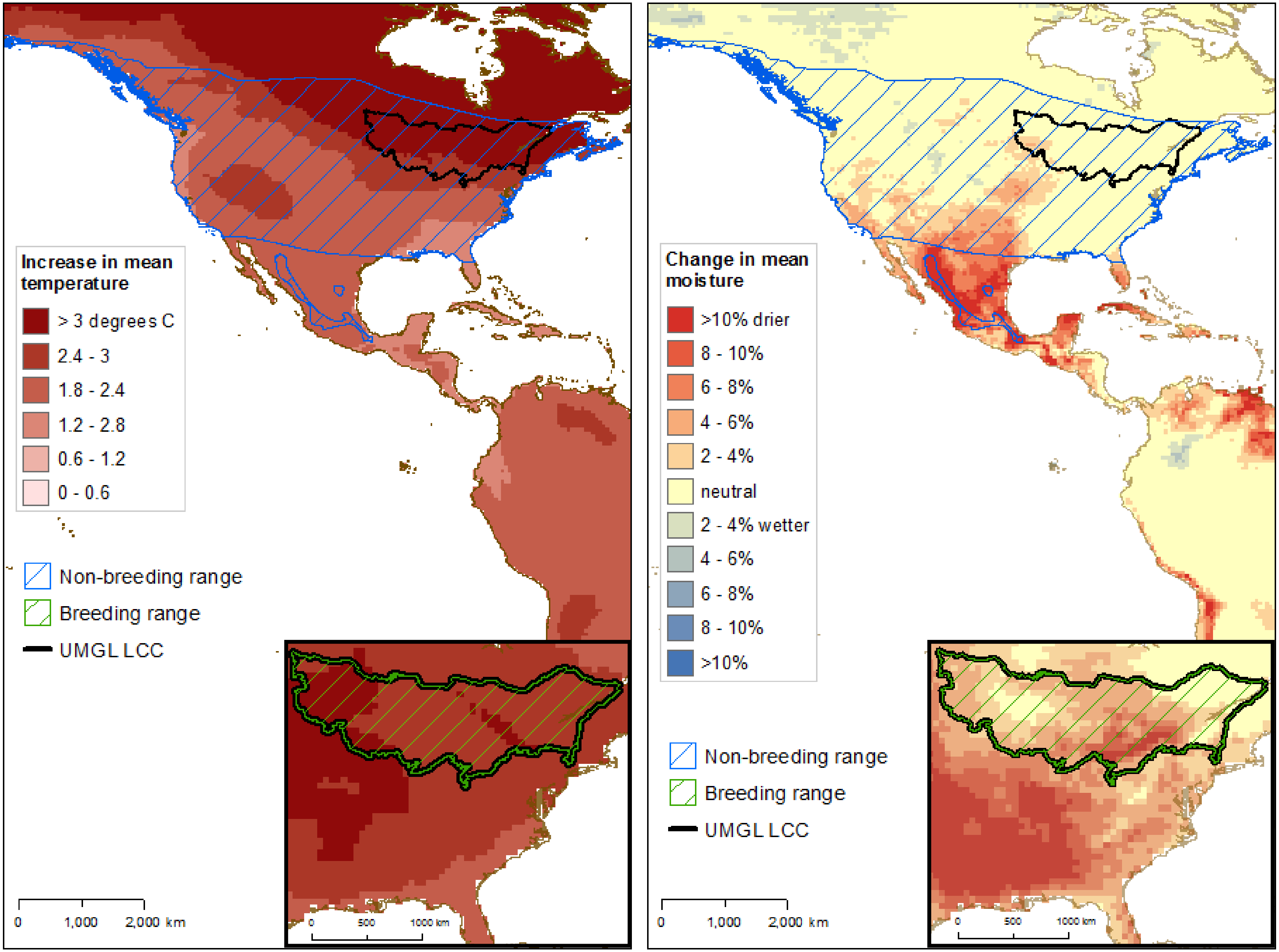


Figure 5.46. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Northern Saw-whet Owl's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

NORTHERN SAW-WHET OWL DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 2.8)
• Non-breeding PIF conservation	(score = 2.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 2.0) Non-migrant, short-distance migrant (mean distance = 0 km)
• Breeding habitat niche specialization	(score = 2.0) Macro habitats deciduous and mixed forest, coniferous forest (including boreal), woodland, riparian; nesting micro habitat secondary cavities and nest boxes (4-18 m high)
• Breeding diet niche specialization	(score = 3.9) Many species of small mammals; captured by swooping from perches in forest edges
• Breeding site fidelity	(score = 3.0) Some (possibly shift locations depending on prey abundance)
• Non-breeding habitat niche specialization	(score = 3.0) Mature forest, second-growth forest, riparian (with dense vegetation and perches)
• Non-breeding diet niche specialization	(score = 3.9) Many species of small mammals
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 21.1° C
• Breeding precipitation range	(score = 3.5) 60 cm
• Non-breeding thermal range	(score = 1.0) 17.3° C
• Non-breeding precipitation range	(score = 2.0) 101 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.0% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 4.0) 2.7° C increase N. America (score = 4.0) 2.7° C increase Mexico (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 0) 0.8% drier N. America (score = 0) 0.8% drier Mexico (score = 5.0) 10.9% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.4) Some vulnerability of deciduous forest, particularly in the southern USA (USFS 2013), though may expand range in the north (USFS 2013); high vulnerability of coniferous forest (both in the southern USA and boreal) due to fire, pests, and succession by hardwoods (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013); very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); riparian habitat vulnerability may depend on location with western riparian habitat highly vulnerable (Perry et al. 2012, USFS 2013) and eastern riparian habitat less vulnerable
• Breeding biotic interaction vulnerability	(score = 1.0) Very little vulnerability of small mammals, which may even increase in abundance (Johnston et al. 2012, Korpela et al. 2013, Karl et al. 2009)
• Non-breeding habitat vulnerability	(score = 2.5) Coverage of mature forest is expected to decrease overall due to increased fire and pests while second-growth forests will increase (USFS 2013); riparian habitat vulnerability may depend on location (see above)
• Non-breeding biotic interaction vulnerability	(score = 1.0) Very little vulnerability of small mammals (see above)

5.17. Common Nighthawk
(Chordeiles minor)


photo by GK Schaefer.

USFWS Region 3 status: common
AOU number: 4200
AOU abbreviation: CONI

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.2	**0**	**2.0**	**2.4**	**0**	**3.6**	**1.0**	**2.9**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Common Nighthawk was moderate, scoring 2.2 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability. This was mostly due to a specialized diet of aerial insects and their supposed high degree of breeding site fidelity. However, there is very little information on breeding site fidelity and more research is needed on this subject. In addition, during the non-breeding season we have no information on diet and only anecdotal data on habitat use. These traits may be similar to other times of the year, however, more precise knowledge would help conservationists better understand the nighthawk's needs and limitations. These knowledge gaps also hindered our capacity to assess the indirect effects of climate change. Temperature increases on the UMGL breeding grounds are not predicted to have much effect on vulnerability (Figure 5.47) because Common Nighthawks are not sensitive to temperature change during this time period. Temperature increases on the non-breeding grounds, however, will have some effect. In addition, drying on the UMGL breeding grounds and the Caribbean non-breeding grounds will also have some effect (Figure 5.47). We had very little connectivity information on Common Nighthawks from banding data (Figure 5.48) and found no information on migratory connectivity from the literature. For this reason, we were unable to deduce possible migratory connectivity with the UMGL maintained a broad approach in our vulnerability analysis. We lack basic knowledge of Common Nighthawks during the non-breeding season, which may hinder our ability to manage and conserve them. Work on the non-breeding grounds would greatly improve our understanding of vulnerability for the species. Nevertheless, our assessment was similar to their status in USFWS Region 3.

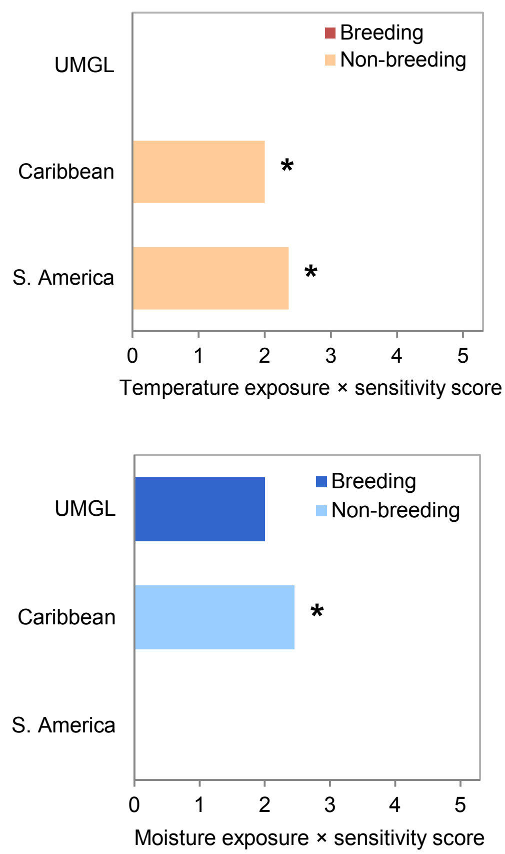


Figure 5.47. Common Nighthawk subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

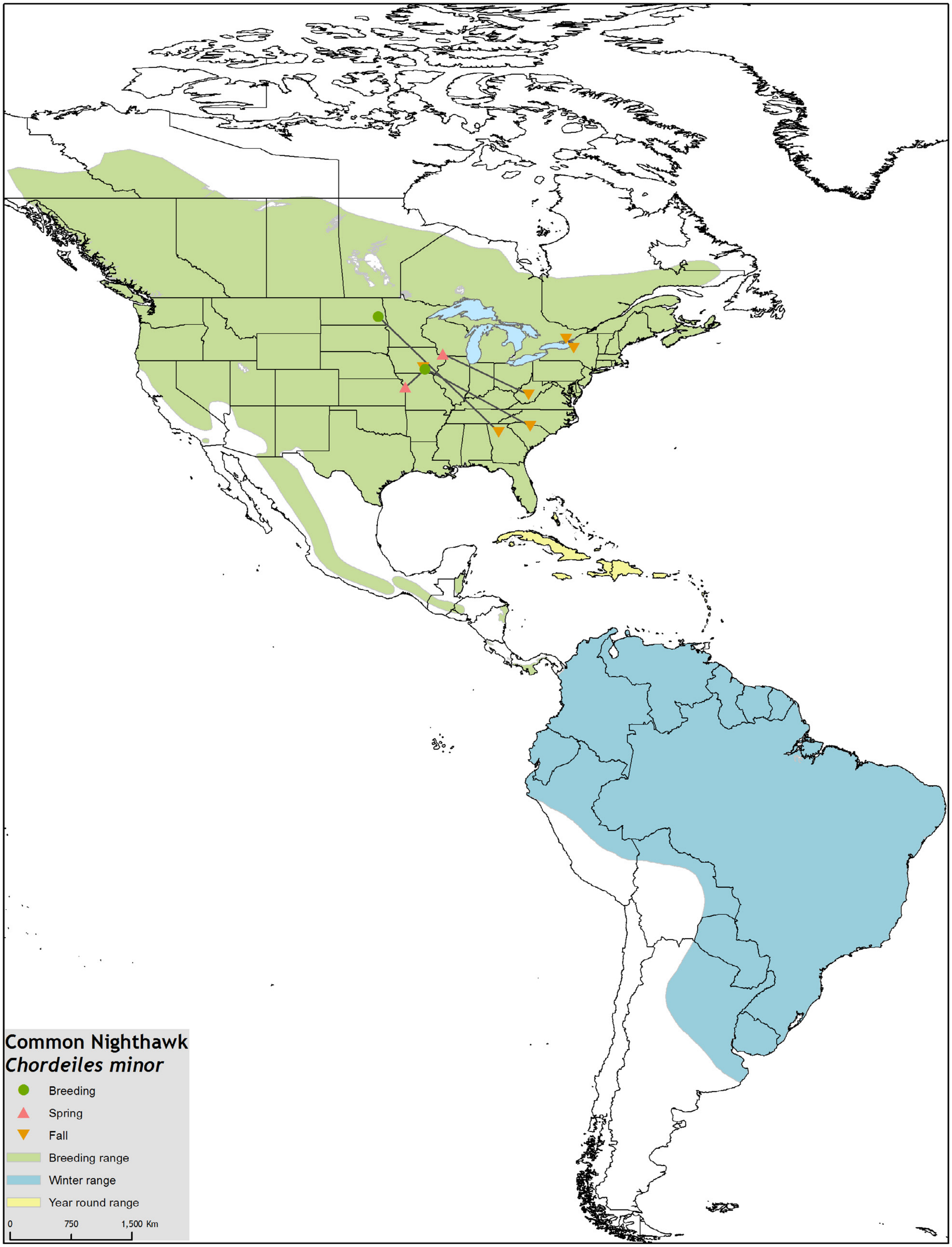


Figure 5.48. Common Nighthawk banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

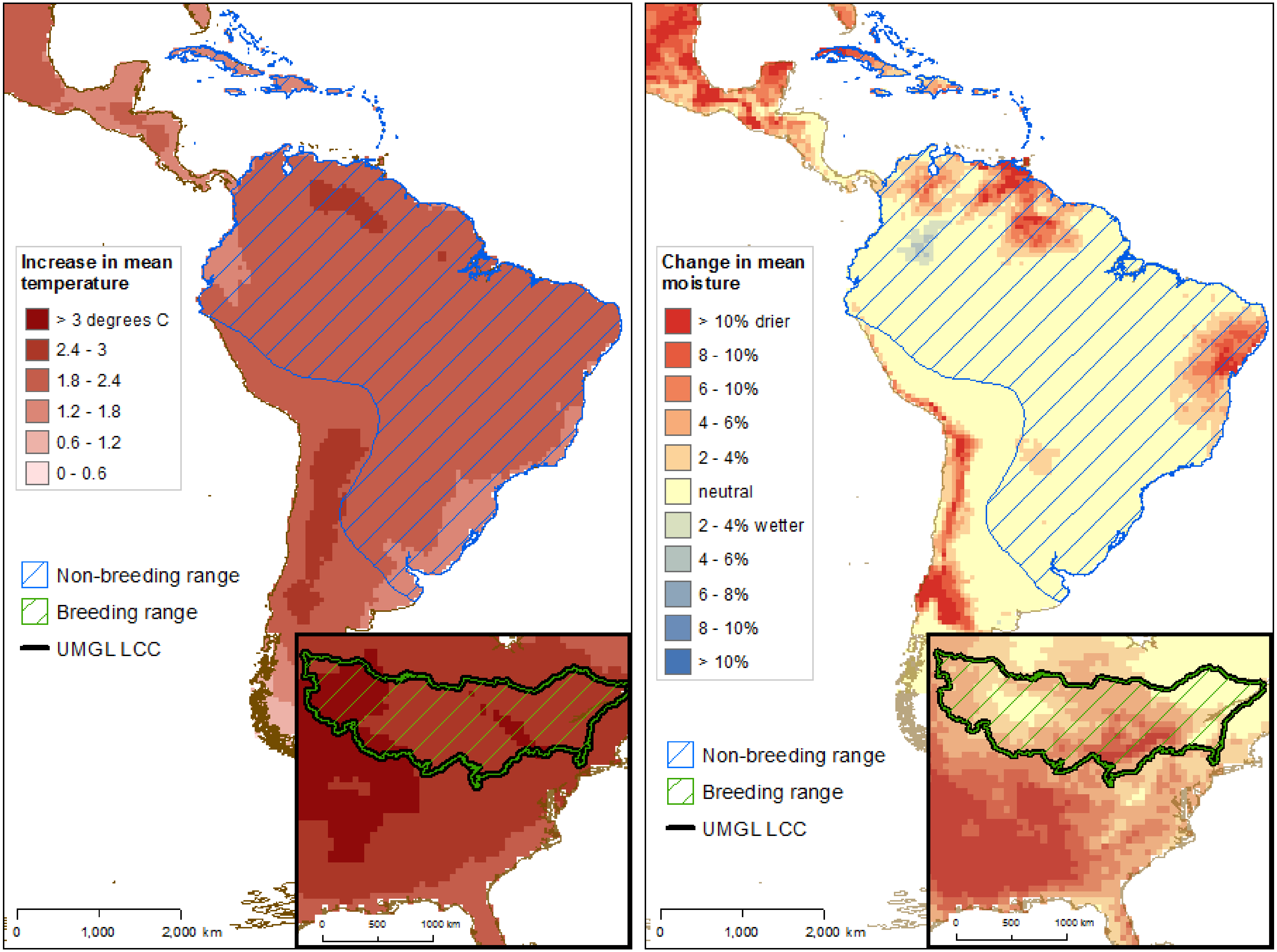


Figure 5.49. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Common Nighthawk's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

COMMON NIGHTHAWK DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 2.9)
• Non-breeding PIF conservation	(score = 2.8)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant, long-distance migrant (mean distance = 5458 km)
• Breeding habitat niche specialization	(score = 1.9) Macro habitats woodland (including logged), shrub steppe, grassland (including prairie), agriculture, urban (roof top); nesting micro habitat ground with and without vegetation, roof tops (0 m high)
• Breeding diet niche specialization	(score = 4.0) Aerial insects (diurnal, crepuscular, and nocturnal); captured by aerial foraging in open areas and above forest canopies
• Breeding site fidelity	(score = 5.0) No data but may be high
• Non-breeding habitat niche specialization	(score = 4.0) Uncertain –from anecdotal data open habitat, urban
• Non-breeding diet niche specialization	(score = unknown) No data available
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 22.4° C
• Breeding precipitation range	(score = 2.0) 96 cm
• Non-breeding thermal range	(score = 20) 15.1° C
• Non-breeding precipitation range	(score = 2.0) 115 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.0% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.0° C increase Caribbean (score = 2.0) 1.6° C increase S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 0) 1.3% drier Caribbean (score = 3.0) 6.0% drier S. America (score = 0) 1.3% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.0) Very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); high vulnerability of shrub steppe due to encroachment from woodland habitat (USDA 2012) and from fire and invasive grasses (USDA 2012); Very little vulnerability of grasslands although specific components may change or disappear, particularly in wet prairies (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); zero vulnerability of agricultural and urban areas
• Breeding biotic interaction vulnerability	(score = 2.0) There is little evidence that aerial insectivores will suffer from phonological mismatch (e.g. Dunn et al. 2011)
• Non-breeding habitat vulnerability	(score = 0) Habitats used during the non-breeding season are not well known, but there is zero vulnerability of urban areas
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.18. Eastern Whip-poor-will
(Antrostomus vociferus)

USFWS Region 3 status: conservation concern
AOU number: 4170
AOU abbreviation: EWPW

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.2	**3.2**	**2.4**	**2.4**	**3.5**	**4.3**	**2.0**	**3.7**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Eastern Whip-poor-will (Whip-poor-will) was high, scoring 3.2 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability. This was driven by a high degree of habitat specialization throughout the year (Whip-poor-wills require woodlands), a specialized diet of aerial insects (especially moths), and a high breeding site fidelity. However, there is very little information on breeding site fidelity limiting our ability to draw conclusions about Whip-poor-will vulnerability. In addition, we have no information on diet during the non-breeding season. Though it is probably composed of aerial insects, knowledge of which aerial insects are preferred would help conservationists understand the Whip-poor-will's needs and limitations. This knowledge gap also limited our capacity to assess the indirect effects of climate change. Temperature increases on the UMGL breeding grounds were predicted to have large effects on vulnerability, while drying on the Mexican non-breeding grounds was predicted to have a large effect (Figure 5.50). We had very little connectivity information on Whip-poor-wills from banding data and no breeding to non-breeding encounters originating from the UMGL region (Figure 5.51). We also found no information on migratory connectivity from the literature. For this reason, we were unable to measure migratory connectivity with the UMGL, and we maintained a broad approach in our vulnerability analysis. In general, we lack basic knowledge of Whip-poor-wills during the non-breeding season and this may hinder our ability to manage and conserve them. Work on the non-breeding grounds would greatly improve our understanding of vulnerability for the species. As with the USFWS Region 3 status, we found the species to be at risk. Aerial insectivores are among the most imperiled species (COSEWIC 2009, Nebel et al. 2010) and the current declines may only be exacerbated by climate change.

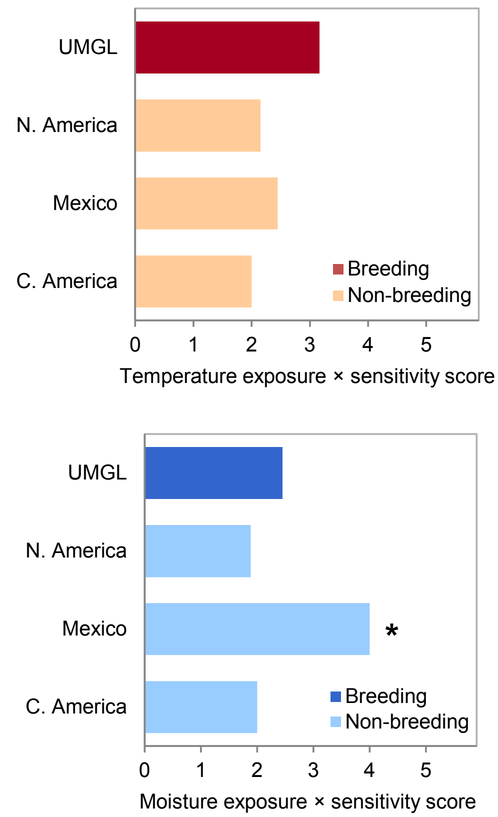


Figure 5.50. Eastern Whip-poor-will subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

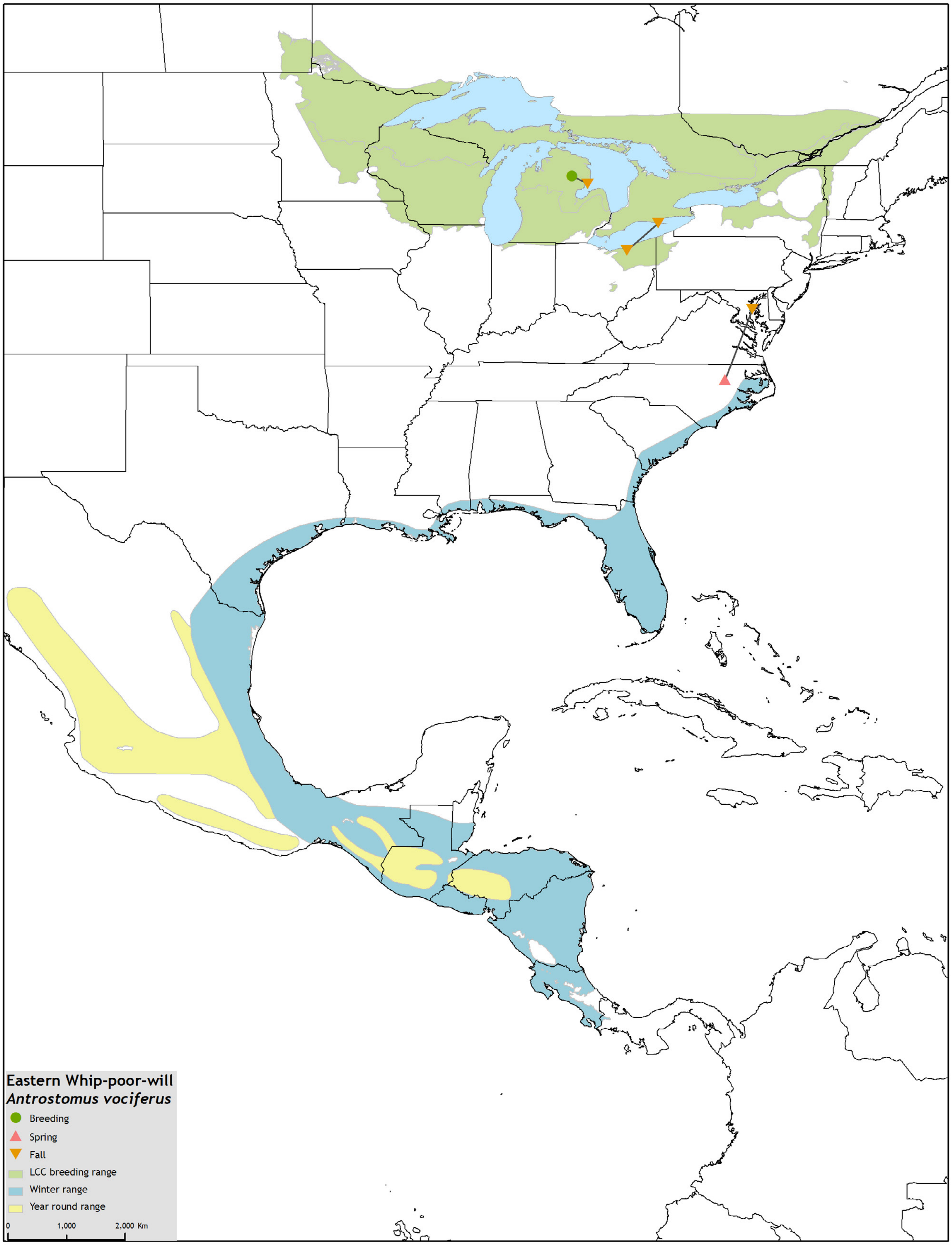


Figure 5.51. Eastern Whip-poor-will banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green. There were no breeding to stationary non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

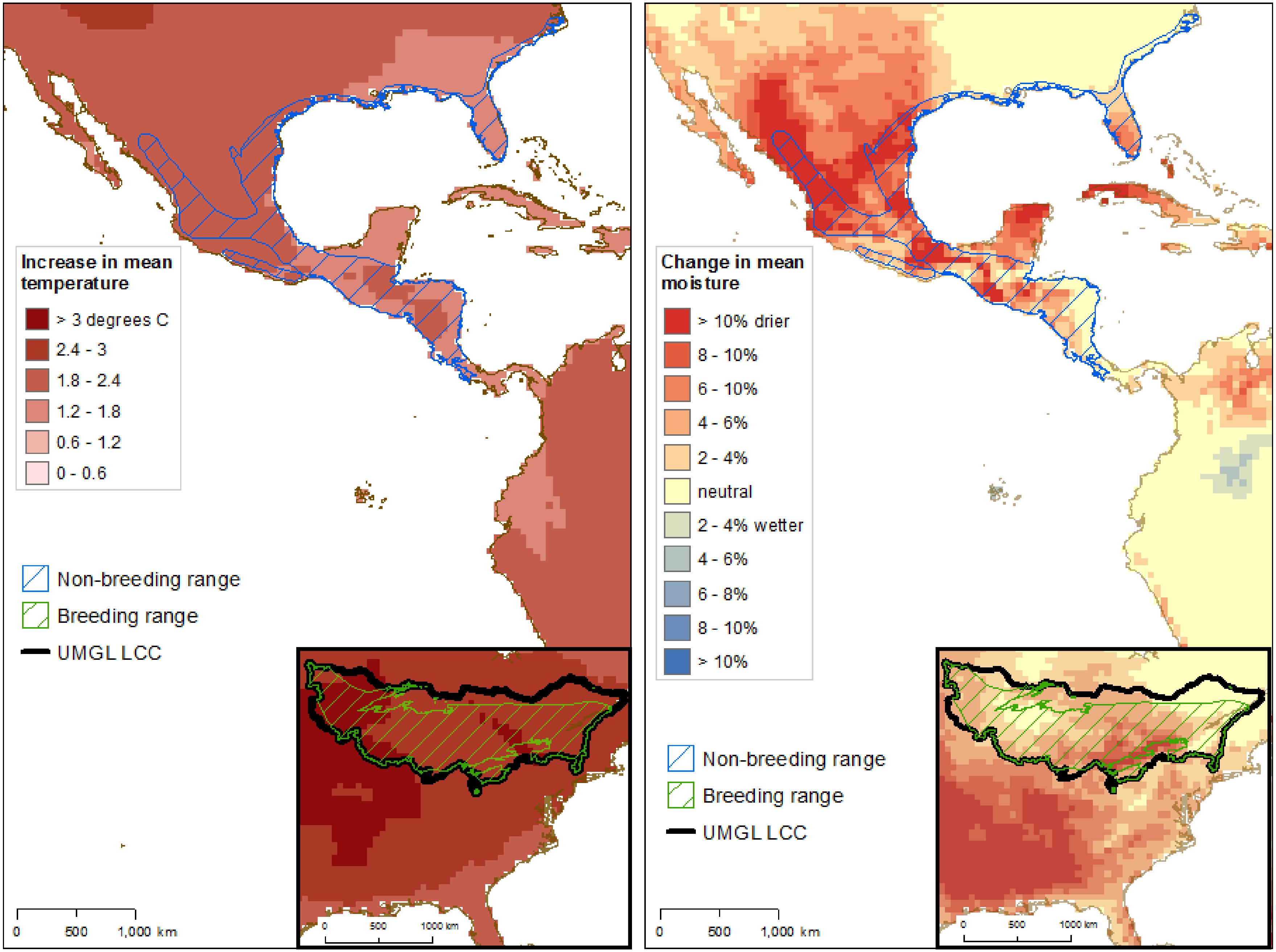


Figure 5.52. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Eastern Whip-poor-will's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

EASTERN WHIP-POOR-WILL DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 3.7)
• Non-breeding PIF conservation	(score = 3.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant, short-distance migrant, long-distance migrant (mean distance = 1358 km)
• Breeding habitat niche specialization	(score = 4.5) Macro habitats deciduous forest, woodland (no understory, open canopy, including second-growth/logged); nesting micro habitat ground with leaf litter and near vegetation (0 m high)
• Breeding diet niche specialization	(score = 4.2) Aerial insects (crepuscular and nocturnal, especially moths); captured by aerial foraging in woodlands and along roads
• Breeding site fidelity	(score = 5.0) No data but may be high
• Non-breeding habitat niche specialization	(score = 5.0) Mixed woodlands
• Non-breeding diet niche specialization	(score = unknown) No data available
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.5) 12.1° C
• Breeding precipitation range	(score = 3.0) 83 cm
• Non-breeding thermal range	(score = 2.0) 15.1° C
• Non-breeding precipitation range	(score = 4.0) 53 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.4% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase N. America (score = 2.0) 1.8° C increase Mexico (score = 3.0) 2.0° C increase C. America (score = 2.0) 1.8° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 3.0) 6.3% drier N. America (score = 1.0) 3.3% drier Mexico (score = 4.0) 9.2% drier C. America (score = 1.0) 3.9% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.5) Some vulnerability of deciduous forest, particularly in the southern USA, though may expand range in the north (USFS 2013); very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.5) Although there is little evidence that aerial insectivores will suffer from phonological mismatch (e.g. Dunn et al. 2011), there may be moderate to high vulnerability for Whip-poor-wills because they are more particular in the timing of their foraging during crepuscular and nocturnal hours
• Non-breeding habitat vulnerability	(score = 1.0) Very little vulnerability of temperate woodlands (see above); very little vulnerability of dry tropical woodlands also as these habitats may increase in area (Khatun et al. 2013);
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.19. Red-headed Woodpecker
(Melanerpes erythrocephalus)

USFWS Region 3 status: conservation concern
AOU number: 4060
AOU abbreviation: RHWO

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.0	**2.8**	**2.8**	**0**	**0**	**3.0**	**1.4**	**2.2**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Red-headed Woodpecker was moderate, scoring 2.0 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability, suggesting that climate change-related factors might be a priority. This was driven primarily by their high degree of site fidelity and tendency to return to the same breeding territories year after year. Temperature increases and drying on the UMGL breeding grounds were predicted to have moderate effects on vulnerability. In contrast, climate on the non-breeding grounds was not predicted to have much effect. This was because (1) Red-headed Woodpeckers were relatively insensitive to temperature change during the winter and because (2) moisture change on the woodpecker's non-breeding grounds in N. America was predicted to be very small (1.8% change from current conditions, Figure 5.54). We had very little connectivity information on Red-headed Woodpeckers from banding data with only three breeding to non-breeding encounters from the UMGL (Figure 5.53). We also found no information on migratory connectivity from the literature. For this reason, we were unable to measure migratory connectivity with the UMGL, and we maintained a broad approach in our vulnerability analysis.

Red-headed woodpeckers excavate their own cavities and do not use nest boxes © Luanne Brooker

MIGRATORY CONNECTIVITY

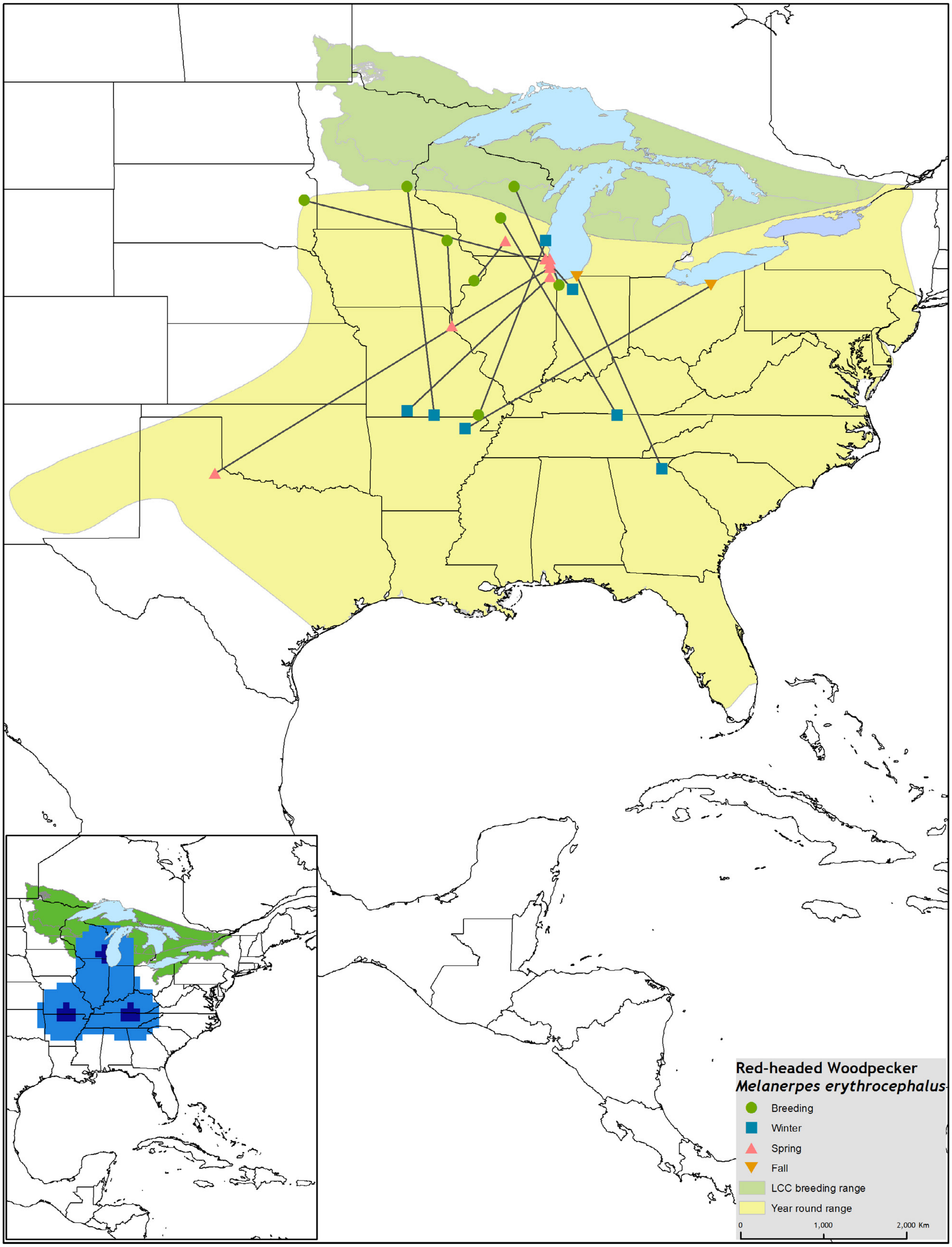


Figure 5.53. Red-headed Woodpecker banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green on the main map. There were only three breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

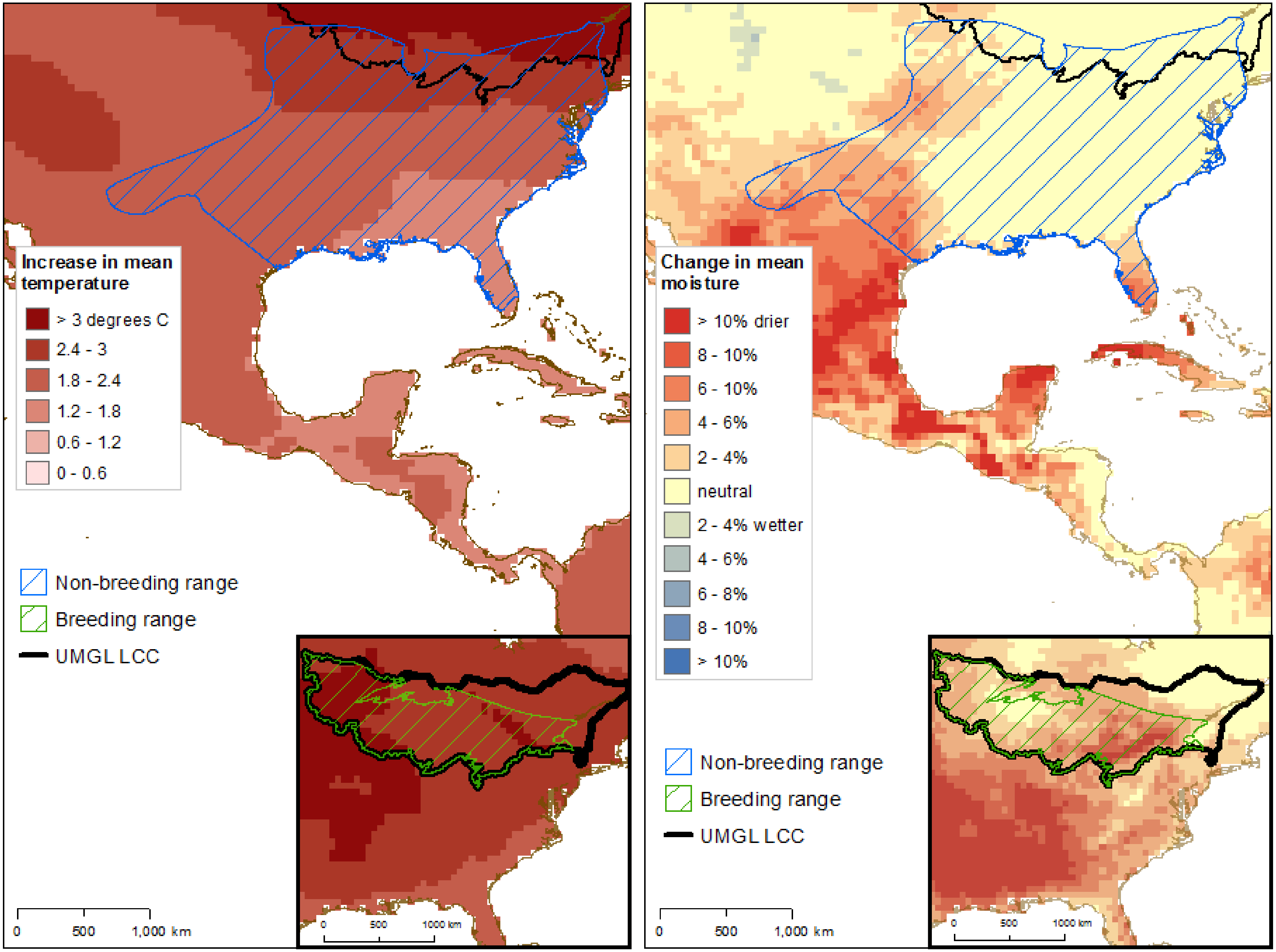
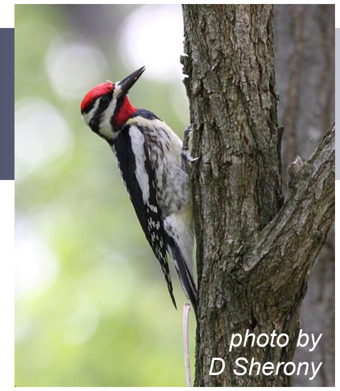


Figure 5.54. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Red-headed Woodpecker's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

RED-HEADED WOODPECKER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0.02 (95% CI = 0, 0.26)
• Range size	(score = 2.0) breeding = 4,664,275 km2; non-breeding = 3,342,646 km2
• PIF threats	(score = 3.5) breeding score = 3.5; non-breeding score = 3.0
• Breeding PIF conservation	(score = 3.7)
• Non-breeding PIF conservation	(score = 3.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 2.0) Non-migrant, short-distance migrant (mean distance = 0 km)
• Breeding habitat niche specialization	(score = 2.7) Macro habitats deciduous and mixed forest (with clearings), woodland/savannah (with snags), urban/parks; nesting micro habitat cavity in a snag or mostly dead tree (primary, natural) (2.5-25 m high)
• Breeding diet niche specialization	(score = 2.4) Insects, seeds/nuts, fruit, eggs; usually captured by hawking in the forest mid-canopy and near the ground
• Breeding site fidelity	(score = 5.0) High (known to return to same territories year after year)
• Non-breeding habitat niche specialization	(score = 3.0) Mature forest, woodland, clearings (with snags, masting nuts)
• Non-breeding diet niche specialization	(score = 2.8) Seeds/nuts (especially masting nuts), insects and fruit if available
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 14.9° C
• Breeding precipitation range	(score = 4.0) 46 cm
• Non-breeding thermal range	(score = 0) 23.7° C
• Non-breeding precipitation range	(score = 4.0) 39 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.6% drier
• Winter (Dec – Feb) non-breeding temperature	N. America (score = 3.0) 2.2° C increase
• Winter (Dec – Feb) non-breeding moisture	N. America (score = 0) 1.8% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.0) Some vulnerability of deciduous forest, particularly in the southern USA, though may expand range in the north (USFS 2013); very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); zero vulnerability of urban areas; snags may increase due to fire, pests, and disease (USFS 2013)
• Breeding biotic interaction vulnerability	(score = 1.2) Very little information on potential change in insect abundance, probably resilient overall –especially for species that eat a diversity of taxa; also very little information on changes in nuts and fruit –similar to insects
• Non-breeding habitat vulnerability	(score = 2.0) Coverage of mature forest is expected to decrease overall due to increased fire and pests while second-growth forests will increase (USFS 2013); very little vulnerability of woodlands (see above); clearings and snags may increase (see above)
• Non-breeding biotic interaction vulnerability	(score = 1.5) Very little information on potential change in insect abundance (see above); very little information on changes in nuts and fruit but masting may be resilient (evidence that mean temperature will not affect mast frequency, though annual variability probably will, Kelley et al. 2012)

5.20. Yellow-bellied Sapsucker *(Sphyrapicus varius)*



USFWS Region 3 status: common
AOU number: 4020
AOU abbreviation: YBSA

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.3	**2.8**	**2.2**	**0**	**2.8**	**3.3**	**1.7**	**2.4**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability of the Yellow-bellied Sapsucker was moderate, scoring 2.3 out of 5.0. Drying on the Mexican non-breeding grounds was the largest contributor to vulnerability followed by drying on the Caribbean non-breeding grounds (Figure 5.55). The adaptive capacity category also had a large effect on vulnerability, mostly driven by a presumed high degree of site fidelity during the breeding season. However, we have little data on site fidelity and most information is anecdotal. More research needs to be done in this area. We also have limited information on potential changes to important biotic interactions as a result of climate change. Namely, how will climate change affect Yellow-bellied Sapsucker diet (insects, sap, and fruit)? This affected our ability to comprehensively assess indirect effects of climate change. Temperature increases on the UMGL breeding grounds were predicted to have a moderate effect on vulnerability (Figure 5.55). We had very little connectivity information on Yellow-bellied Sapsuckers from banding data and only three breeding to non-breeding encounters from the UMGL (Figure 5.56). We also found no information on migratory connectivity from the literature. For this reason, we were unable to measure migratory connectivity with the UMGL, and we maintained a broad approach in our vulnerability analysis. Work on this topic would greatly improve our understanding of vulnerability for the species. However, our assessment found that they were not vulnerable which is in agreement with their current Region 3 conservation status.

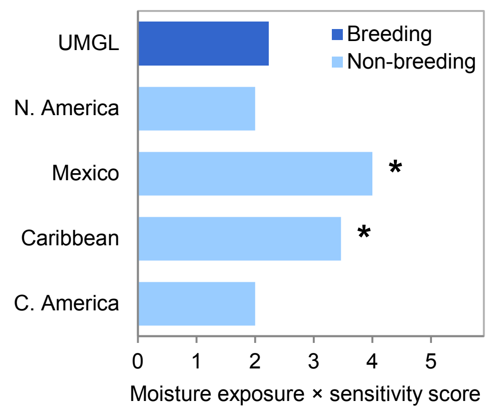


Figure 5.55. Yellow-bellies Sapsucker subscores for moisture exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). Temperature results not shown as all non-breeding scores equaled zero. *Non-breeding score ≥ 20% greater than breeding.

Sapsucker drillings (photo by SP Barrette)

MIGRATORY CONNECTIVITY

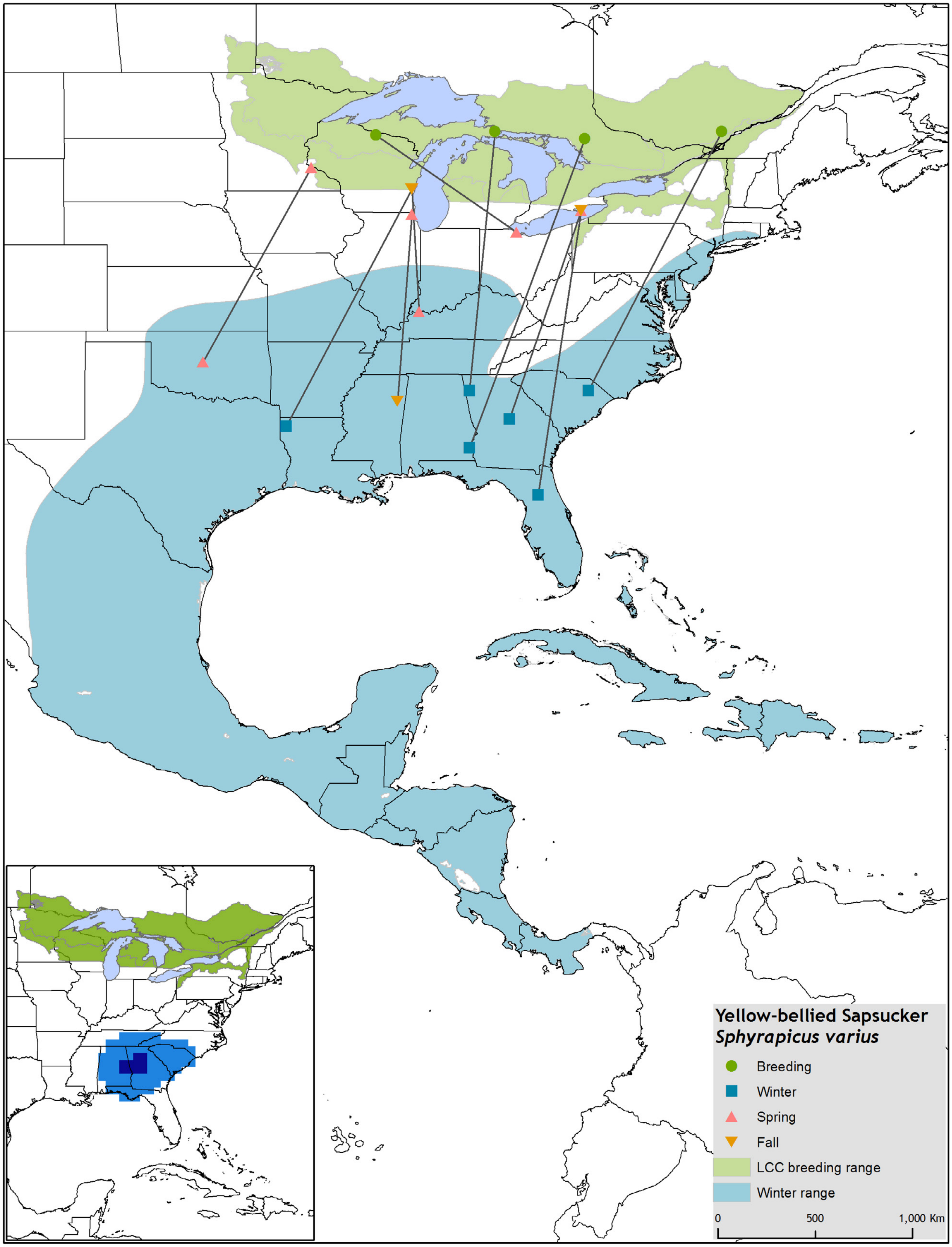


Figure 5.56. Yellow-bellied Sapsucker banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green on the main map. There were only three breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentration of non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

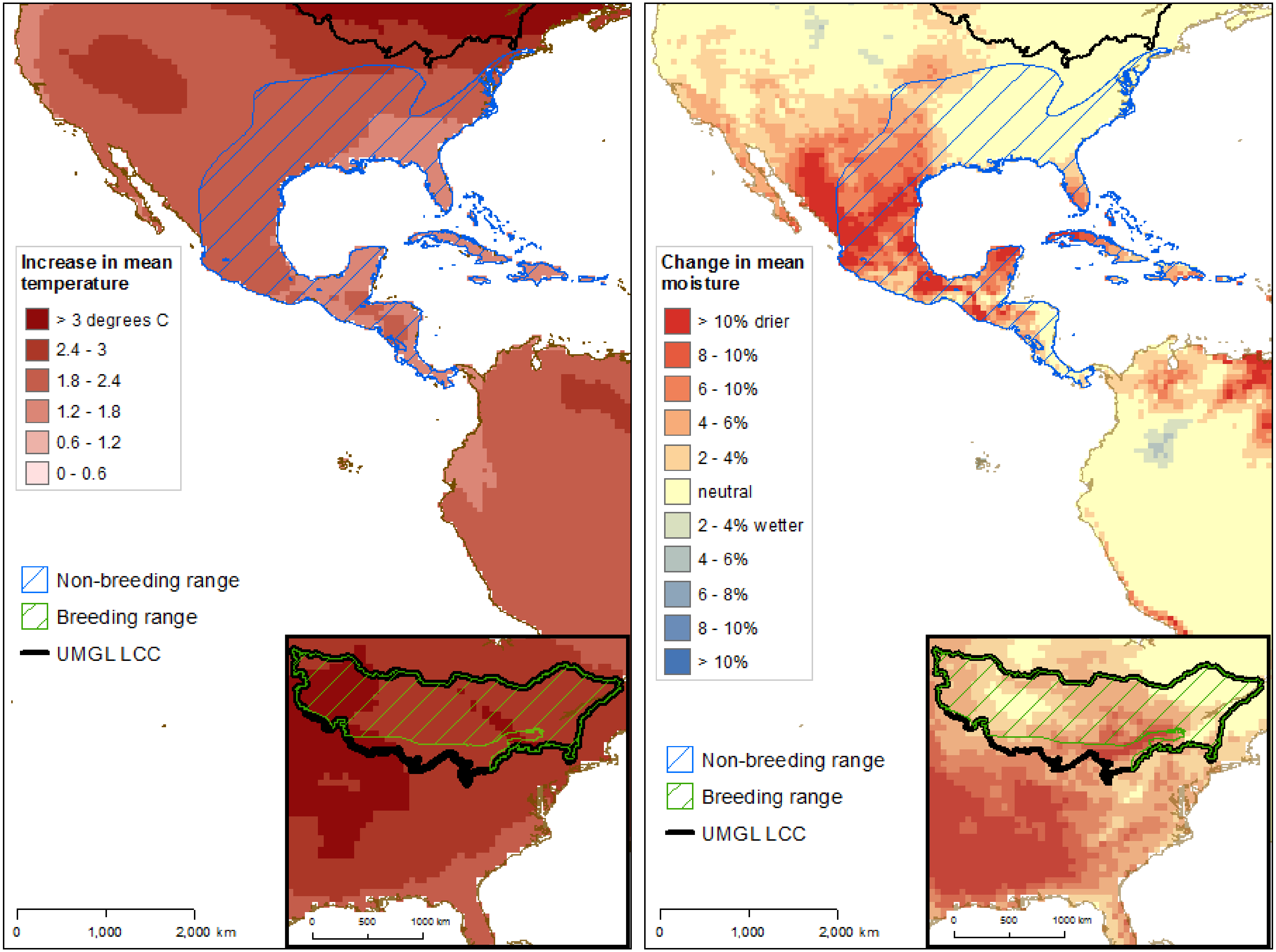


Figure 5.57. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Yellow-bellied Sapsucker's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

YELLOW-BELLIED SAPSUCKER DATA

i. Background Risk	
• Quasi-extinction risk	Unknown (species not well surveyed by BBS methods)
• Breeding PIF conservation	(score = 2.4)
• Non-breeding PIF conservation	(score = 1.8)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant, long-distance migrant (mean distance = 2985 km)
• Breeding habitat niche specialization	(score = 3.2) Macro habitats woodland, deciduous forest, coniferous forest (including second growth and logged); nesting micro habitat primary cavities in live trees (especially birch, poplar, aspen) (7.5 m high)
• Breeding diet niche specialization	(score = 2.8) Arthropods, sap, fruit; captured by gleaning bark of trees and shrubs
• Breeding site fidelity	(score = 5.0) No data but may be high
• Non-breeding habitat niche specialization	(score = 3.0) Deciduous and mixed forest, forest edge
• Non-breeding diet niche specialization	(score = 2.8) Sap mostly, arthropods and fruit as available
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 12.9° C
• Breeding precipitation range	(score = 5.0) 25 cm
• Non-breeding thermal range	(score = 0) 26.5° C
• Non-breeding precipitation range	(score = 4.0) 53 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 3.5% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase N. America (score = 3.0) 2.0° C increase Mexico (score = 3.0) 1.9° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.4% drier N. America (score = 1.0) 2.4% drier Mexico (score = 4.0) 8.2% drier Caribbean (score = 3.0) 6.2% drier C. America (score = 1.0) 3.8% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.3) Very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); some vulnerability of deciduous forest, particularly in the southern USA, though may expand range in the north (USFS 2013); high vulnerability of coniferous forest (both in the southern USA and boreal) due to fire, pests, and succession by hardwoods (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 1.3) Very little information on potential change in insect abundance, probably resilient overall – especially for species that eat a diversity of taxa; also very little information on changes in sap and fruit –may depend on whether trees remain stable and abundant
• Non-breeding habitat vulnerability	(score = 1.5) Some vulnerability of deciduous forest (see above); some vulnerability of mixed forests due to loss of conifers (Bachelet et al. 2001, Gonzalez et al. 2010); forest edges may increase due to fire, pests, and disease (USFS 2013)
• Non-breeding biotic interaction vulnerability	(score = 1.5) Very little information on changes in sap and fruit (see above); also very little information on potential change in insect abundance (see above)

5.21. Yellow-bellied Flycatcher *(Empidonax flaviventris)*

USFWS Region 3 status: common
AOU number: 4630
AOU abbreviation: YBFL

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.2	**2.8**	**1.7**	**2.8**	**2.8**	**3.8**	**2.8**	**3.7**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Yellow-bellied Flycatcher was high, scoring 3.2 out of 5.0. The adaptive capacity category was the largest contributor, due to a combination of their high breeding site fidelity, breeding diet specialized on aerial insects, and long-distance migration. The background risk category also had a high score, suggesting that both climate-change factors and non-climate change factors could be important for the species. Among the indirect effects of climate change, habitat vulnerability on the breeding grounds had the most impact—particularly coniferous forest and bogs. Unfortunately, we have no information on diet during the non-breeding season, and this knowledge gap affected our ability to comprehensively assess both the adaptive capacity and indirect effects categories. More research on this topic is needed for a complete understanding of Yellow-bellied Flycatcher vulnerability. Temperature increases on the UMGL breeding grounds and throughout the non-breeding range were predicted to have moderate effects on vulnerability (Figure 5.58). Drying on the Mexican non-breeding grounds, however, was predicted to have a larger effect (Figure 5.58). We had very little connectivity information on Yellow-bellied Flycatchers from banding data, including no breeding to non-breeding encounters from the UMGL (Figure 5.59). We also found no information on migratory connectivity from the literature. For this reason, we were unable to measure migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would greatly improve our understanding of vulnerability for the species. In addition, the winter range is small and research on Yellow-bellied Flycatcher migratory connectivity might be easier to conduct and more informative with less effort compared to other species.

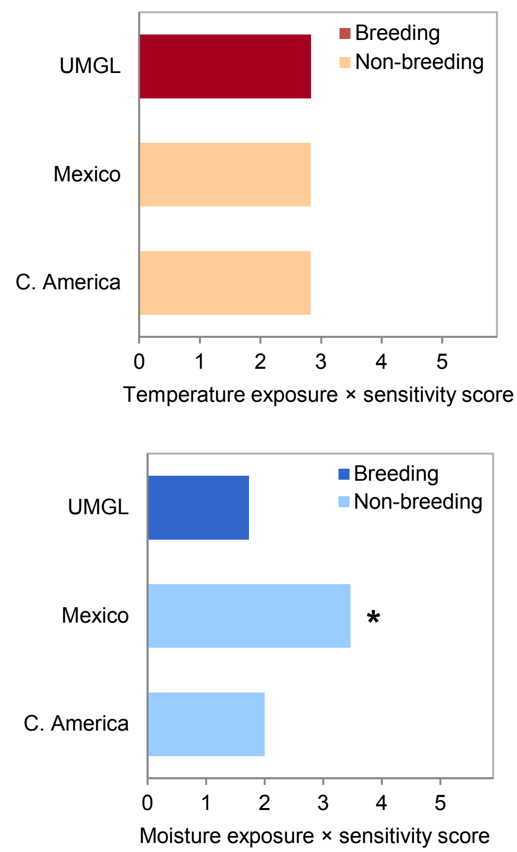


Figure 5.58. Yellow-bellied Flycatcher subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

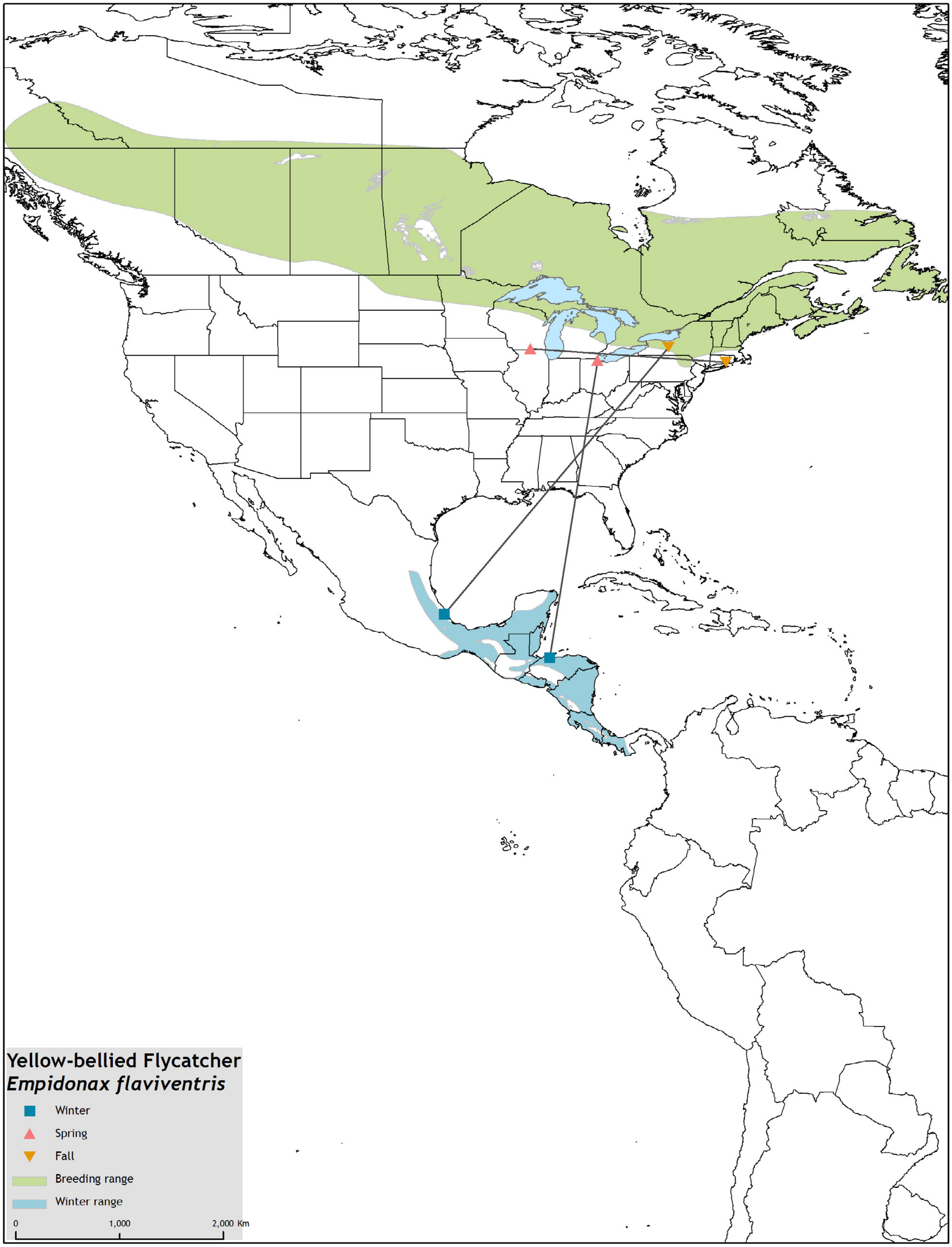


Figure 5.59. Yellow-bellied Flycatcher banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

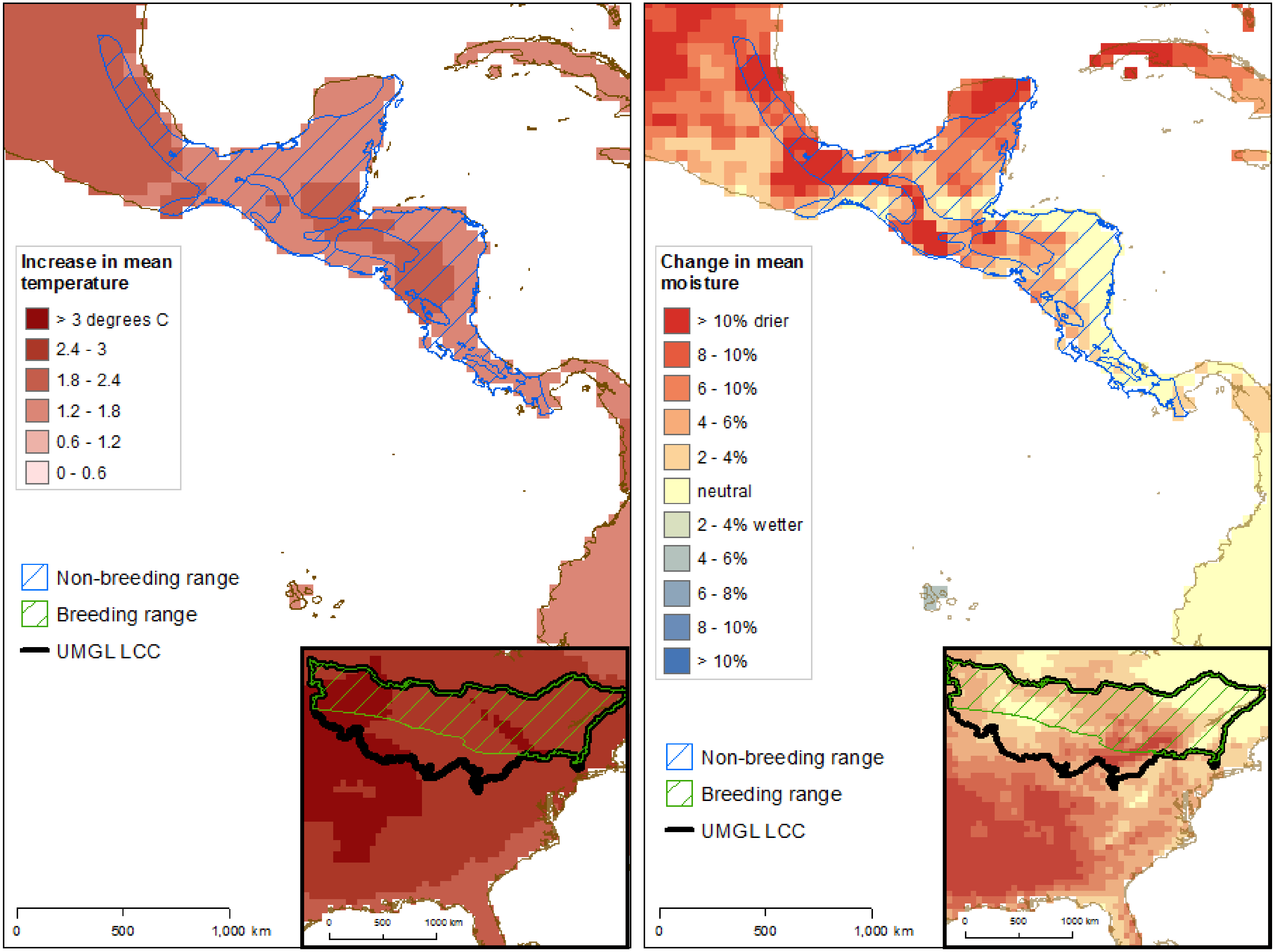


Figure 5.60. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Yellow-bellied Flycatcher's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

YELLOW-BELLIED FLYCATCHER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 5.0) 1.00 probability (95% CI = 1.00, 1.00)
• Range size	(score = 3.0) breeding = 5,308,917 km2; non-breeding = 682,678 km2
• PIF threats	(score = 3.0): breeding score = 2.5; non-breeding score = 3.0
• Breeding PIF conservation	(score = 2.6)
• Non-breeding PIF conservation	(score = 2.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 4151 km)
• Breeding habitat niche specialization	(score = 2.7) Macro habitats boreal forests, bog wetlands, mixed forests; nesting micro habitat ground and low vegetation with dense cover (0-9 m high)
• Breeding diet niche specialization	(score = 4.5) Aerial arthropods; captured by hawking in the forest sub-canopy
• Breeding site fidelity	(score = 5.0) High (returns to same territories year after year)
• Non-breeding habitat niche specialization	(score = 3.0) Primary/evergreen forest (humid and dry), secondary mixed forest (humid and dry), coffee agriculture
• Non-breeding diet niche specialization	(score = unknown) No data available
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 15.1° C
• Breeding precipitation range	(score = 3.0) 83 cm
• Non-breeding thermal range	(score = 4.0) 6.7° C
• Non-breeding precipitation range	(score = 4.0) 49 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 3.6% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.8° C increase Mexico (score = 2.0) 1.7° C increase C. America (score = 2.0) 1.8° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.9% drier Mexico (score = 3.0) 7.2% drier C. America (score = 1.0) 2.9% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.0) High vulnerability of boreal forest due to fire, pests, hardwood succession (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013); high vulnerability of mixed northern forests due to loss of conifers (Bachelet et al. 2001, Gonzalez et al. 2010); high vulnerability of bogs due to drying (Goulatowitsch et al. 2009, Karl et al. 2009, USDA 2012, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.0) There may be some vulnerability of aerial arthropods (but see Dunn et al., 2011, which concludes no timing mismatch timing between aerial insects and Tree Swallows); small mammalian nest predators may increase in abundance with climate change, especially in warm temperate regions (Johnston et al. 2012, Korpela et al. 2013, Karl et al. 2009)
• Non-breeding habitat vulnerability	(score = 1.3) Very little vulnerability of dry tropical forest as these habitats may increase in area (Khatun et al. 2013); vulnerability of broadleaf tropical forest may depend on location and exact forest type—lowland forests may be stable partly because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013); vulnerability of primary tropical forest may depend on location and exact forest type—stable in most areas partly because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013) but Brazil and eastern Amazon may be exception (Freeley et al. 2010, Gonzalez et al. 2010); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.22. Acadian Flycatcher (*Empidonax virescens*)

USFWS Region 3 status: conservation concern
AOU number: 4650
AOU abbreviation: ACFL

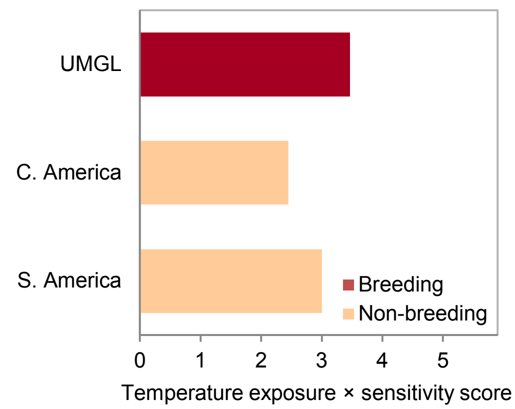
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.8	**3.5**	**3.0**	**3.0**	**0**	**3.9**	**2.5**	**2.4**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Acadian Flycatcher was moderate, scoring 2.8 out of 5.0. Category scores suggest that climate-change related factors may be a priority when compared to background risk. The adaptive capacity category was the largest contributor to vulnerability—due to a combination of factors, including high breeding site fidelity, a diet that is fairly specialized throughout the year, and fairly specialized habitat needs during the non-breeding season. Among indirect effects of climate change, habitat vulnerability on the breeding grounds had the greatest impact—particularly mature forest stands, which are expected to decrease due to increased disturbance under climate change. Unfortunately, we have no information on arthropod vulnerability during the non-breeding season, which affected confidence in our assessment of indirect effects. Temperature increases on both the UMGL breeding grounds and the S. American non-breeding grounds were predicted to have large effects on vulnerability, though the effect during the breeding season was expected to be greater (Figure 5.61). Drying on the UMGL breeding grounds was also expected to have a large effect; however, drying on the non-breeding grounds was not expected to have much effect (Figure 5.61). We had very little connectivity information on Acadian Flycatchers from banding data, including no breeding to non-breeding encounters from the UMGL (Figure 5.62). We also found no information on migratory connectivity from the literature. For this reason, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on migratory connectivity would greatly improve our understanding of vulnerability for Acadian Flycatchers, and because the winter range is somewhat small, this research might be a more informative undertaking with relatively little effort.



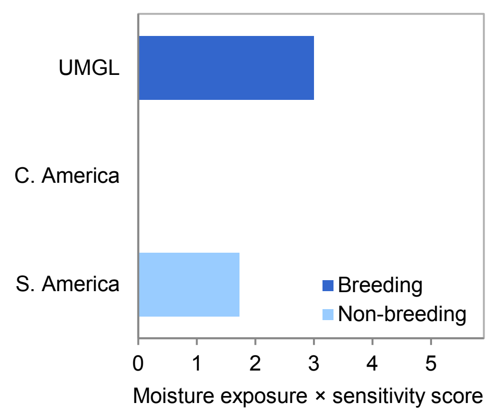


Figure 5.61. Acadian Flycatcher subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

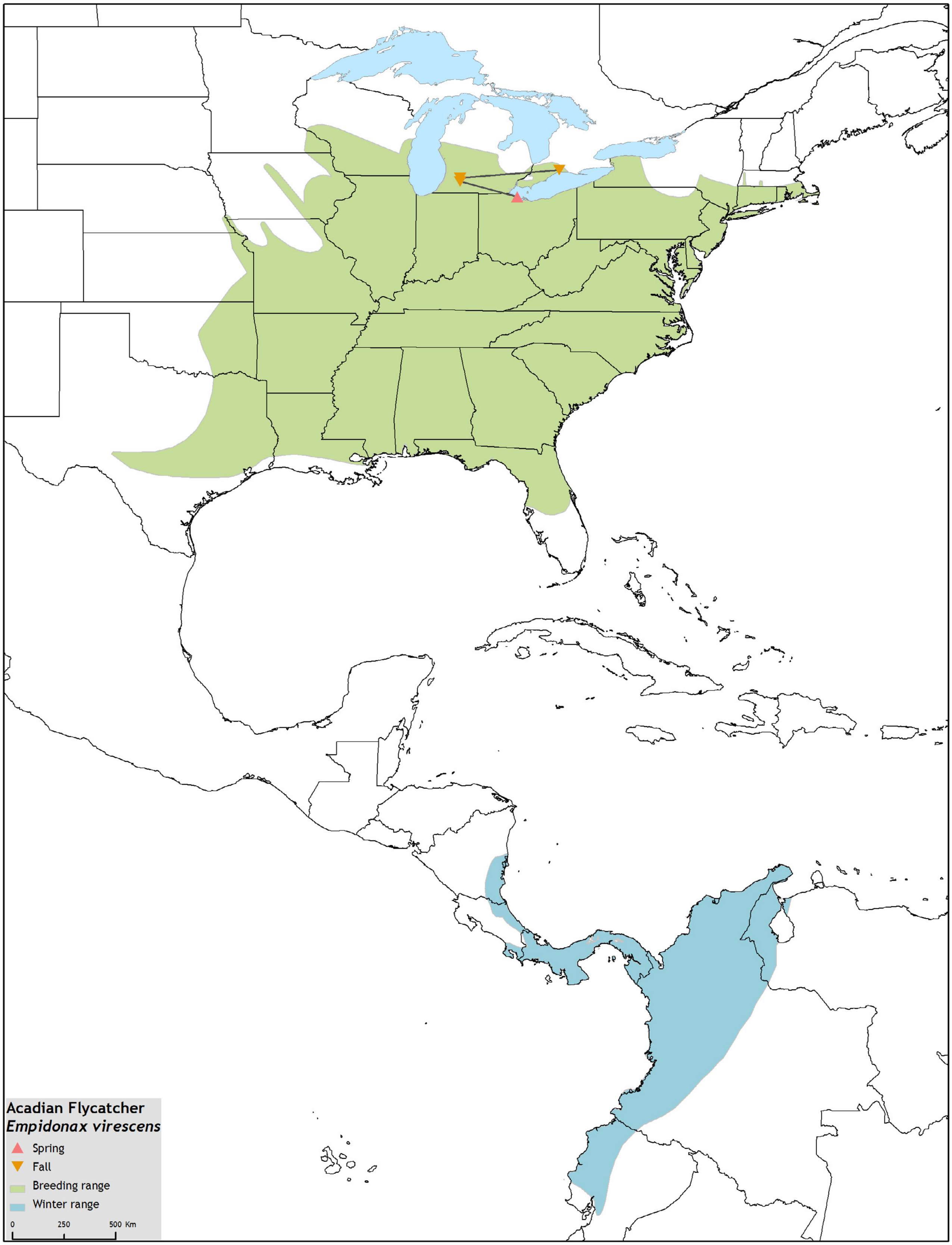


Figure 5.62. Acadian Flycatcher banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

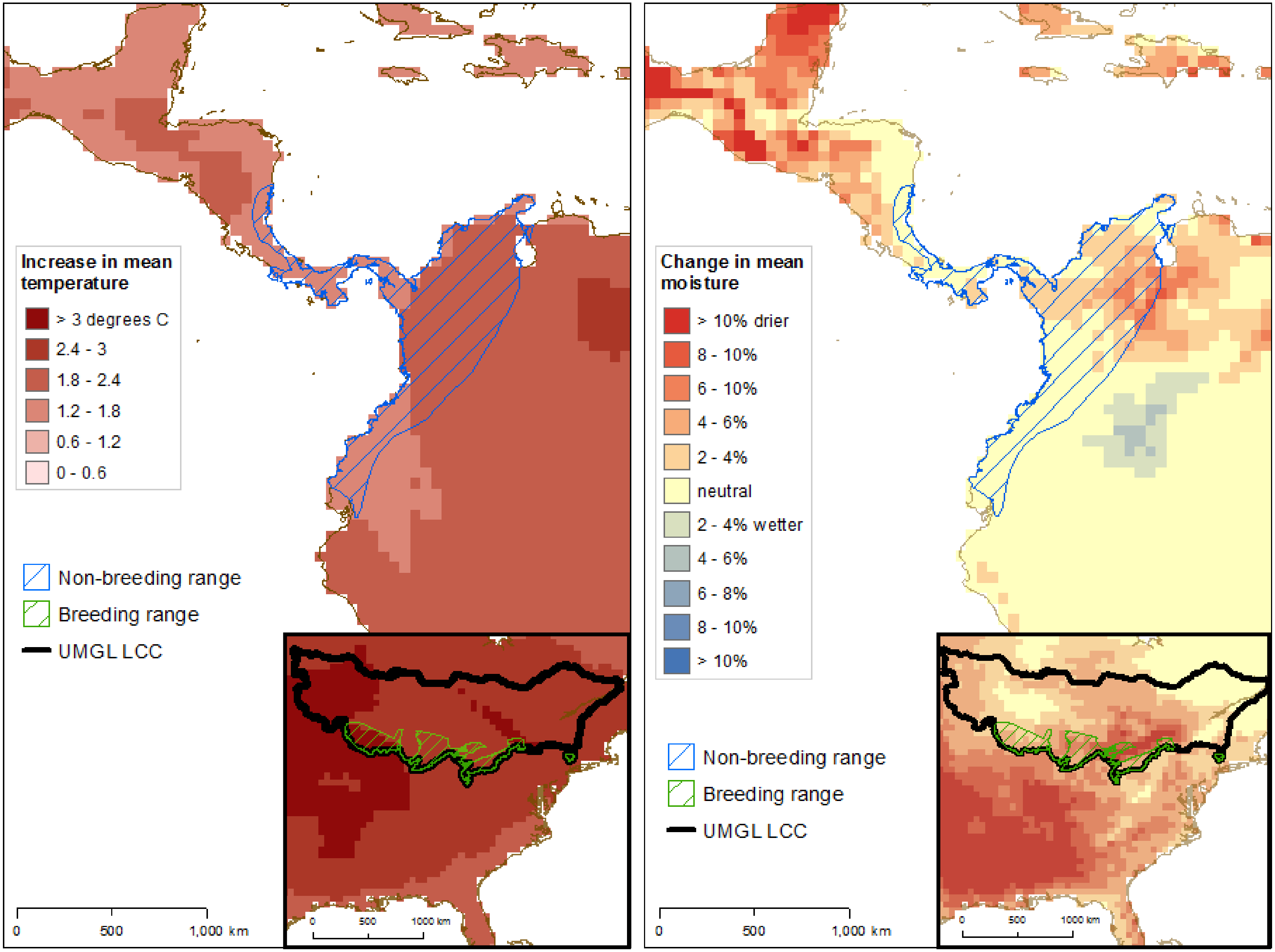


Figure 5.63. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Acadian Flycatcher's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

ACADIAN FLYCATCHER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 3.0) breeding = 2,461,383 km2; non-breeding = 569,279 km2
• PIF threats	(score = 3.1): breeding score = 3.1; non-breeding score = 3.0
• Breeding PIF conservation	(score = 3.1)
• Non-breeding PIF conservation	(score = 2.8)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 3407 km)
• Breeding habitat niche specialization	(score = 3.5) Macro habitats deciduous forest (mature and wet); nesting micro habitat small tree or shrub (2.5-6 m high)
• Breeding diet niche specialization	(score = 4.0) Aerial arthropods; captured by hawking in the forest mid-canopy and sub-canopy
• Breeding site fidelity	(score = 5.0) High (returns to same territories year after year)
• Non-breeding habitat niche specialization	(score = 4.0) Secondary/patchy forest (wet and dry), primary forest (wet and dry)
• Non-breeding diet niche specialization	(score = 4.0) Arthropods (adults and larvae, variety of families)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.0) 8.7° C
• Breeding precipitation range	(score = 4.5) 31 cm
• Non-breeding thermal range	(score = 3.0) 10.9° C
• Non-breeding precipitation range	(score = 3.0) 73 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.6% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase C. America (score = 2.0) 1.7° C increase S. America (score = 3.0) 1.9° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 0) 1.9% drier C. America (score = 0) 1.6% drier S. America (score = 1.0) 2.0% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.0) Uncertain vulnerability of wet mature deciduous forest but may be high in some areas—vulnerability may be greatest in the southern USA (USFS 2013); mature forests are expected to decrease with increased disturbance from fire, pests, and disease (USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.0) Very little information on vulnerability of aerial arthropods, there may be some (but see Dunn et al., 2011, which concludes no mismatch in timing between aerial insects and Tree Swallows, Tachycineta bicolor); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Johnston et al. 2012, Korpela et al. 2013, Karl et al. 2009)
• Non-breeding habitat vulnerability	(score = 2.0) Very little vulnerability of dry tropical forest as these habitats may increase in area (Khatun et al. 2013); vulnerability of broadleaf tropical forest may depend on location and exact forest type—lowland forests may be stable partly because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013); vulnerability of primary tropical forest may depend on location and exact forest type—stable in most areas partly because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013), though Brazil and eastern Amazon may be exception (Freeley et al. 2010, Gonzalez et al. 2010)
• Non-breeding biotic interaction vulnerability	(score = 2.0) No information on potential of aerial arthropods to increase or decrease on the non-breeding grounds but there may be some vulnerability

5.23. Swainson’s Thrush *(Catharus ustulatus)*

USFWS Region 3 status: common
AOU number: 7580
AOU abbreviation: SWTH

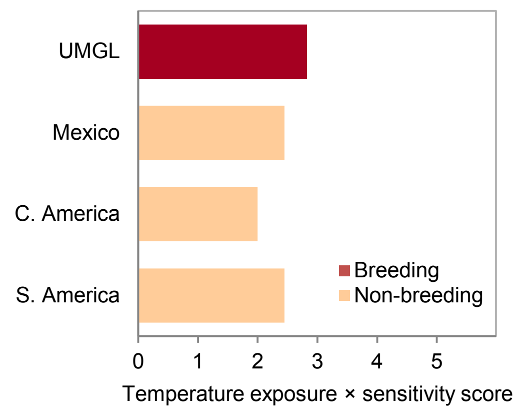
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.8	**2.8**	**2.0**	**2.4**	**0**	**3.7**	**2.3**	**3.3**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Swainson’s Thrush was moderate, scoring 2.8 out of 5.0. The adaptive capacity category was the largest contributor to vulnerability, mostly due to a high degree of breeding site fidelity, fairly long distance migration, and fairly specialized non-breeding habitat needs. The background risk subscore was also in the high category, suggesting that factors unrelated to climate change may be important for Swainson’s Thrushes. The category for indirect effects of climate change was driven by vulnerability of coniferous and boreal forest. This may be compounded by the fact that coniferous forest is one of the main habitats used by Swainson’s Thrushes during the breeding season. Temperature increases on the UMGL breeding grounds and throughout the non-breeding range were predicted to have moderate effects on vulnerability (Figure 5.64). Drying on the Mexican non-breeding grounds was predicted to have a slightly larger effect (Figure 5.64). We had little connectivity information on Swainson’s Thrushes from banding data, including no breeding to non-breeding encounters from the UMGL (Figure 5.65). In addition, there is very limited information in the literature. Using stable isotopes, Kelley et al. (2005) found weak connectivity between populations from Lake Ontario, Canada, and Ecuador. However, the study could not make conclusions regarding other breeding and non-breeding locations. For this reason, we maintained a broad approach in our analysis and included the entire non-breeding range. More work on this topic would greatly improve our understanding of vulnerability for the species.



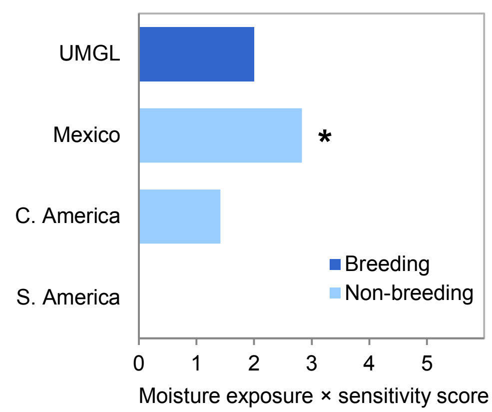


Figure 5.64. Swainson’s Thrush subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

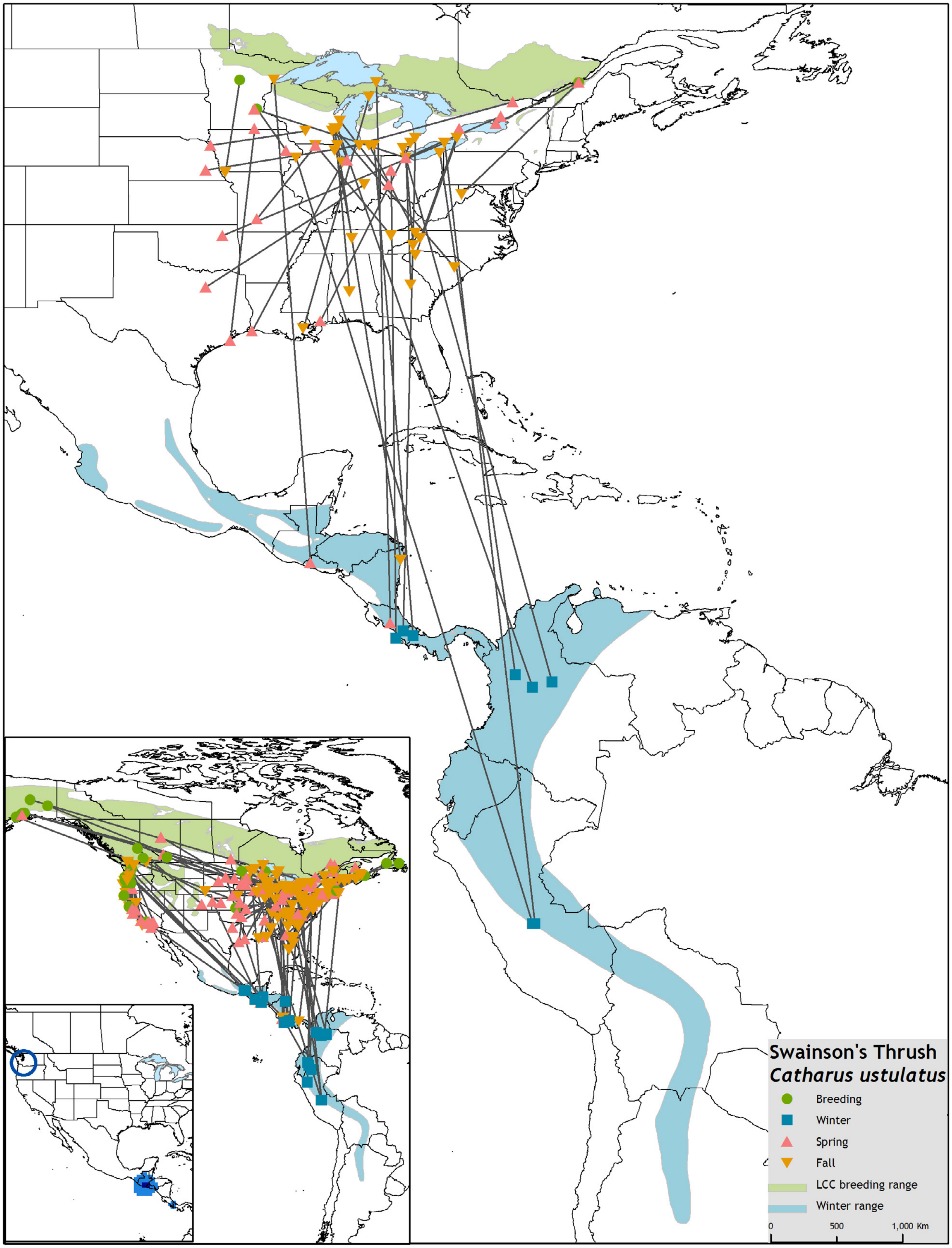


Figure 5.65. Swainson's Thrush banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green on the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Inset map shows data from the entire breeding range along with concentrations of stationary non-breeding encounters from the Pacific Northwest.

CLIMATE EXPOSURE

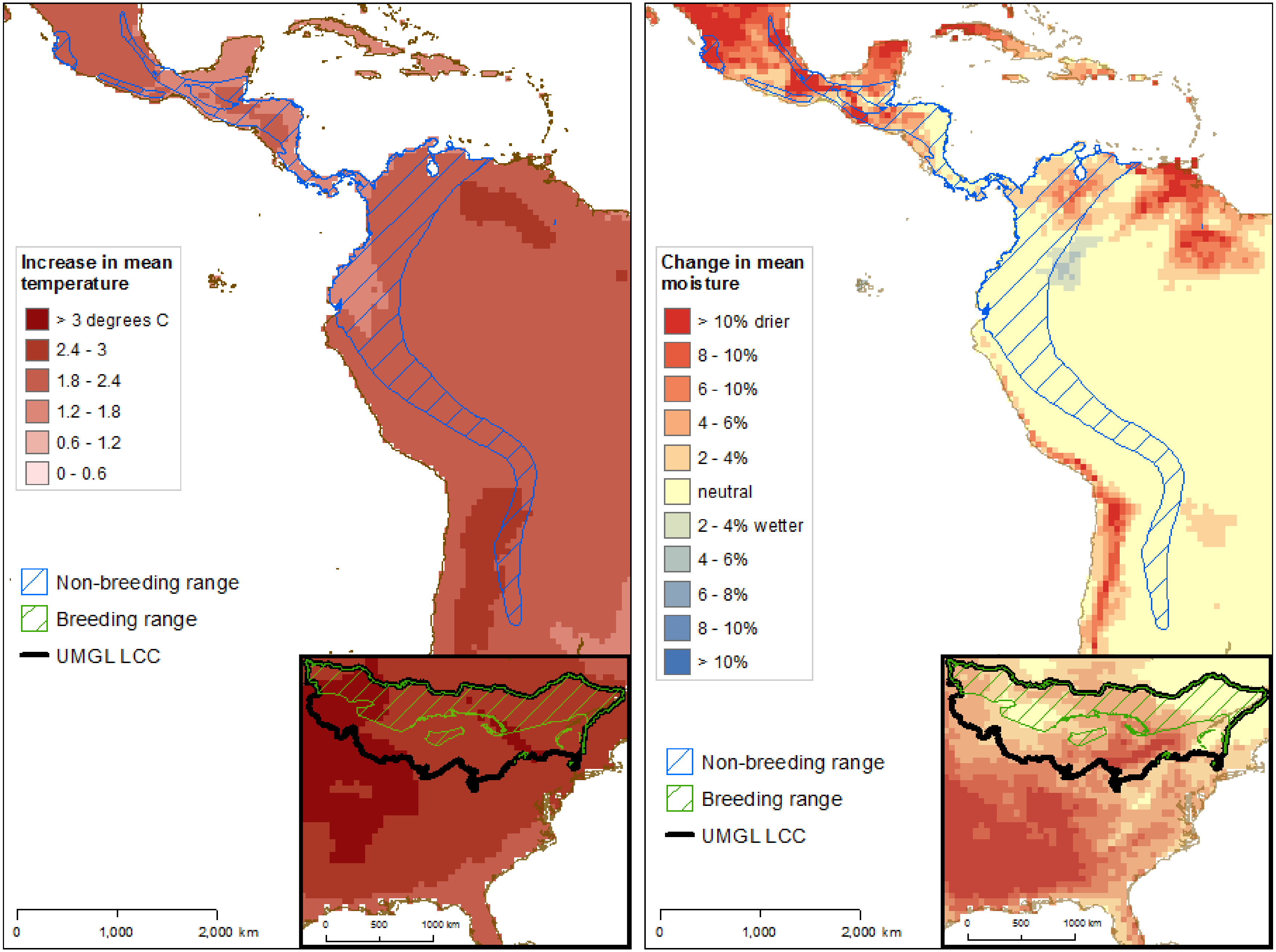
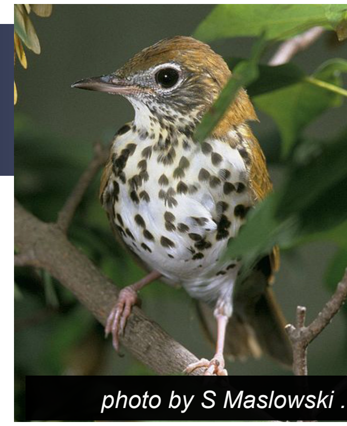


Figure 5.66. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Swainson's Thrush non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

SWAINSON'S THRUSH DATA

i. Background Risk	
• Quasi-extinction risk	(score = 5.0) 1.00 probability (95% CI = 1.00, 1.00)
• Range size	(score = 2.0) breeding = 7,525,849 km2; non-breeding = 2,788,297 km2
• PIF threats	(score = 3.0): breeding score = 2.8; non-breeding score = 3.0
• Breeding PIF conservation	(score = 2.4)
• Non-breeding PIF conservation	(score = 2.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 6065 km)
• Breeding habitat niche specialization	(score = 3.5) Macro habitats coniferous forest (including boreal), riparian; nesting micro habitat small trees and shrubs (1-6 m high)
• Breeding diet niche specialization	(score = 2.7) Insects, fruit; captured mostly by gleaning foliage near the ground, in leaf litter, and forest sub-canopy
• Breeding site tenacity	(score = 5.0) High (anecdotal evidence for strong breeding site fidelity between years)
• Non-breeding habitat niche specialization	(score = 4.0) Primary tropical semi-deciduous forest (including rain and humid/semi-humid), second growth forest and edges
• Non-breeding diet niche specialization	(score = 2.7) Insects, fruit (similar to breeding but more fruit)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 14.4° C
• Breeding precipitation range	(score = 4.0) 34 cm
• Non-breeding thermal range	(score = 2.0) 14.5° C
• Non-breeding precipitation range	(score = 2.0) 112 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.8° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 2.9% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.0° C increase Mexico (score = 3.0) 1.9° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.1° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 0) 1.9% drier Mexico (score = 4.0) 8.2% drier C. America (score = 1.0) 3.5% drier S. America (score = 0) 1.0% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.3) High vulnerability of coniferous forest (both southern USA and boreal) due to fire, pests, and succession by hardwoods (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013); riparian habitat vulnerability may depend on location with western riparian habitat highly vulnerable (Perry et al. 2012, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 2.3) Vulnerability of arthropods general unknown, but native species may have some vulnerability (Chown et al. 2007); potential changes to fruit abundance and phenology largely unknown but may be very little; small mammalian nest predators may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 2.0) Vulnerability of primary tropical forest may depend on location and forest type—stable in most areas because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013) but Brazil and eastern Amazon may be exception (Freeley et al. 2010, Gonzalez et al. 2010); very little vulnerability of dry tropical forest, which may increase in area (Khatun et al. 2013); vulnerability of broadleaf tropical forest may depend on location and forest type—lowland forests may be stable due to high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013)
• Non-breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in the tropics is largely unknown, but there may be some; potential changes to abundance and phenology of fruit is largely unknown but may be very little

5.24. Wood Thrush (*Hylocichla mustelina*)



USFWS Region 3 status: conservation concern
AOU number: 7550
AOU abbreviation: WOTH

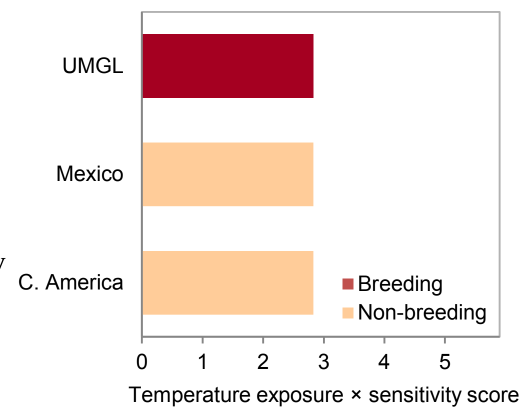
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.8	**2.8**	**3.0**	**2.8**	**2.8**	**3.5**	**2.0**	**2.7**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Wood Thrush was moderate, scoring 2.8 out of 5.0. The adaptive capacity category and drying effect in Mexico during the non-breeding season were the largest contributors to vulnerability. This suggests that climate-change factors may be a priority compared to background risk. The adaptive capacity subscore was driven by a high degree of breeding site fidelity and fairly specialized habitat needs during the non-breeding season requiring either primary or mixed forest types. Subscores for indirect effects of climate change were all relatively low, placing more focus on adaptive capacity and climate exposure. However, we have no information on diet during the non-breeding season, which limited our assessments of both adaptive capacity and indirect effects. More research on this topic is needed to better understand Wood Thrush vulnerability. Temperature increases on the UMGL breeding grounds and throughout the non-breeding range were predicted to have moderate effects on vulnerability (Figure 5.67). Drying on the UMGL breeding grounds and the Mexican non-breeding grounds were both predicted to have large effects, though the effect was greatest in Mexico (Figure 5.67). We had very little connectivity information on Wood Thrush from banding data, including no breeding to non-breeding encounters originating from the UMGL (Figure 5.68). Research using geolocators and stable isotopes suggest that Wood Thrush populations from the UMGL have weak migratory connectivity and a high degree of mixing throughout the non-breeding range (Stutchbury et al. 2011, Stanley et al. 2012, Rushing et al. 2014). For this reason, we maintained a broad approach in our analysis and focused on the entire non-breeding range. More research on Wood Thrush from throughout the breeding range would greatly benefit conservation efforts for the species.



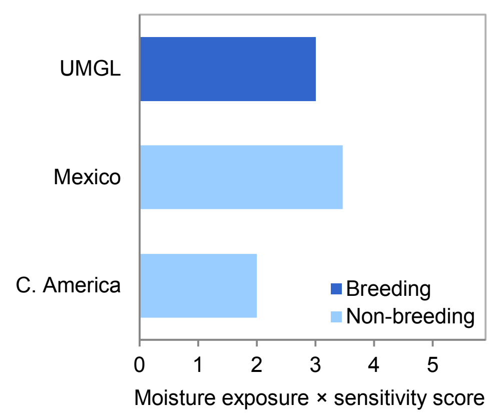


Figure 5.67. Wood Thrush subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

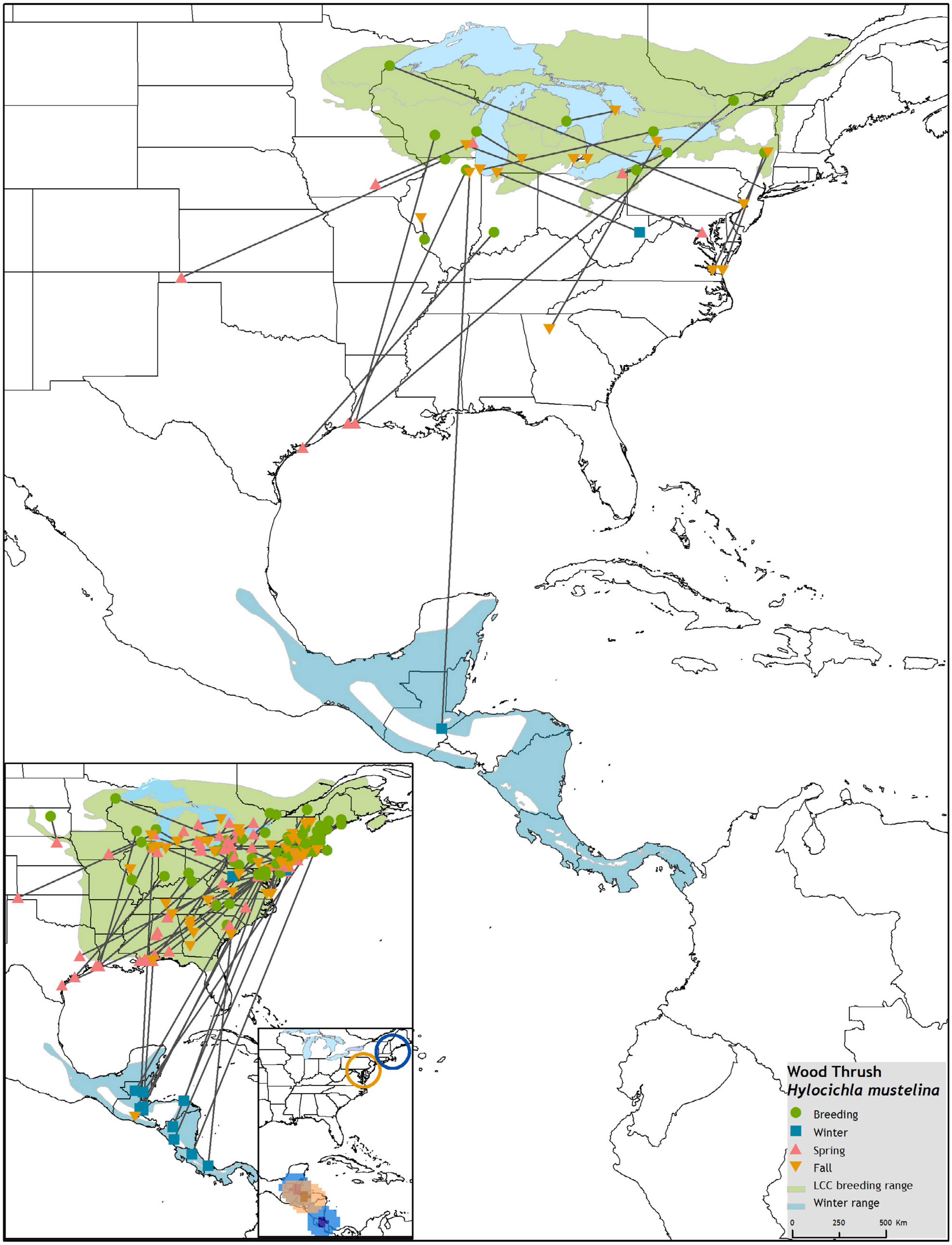


Figure 5.68. Wood Thrush banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Inset map shows data from the entire breeding range along with concentrations of stationary non-breeding encounters originating from two breeding regions.

CLIMATE EXPOSURE

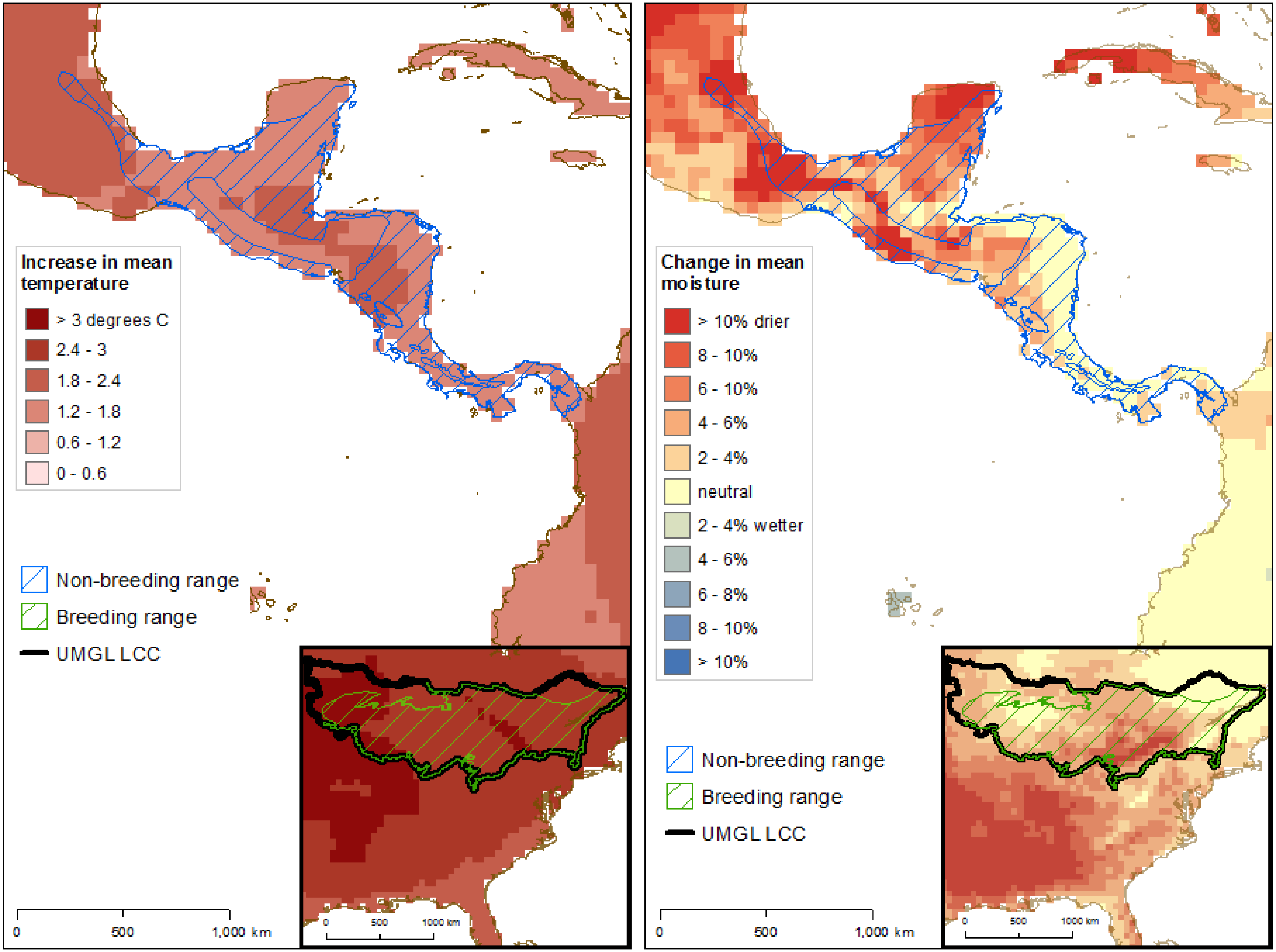


Figure 5.69. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Wood Thrush’s non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

WOOD THRUSH DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 3.0) breeding = 3,489,351 km2; non-breeding = 646,795 km2
• PIF threats	(score = 4.0): breeding score = 3.1; non-breeding score = 4.0
• Breeding PIF conservation	(score = 3.6)
• Non-breeding PIF conservation	(score = 3.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 2738 km)
• Breeding habitat niche specialization	(score = 3.0) Macro habitats deciduous and mixed forests (with shrubs and leaf litter); nesting micro habitat trees and shrubs (2-15 m high)
• Breeding diet niche specialization	(score = 2.4) Arthropods, other invertebrates, fruit; captured mostly by gleaning foliage near the ground, in leaf litter, and forest sub-canopy
• Breeding site fidelity	(score = 5.0) High (but some evidence for several-km-movement after nest failure)
• Non-breeding habitat niche specialization	(score = 4.0) Primary forest (tropical, evergreen, broadleaf), mixed forest
• Non-breeding diet niche specialization	(score = unknown) No data available
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 12.5° C
• Breeding precipitation range	(score = 4.5) 27 cm
• Non-breeding thermal range	(score = 4.0) 6.7° C
• Non-breeding precipitation range	(score = 4.0) 46 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.2% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.8° C increase Mexico (score = 2.0) 1.7° C increase C. America (score = 2.0) 1.8° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.4% drier Mexico (score = 3.0) 7.4% drier C. America (score = 1.0) 3.9% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.0) Some vulnerability of deciduous forest, particularly in the southern USA though may expand range in the north (USFS 2013); some vulnerability of mixed forests due to loss of conifers (Bachelet et al. 2001, Gonzalez et al. 2010)
• Breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in general is largely unknown, but there may be some vulnerability for native species (Chown et al. 2007); potential changes to abundance and phenology of fruit is largely unknown but may be very little; small mammalian nest predators are another potential biotic interaction, which may increase in abundance with climate change, especially in warm temperate regions (Johnston et al. 2012, Korpela et al. 2013, Karl et al. 2009)
• Non-breeding habitat vulnerability	(score = 2.0) Vulnerability of primary tropical forest may depend on location and exact forest type—stable in most areas partly because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013), but Brazil and eastern Amazon may be exception (Freeley et al. 2010, Gonzalez et al. 2010); Very little vulnerability of dry tropical forest as these habitats may increase in area (Khatun et al. 2013); vulnerability of broadleaf tropical forest may depend on location and exact forest type —lowland forests may be stable partly because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013)
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.25. Worm-eating Warbler (*Helmitheros vermivorum*)

USFWS Region 3 status: conservation concern
AOU number: 6390
AOU abbreviation: WEWA

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.2	**3.7**	**3.2**	**2.8**	**2.8**	**3.8**	**2.4**	**3.3**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Worm-eating Warbler was high, scoring 3.2 out of 5.0. The adaptive capacity category was the largest contributor, which was driven by a high degree of breeding site fidelity and very highly specialized habitat needs during the breeding season. This habitat specialization is compounded by the high vulnerability of large, mature, forest (their preferred habitat type) to climate change. Unfortunately, less is known about the warbler's non-breeding habitat, though there is some evidence that they will use both humid and dry tropical forests as well coffee farms. More winter research during winter will help verify this information and would make vulnerability assessments more informative. Temperature increases and drying on the UMGL breeding grounds are also expected to have large effects on vulnerability (Figure 5.70). In addition, drying on the Mexican and Caribbean non-breeding grounds are expected to have large effects (Figure 5.70). Consequently, we predicted that climate change will negatively affect Worm-eating Warblers throughout their annual cycle. Background risk is another large contributor to vulnerability, suggesting that both climate change factors and factors unrelated to climate change may be important for this species. We had very little connectivity information on Worm-eating Warblers from banding data and no breeding to non-breeding encounters from the UMGL (Figure 5.71). We also found no information on migratory connectivity from the literature. For this reason, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would greatly improve our understanding of vulnerability for the species.

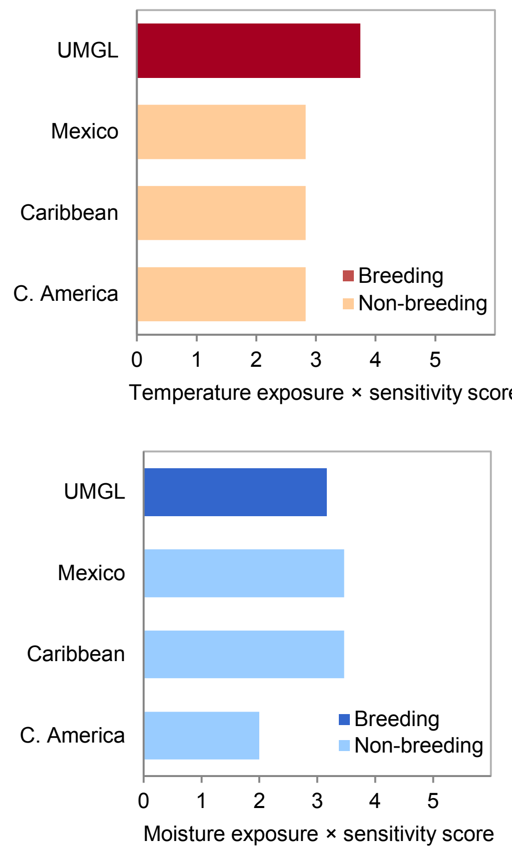


Figure 5.70. Worm-eating Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

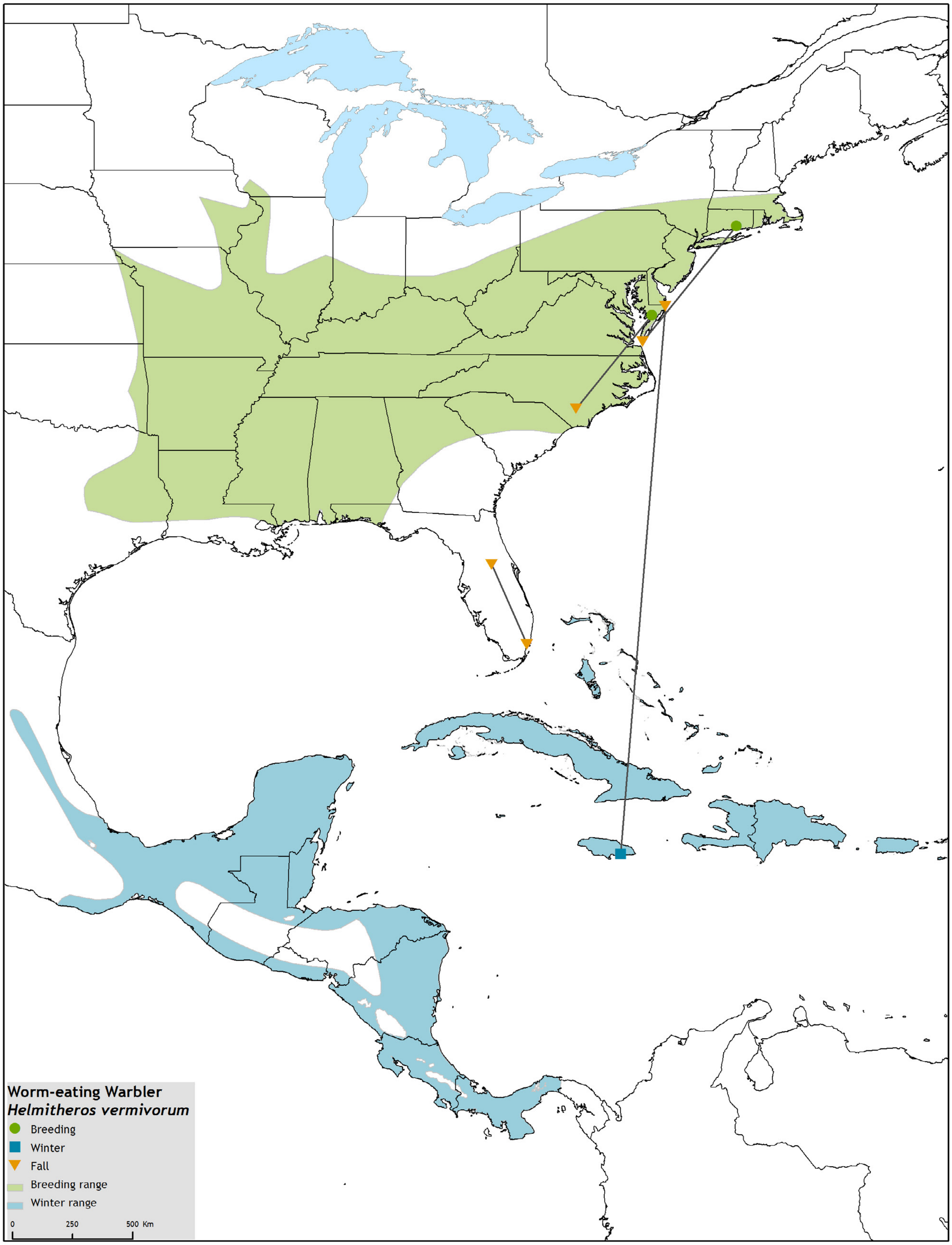


Figure 5.71. Worm-eating Warbler banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

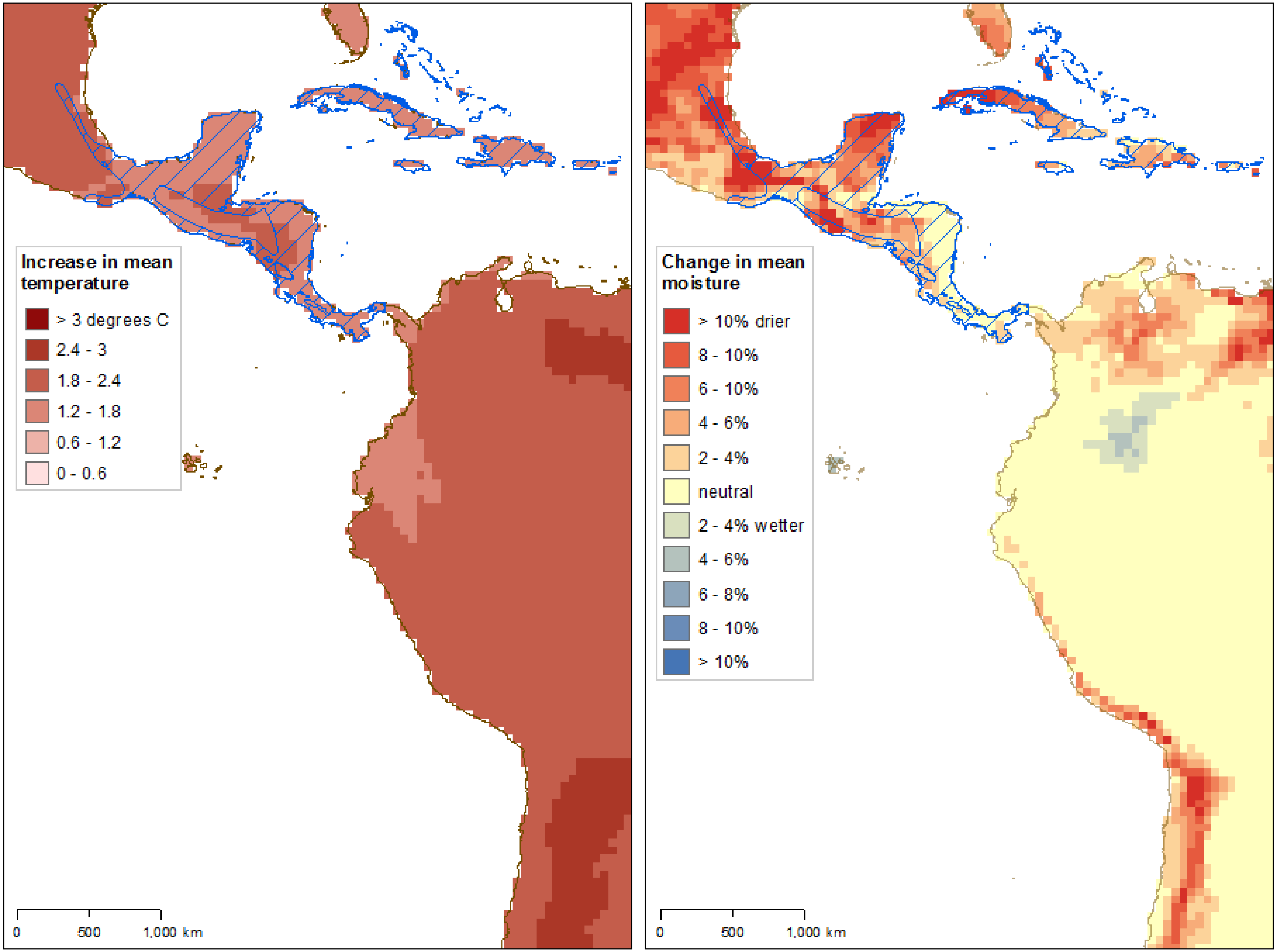


Figure 5.72. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Worm-eating Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

WORM-EATING WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 3.0) 0.12 probability (95% CI = 0.08, 0.51)
• Range size	(score = 2.0) breeding = 1,753,323 km2; non-breeding = 902,709 km2
• PIF threats	(score = 4.0): breeding score = 3.1; non-breeding score = 4.0
• Breeding PIF conservation	(score = 3.1)
• Non-breeding PIF conservation	(score = 3.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 2163 km)
• Breeding habitat niche specialization	(score = 5.0) Macro habitats deciduous and mixed forest (mature and large with dense understory); nesting micro habitat on ground of steep hillsides with thick vegetation (0 m high)
• Breeding diet niche specialization	(score = 3.5) Exclusively insects; captured by gleaning foliage in the sub-, mid-, and upper canopy layers
• Breeding site fidelity	(score = 5.0) High (especially among males)
• Non-breeding habitat niche specialization	(score = 3.0) Not well known, broadleaf/evergreen/wet forest, dry forest, coffee agriculture
• Non-breeding diet niche specialization	(score = 3.2) Insects, spiders (no details available)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.5) 7.6° C
• Breeding precipitation range	(score = 5.0) 20 cm
• Non-breeding thermal range	(score = 4.0) 5.8° C
• Non-breeding precipitation range	(score = 4.0) 52 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.2% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.7° C increase Mexico (score = 2.0) 1.7° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.5% drier Mexico (score = 3.0) 7.6% drier Caribbean (score = 3.0) 6.2% drier C. America (score = 1.0) 2.9% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.0) Some vulnerability of mixed deciduous forest, particularly in the southern USA, though northern forests may expand (USFS 2013); high vulnerability of mature forest, which is expected to decrease overall due to increased fire and pests (USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.3) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.3) Vulnerability of broadleaf/humid forest may depend on location and forest type—stable in many areas because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013); very little vulnerability of dry forests, which may increase (Khatun et al. 2013); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in the tropics largely unknown, but there may be some

5.26. Golden-winged Warbler
(Vermivora chrysoptera)

photo by A Reago

USFWS Region 3 status: conservation concern
AOU number: 6420
AOU abbreviation: GWWA

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.8	**3.7**	**3.2**	**2.4**	**2.0**	**3.8**	**1.7**	**2.7**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Golden-winged Warbler was moderate, scoring 2.8 out of 5.0. The adaptive capacity category was the largest contributor, which was driven by a high degree of breeding site fidelity and highly specialized habitat needs during the breeding season. We had no information on non-breeding diet, however, and this limited our ability to assess both the adaptive capacity and indirect effects categories. More data are needed for a comprehensive understanding of Golden-winged Warbler vulnerability, and winter research should be a priority. Similar to the Blue-winged Warbler, this species has very specific requirements for shrubby forest edges, but this habitat is not expected to be especially vulnerable under climate change. This helped to lower their subscore for the indirect effects category and for total vulnerability. Nevertheless, climate change in the UMGL region during the breeding season had large effects on vulnerability—particularly temperature increases (Figure 5.73). Climate change throughout the non-breeding range had less of an effect (Figure 5.73). Therefore, climate change factors during the breeding season may be a priority for this species. We had little connectivity information on Golden-winged Warblers from banding data and no breeding to non-breeding encounters from the UMGL (Figure 5.74). We also found no information on migratory connectivity in the literature. For this reason, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species.

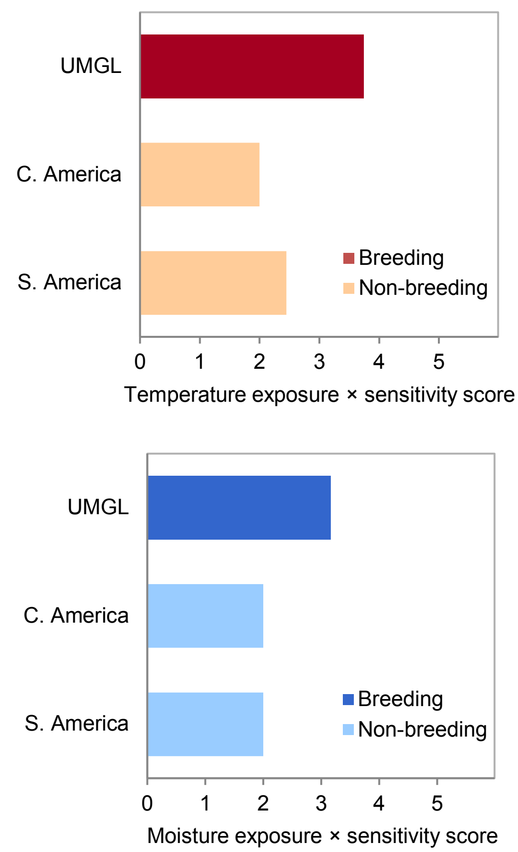


Figure 5.73. Golden-winged Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

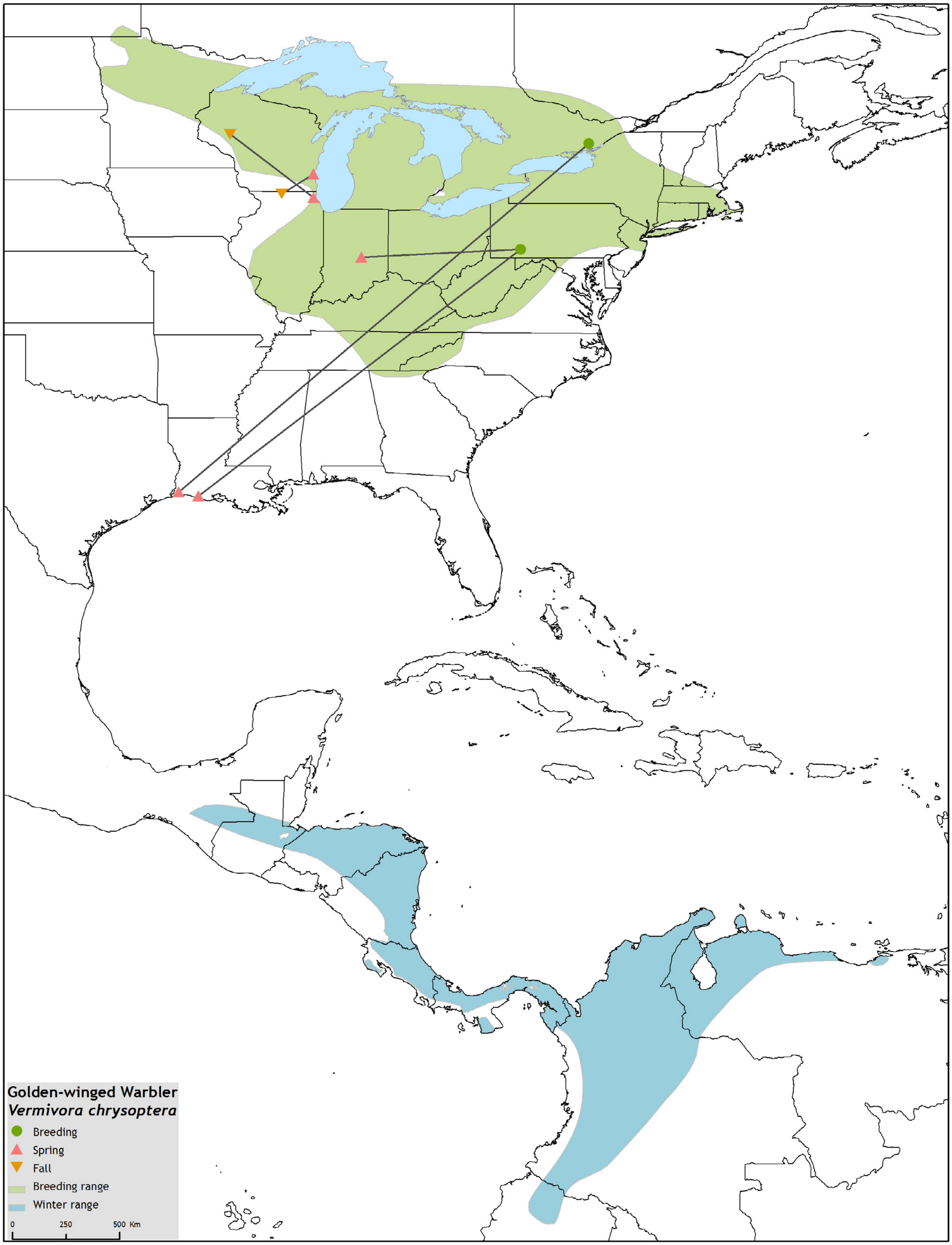


Figure 5.74. Golden-winged Warbler banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

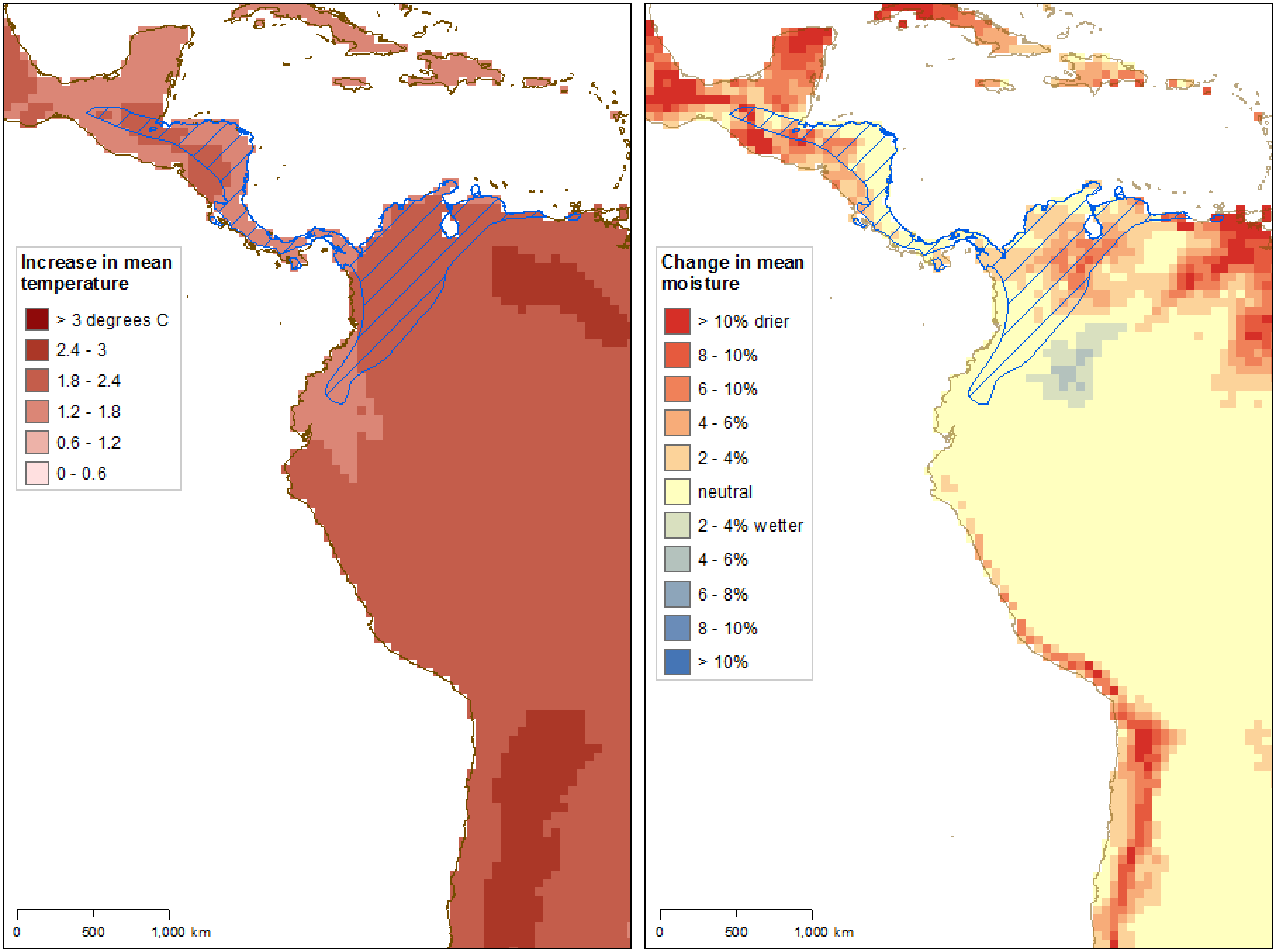


Figure 5.75. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Golden-winged Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

GOLDEN-WINGED WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 3.0) breeding = 1,392,211 km2; non-breeding = 944,931 km2
• PIF threats	(score = 4.0): breeding score = 4.0; non-breeding score = 3.0
• Breeding PIF conservation	(score = 4.3)
• Non-breeding PIF conservation	(score = 3.8)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 3709 km)
• Breeding habitat niche specialization	(score = 4.5) Macro habitats shrub/early successional (including forest-edge); nesting micro habitat ground and low vegetation with dense cover (0 m high)
• Breeding diet niche specialization	(score = 3.5) Arthropods (especially Lepidoptera adults and larvae, spiders); captured by gleaning foliage in the forest sub-, mid-, and upper canopies
• Breeding site fidelity	(score = 5.0) High
• Non-breeding habitat niche specialization	(score = 3.0) Woodland, riparian, forest-dry/edge
• Non-breeding diet niche specialization	(score = unknown) No data available
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.5) 7.7° C
• Breeding precipitation range	(score = 5.0) 12 cm
• Non-breeding thermal range	(score = 2.0) 12.5° C
• Non-breeding precipitation range	(score = 4.0) 56 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.8% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 1.0) 2.8% drier C. America (score = 1.0) 2.7% drier S. America (score = 1.0) 2.9% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.0) Overall, shrublands may be moderately vulnerable as woodland habitat encroaches on them (USDA 2012, USFS 2013), however, there will also be more disturbance of forests, which may create openings for shrub habitat
• Breeding biotic interaction vulnerability	(score = 2.5) Vulnerability of arthropods in general is largely unknown, but there may be some vulnerability for native species (Chown et al. 2007); in addition, Golden-winged Warblers are somewhat particular in the types of arthropods they prefer, which might increase the vulnerability of their diet; small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warmer temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.5) Very little vulnerability of dry scrub forest as these habitats may increase in area (Khatun et al. 2013); vulnerability of tropical riparian habitat is unknown, however, it may be somewhat vulnerable due to drying effects of climate change
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.27. Blue-winged Warbler (*Vermivora cyanoptera*)

USFWS Region 3 status: conservation concern
AOU number: 6410
AOU abbreviation: BWWA

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.8	**4.0**	**3.2**	**2.8**	**2.8**	**3.8**	**1.3**	**2.4**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Blue-winged Warbler was moderate, scoring 2.8 out of 5.0. Temperature increases during the breeding season (exposure × sensitivity) and drying of Mexico during the non-breeding season (exposure × sensitivity) were the largest contributors. The adaptive capacity category was a close second, driven by a high degree of breeding site fidelity and highly specialized habitat needs during the breeding season. We had no information on non-breeding diet, however, which limited our ability to assess both adaptive capacity and indirect effects categories. More data are needed for a comprehensive understanding of Blue-winged Warbler vulnerability, and winter research should be a priority. Fortunately, although the warblers have very particular requirements for shrubby forest edges, this habitat is not expected to be especially vulnerable under climate change. This helped to lower their subscore for the indirect effects category and for total vulnerability. Nevertheless, climate-change categories out-scored background risk, suggesting that climate change may be a priority. Temperature increases on the UMGL breeding grounds were predicted to have very large effects on vulnerability as was drying on the Mexican and Caribbean non-breeding grounds, though less so for the Caribbean (Figure 5.76). As a result, Blue-winged Warblers had increased vulnerability throughout the year. We had very little connectivity information on Blue-winged Warblers from banding data, including just one breeding to non-breeding encounter originating from the UMGL (Figure 5.77). We also found no information on migratory connectivity from the literature. For this reason, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would greatly improve our understanding of vulnerability for the species.

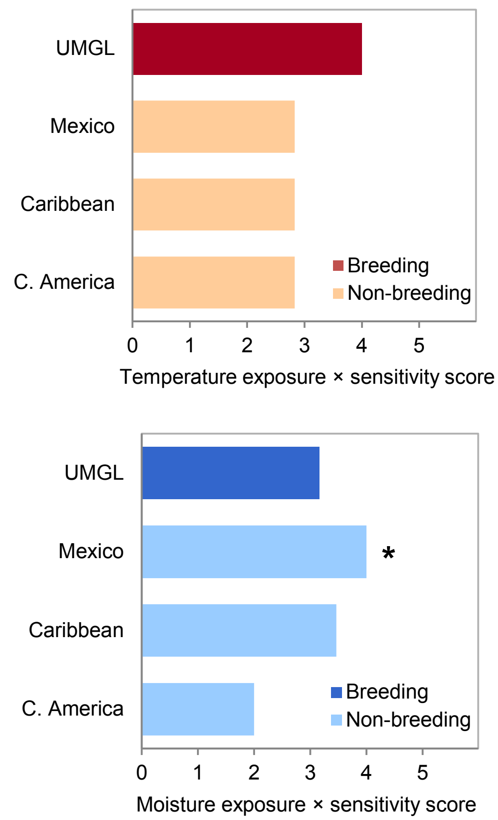


Figure 5.76. Blue-winged Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score 20% greater than breeding.

MIGRATORY CONNECTIVITY

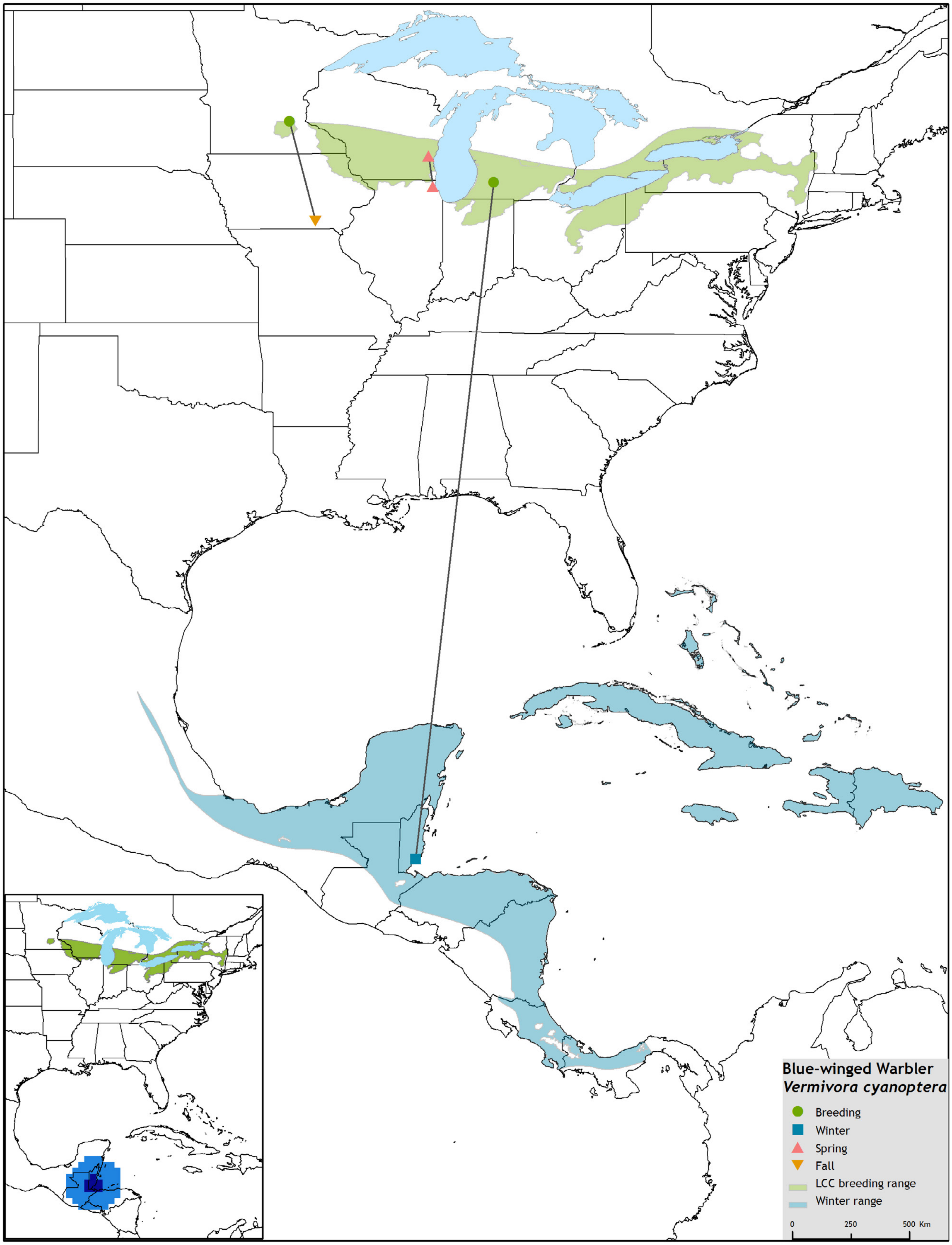


Figure 5.77. Blue-winged Warbler banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There was one breeding to stationary non-breeding encounter from the UMGL. Inset map shows concentrations of stationary non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

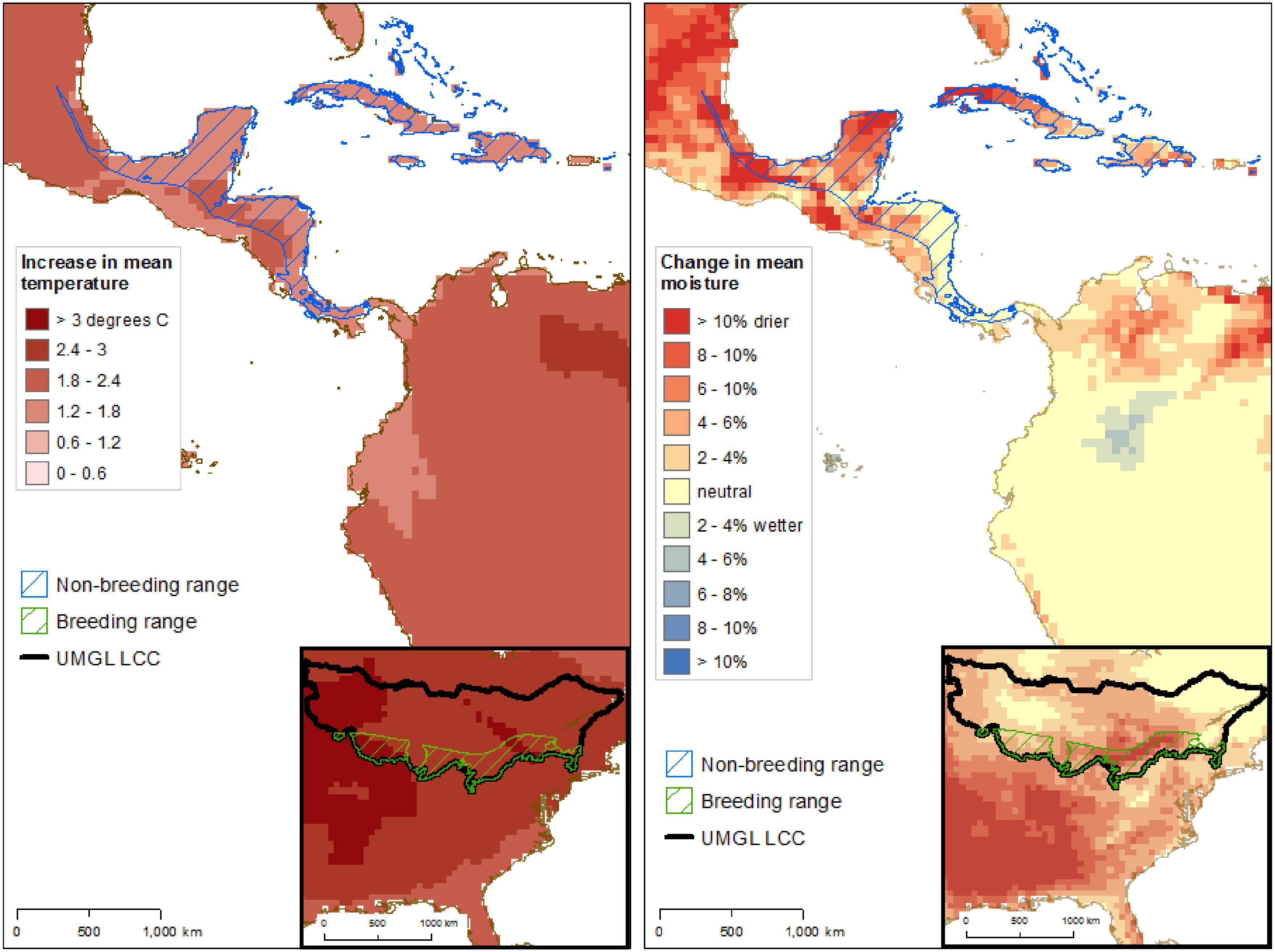


Figure 5.78. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Blue-winged Warbler’s non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

BLUE-WINGED WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 3.0) breeding = 1,782,709 km2; non-breeding = 758,936 km2
• PIF threats	(score = 3.1): breeding score = 3.1; non-breeding score = 3.0
• Breeding PIF conservation	(score = 3.8)
• Non-breeding PIF conservation	(score = 3.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 2365 km)
• Breeding habitat niche specialization	(score = 4.7) Macro habitats shrub (including forest-edge and old fields); nesting micro habitat shrubs and forest edge (0-0.5 m high)
• Breeding diet niche specialization	(score = 3.5) Arthropods; captured mostly by gleaning foliage (especially curled leaves) in the shrub and forest sub-canopy layer
• Breeding site fidelity	(score = 5.0) High (but few data)
• Non-breeding habitat niche specialization	(score = 3.0) Evergreen forest-evergreen (humid and semi-humid), semi-deciduous forest, forest scrub/edge
• Non-breeding diet niche specialization	(score = unknown) No data available
iii. Climate Sensitivity	
• Breeding thermal range	(score = 4.0) 7.0° C
• Breeding precipitation range	(score = 5.0) 12 cm
• Non-breeding thermal range	(score = 4.0) 4.4° C
• Non-breeding precipitation range	(score = 4.0) 44 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.8% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.7° C increase Mexico (score = 2.0) 1.7° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.7% drier Mexico (score = 4.0) 8.2% drier Caribbean (score = 3.0) 6.4% drier C. America (score = 1.0) 3.0% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.0) Overall, shrublands may be moderately vulnerable as woodland habitat encroaches on them (USDA 2012, USFS 2013), however, there will also be more disturbance of forests, which may create openings for shrub habitat
• Breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in general is largely unknown, but there may be some vulnerability for native species (Chown et al. 2007); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.0) Vulnerability of broadleaf tropical forest may depend on location and exact forest type—lowland forests may be stable partly because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013); very little vulnerability of dry scrub forest as these habitats may increase in area (Khatun et al. 2013)
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.28. Black-and-white Warbler
(*Mniotilta varia*)

USFWS Region 3 status: common
AOU number: 6360
AOU abbreviation: BAWW

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.5	**2.0**	**2.2**	**1.7**	**2.4**	**3.8**	**2.3**	**1.8**

(maximum score of 5 for all columns)

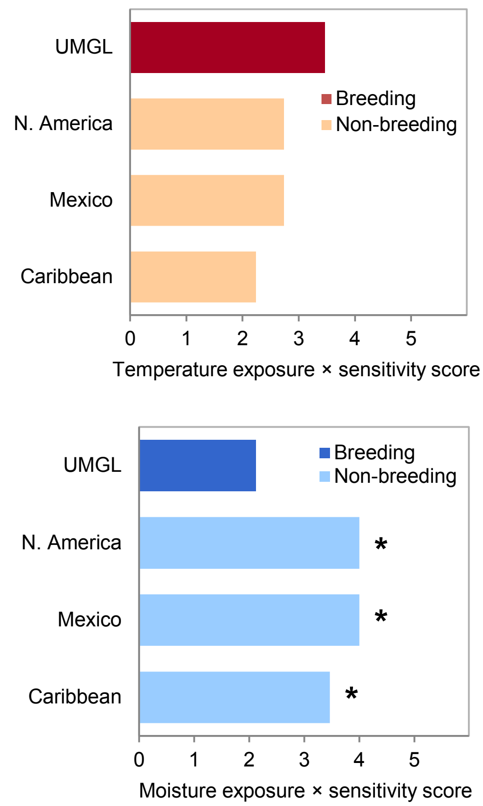


Figure 5.79. Black-and-white Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

SUMMARY

Total vulnerability for Black-and-white Warbler was moderate, scoring 2.5 out of 5.0. The adaptive capacity category was the largest contributor, which was driven by a combination of factors including, a supposed high degree of breeding site fidelity (though more research is needed on this subject), fairly specialized breeding habitat needs, and a fairly specialized breeding season diet. Unfortunately, we had no information on non-breeding diet, which limited our ability to assess both the adaptive capacity and indirect effects categories. More data are needed for a more comprehensive understanding of Black-and-white Warbler vulnerability, and winter research should be a priority. Drying in Mexico and the Caribbean during the non-breeding season was predicted to have large effects on vulnerability (Figure 5.79), more than on the UMGL breeding grounds. Temperature change was not predicted to have as great of an effect—neither on the UMGL breeding grounds nor the non-breeding grounds (Figure 5.79). This was primarily due to the warbler's insensitivity to temperature change, suggesting that winter moisture change may be a priority. We had very little connectivity information on Black-and-white Warblers from banding data, including just one breeding to non-breeding encounter originating from the UMGL (Figure 5.80). We also found limited information from the literature, which consisted of one study by Dugger et al. (2004) using stable isotopes. The study found that non-breeding populations from Puerto Rico breed in the eastern USA, but there was no information for the rest of the non-breeding range. For this reason, we were unable to exclude other non-breeding regions from our analysis and maintained a broad approach. More work on migratory connectivity is needed to fill in the gaps for other regions (both non-breeding and breeding). Such research would improve our understanding of vulnerability for the species and target management priorities.

MIGRATORY CONNECTIVITY

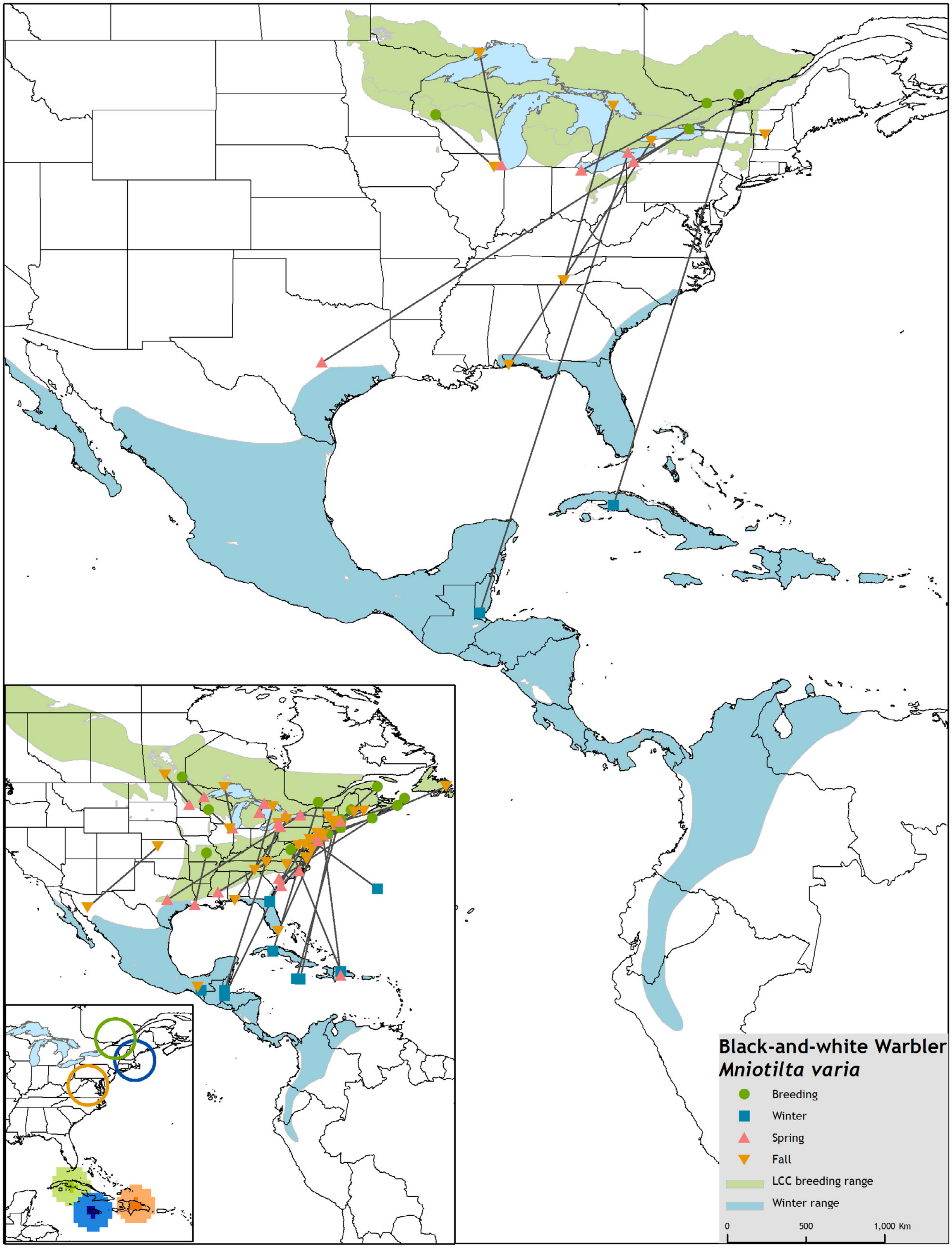


Figure 5.80. Black-and-white Warbler banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green on the main map. There was one breeding to stationary non-breeding encounter from the UMGL. Inset maps show data from the entire breeding range and concentrations of stationary non-breeding encounters originating from three different breeding regions.

CLIMATE EXPOSURE

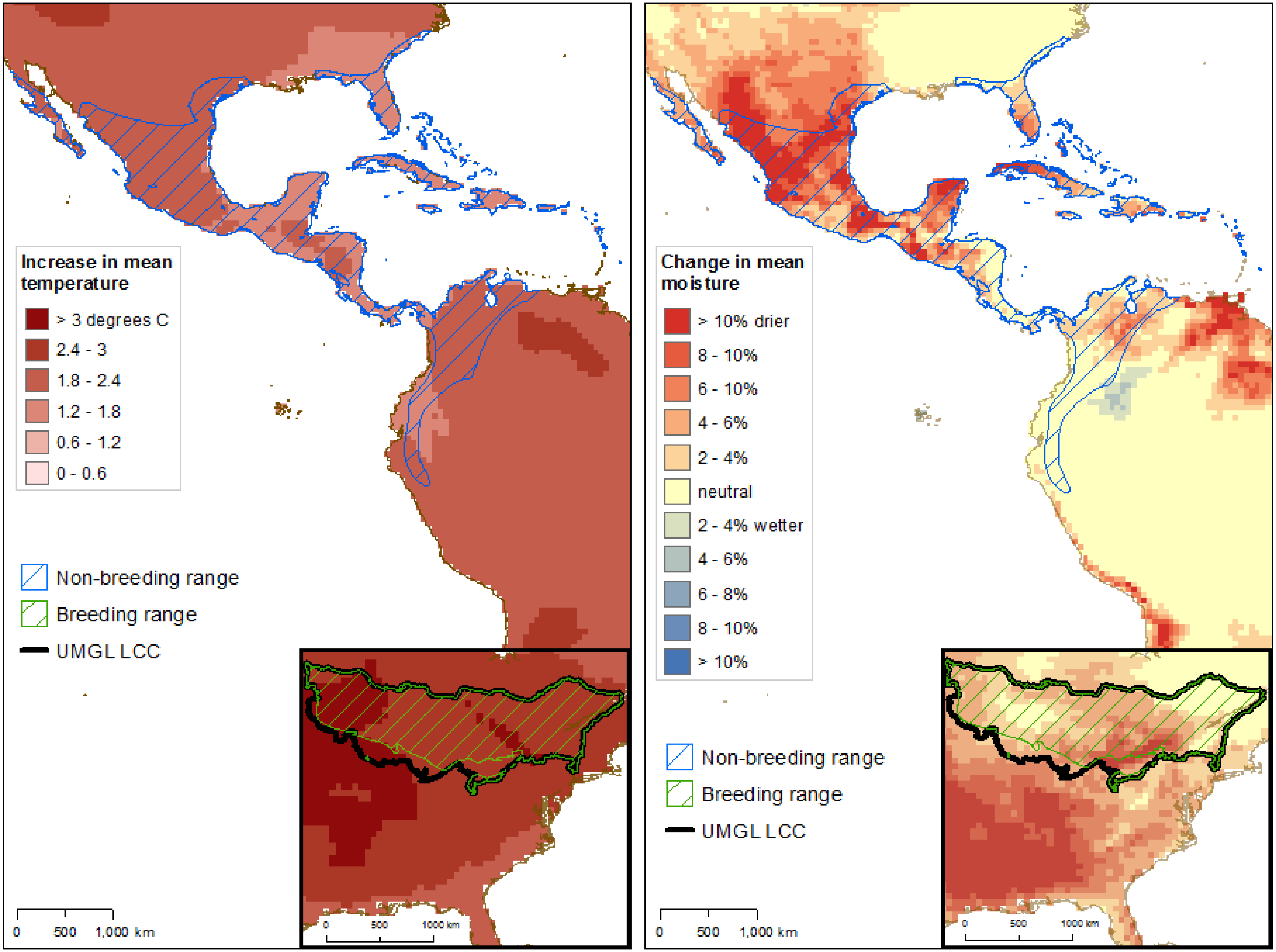


Figure 5.81. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Black-and-white Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

BLACK-AND-WHITE WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 5,369,441 km2; non-breeding = 3,243,152 km2
• PIF threats	(score = 2.5): breeding score = 2.5; non-breeding score = 2.0
• Breeding PIF conservation	(score = 2.8)
• Non-breeding PIF conservation	(score = 2.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Short-distance and long-distance migrant (mean distance = 3795 km)
• Breeding habitat niche specialization	(score = 4.2) Macro habitats deciduous and mixed forest, boreal forest (mature and second-growth); nesting micro habitat on ground at the base of a tree (0 m high)
• Breeding diet niche specialization	(score = 3.9) Arthropods; captured by gleaning tree bark
• Breeding site fidelity	(score = 5.0) Uncertain but may be high
• Non-breeding habitat niche specialization	(score = 3.0) Mature forest, dry second-growth forest, urban gardens
• Non-breeding diet niche specialization	(score = unknown) No data
iii. Climate Sensitivity	
• Breeding thermal range	(score = 1.0) 17.0° C
• Breeding precipitation range	(score = 5.0) 26 cm
• Non-breeding thermal range	(score = 1.0) 17.6° C
• Non-breeding precipitation range	(score = 3.0) 73 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 3.9% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase N. America (score = 2.0) 1.8° C increase Mexico (score = 3.0) 1.9° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.7% drier N. America (score = 2.0) 4.8% drier Mexico (score = 4.0) 8.4% drier Caribbean (score = 3.0) 6.3% drier C. America (score = 1.0) 3.7% drier S. America (score = 1.0) 2.3% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.0) Some vulnerability of deciduous, mixed forest, chiefly in south USA (in north may expand; USFS 2013); high vulnerability of boreal forest due to fire, pests, hardwood succession (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce & Rehfeldt 2013, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 2.8) Vulnerability of arthropods largely unknown, but there may be some for native species (Chown et al. 2007); small mammalian nest predators may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.2) Vulnerability of primary tropical forest may depend on location and forest type—stable in most areas due to high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013), but Brazil and eastern Amazon exception (Freeley et al. 2010, Gonzalez et al. 2010); very little vulnerability of dry scrub forest, which may increase (Khatun et al. 2013); no vulnerability of urban areas
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.29. Tennessee Warbler
(Oreothlypis peregrina)

USFWS Region 3 status: common
AOU number: 6470
AOU abbreviation: TEWA

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.8	**2.8**	**2.2**	**2.4**	**2.4**	**3.5**	**2.0**	**3.1**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Tennessee Warbler was moderate, scoring 2.8 out of 5.0. The adaptive capacity category was the largest contributor, which was driven by highly specialized habitat and diet needs during the breeding season and a fairly long distance migration. In addition to decreasing its flexibility, the warbler's specialization on boreal forest during the breeding season was compounded by a very high vulnerability of boreal habitat under climate change. However, the Tennessee Warbler's preferred diet during the breeding season is spruce budworms (they can experience population growth during good budworm years), and bud worms are expected to increase under climate change due to more mild winters. Thus, Tennessee Warbler vulnerability to climate change was complicated, and the subscore for the indirect effects category was balanced by these two factors. It remains unknown whether one aspect will be more important than the other. Temperature increases on the UMGL breeding grounds were predicted to have a moderate effect on vulnerability, while drying on the Mexican and Caribbean non-breeding grounds was predicted to have a larger effect (Figure 5.82). The background risk category also had a high subscore, suggesting that factors unrelated to climate change are also important for this species. We had very little connectivity information on Tennessee Warblers from banding data and no breeding to non-breeding encounters from the UMGL (Figure 5.83). We also found no information on migratory connectivity in the literature. For this reason, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species by allowing us to focus our analysis on the most appropriate non-breeding regions.

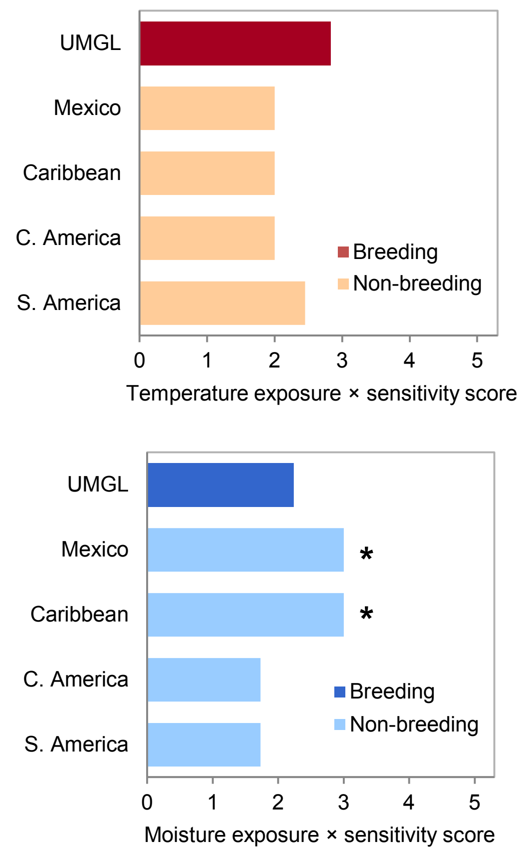


Figure 5.82. Tennessee Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score 20% greater than breeding.

MIGRATORY CONNECTIVITY

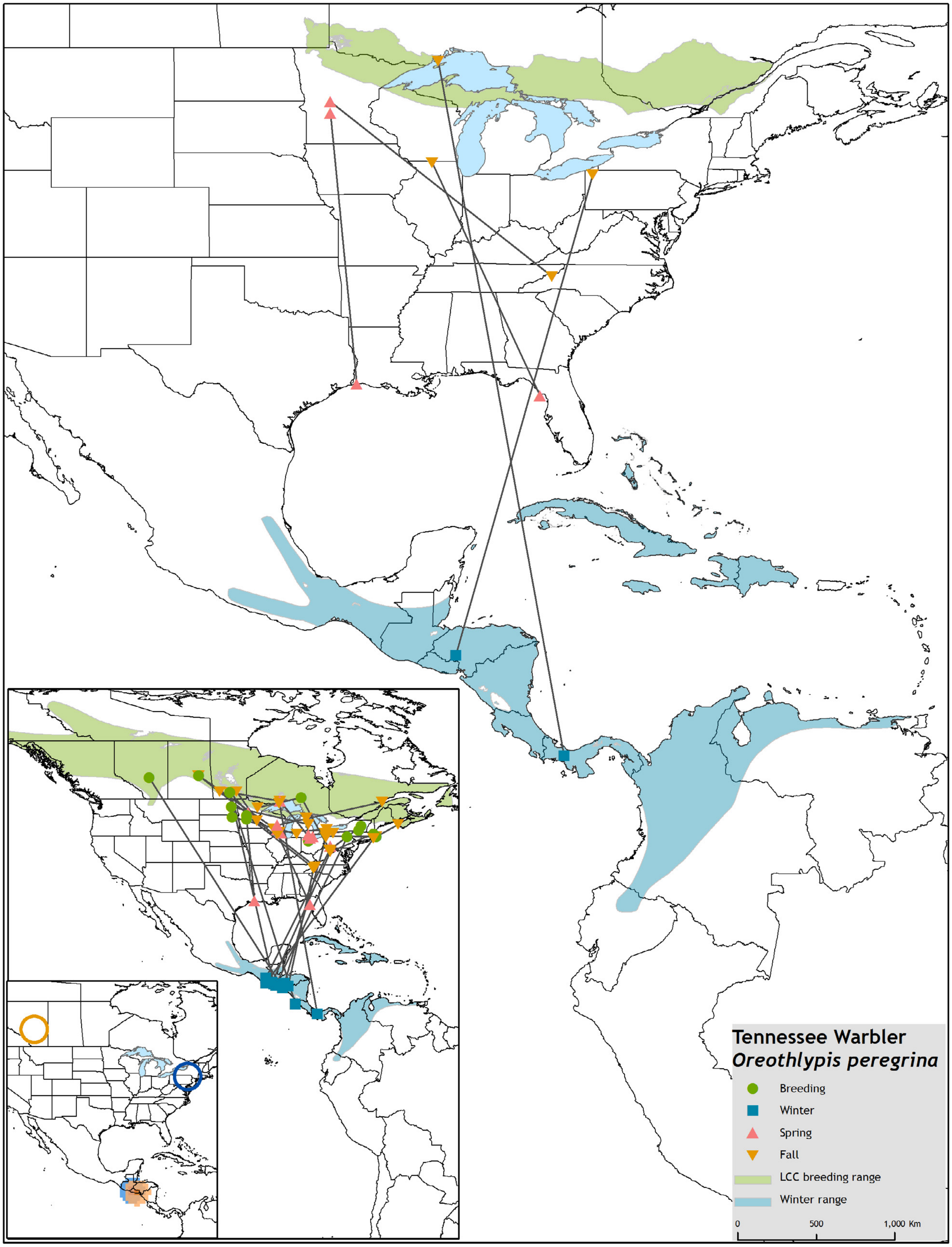


Figure 5.83. Tennessee Warbler banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green on the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Inset map shows data from the entire breeding range and concentrations of stationary non-breeding encounters originating from two different breeding regions.

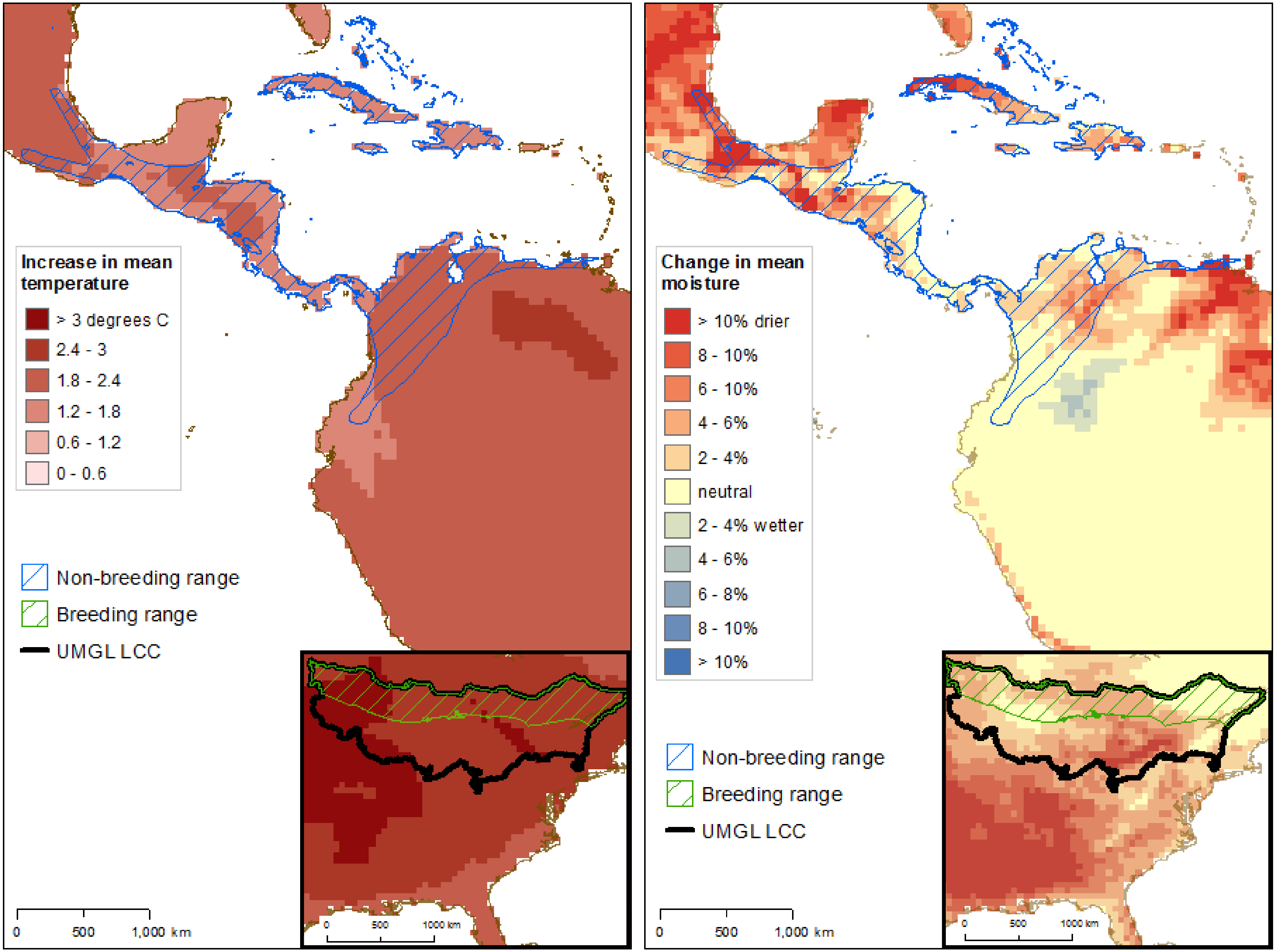


Figure 5.84. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Tennessee Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

TENNESSEE WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 5.0) 1.00 probability (95% CI = 1.00, 1.00)
• Range size	(score = 2.0) breeding = 4,755,556 km2; non-breeding = 1,559,936 km2
• PIF threats	(score = 2.3): breeding score = 2.3; non-breeding score = 2.0
• Breeding PIF conservation	(score = 2.3)
• Non-breeding PIF conservation	(score = 2.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 4679 km)
• Breeding habitat niche specialization	(score = 4.5) Macro habitats boreal forest; nesting micro habitat ground and low vegetation with dense cover (0 m high)
• Breeding diet niche specialization	(score = 4.5) Arthropods (especially spruce budworm, and other insect larvae such as Lepidoptera); captured by gleaning foliage in the forest upper canopy
• Breeding site fidelity	(score = 3.0) Somewhat nomadic (populations fluctuate with budworm outbreaks)
• Non-breeding habitat niche specialization	(score = 2.0) Woodland, second-growth forest/edge, broadleaf forest, coffee agriculture
• Non-breeding diet niche specialization	(score = 3.2) Invertebrates, fruit, nectar (switches between large and small insects depending on availability)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 12.8° C
• Breeding precipitation range	(score = 5.0) 25 cm
• Non-breeding thermal range	(score = 2.0) 13.1° C
• Non-breeding precipitation range	(score = 3.0) 72 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.8° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 2.9% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase Mexico (score = 2.0) 1.8° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.2% drier Mexico (score = 3.0) 7.2% drier Caribbean (score = 3.0) 6.4% drier C. America (score = 1.0) 3.5% drier S. America (score = 1.0) 3.0% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.0) High vulnerability of boreal forest due to fire, pests, and hardwood succession (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in general is largely unknown, but spruce worms (the preferred diet of Tennessee Warblers) may increase in abundance due to more mild winters (USFS 2013); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warmer temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 0.8) Very little vulnerability of dry scrub forest as these habitats may increase in area (Khatun et al. 2013); vulnerability of broadleaf tropical forest may depend on location and exact forest type—lowland forests may be stable partly because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, and Huntingford et al. 2013); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 1.3) Vulnerability of arthropods in the tropics largely unknown, but there may be some; potential changes to abundance and phenology of fruit and nectar largely unknown but may be very little

5.30. Nashville Warbler
(Oreothlypis ruficapilla)

USFWS Region 3 status: common
AOU number: 6450
AOU abbreviation: NAWA

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.7	**3.5**	**2.1**	**2.7**	**4.0**	**3.7**	**2.1**	**2.1**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Nashville Warbler was moderate, scoring 2.7 out of 5.0. Drying of N. America and Mexico during the non-breeding season (exposure × sensitivity) was the largest contributor. The adaptive capacity category was also a large contributor to vulnerability, driven by a combination of characteristics including, a supposed high degree of breeding site fidelity (though more research is needed on this subject), fairly specialized breeding habitat needs, and a fairly specialized year round diet that is exclusive to insects. Indirect effects of climate change did not play as large of a role and helped to lower the total vulnerability score. In addition to drying of N. America and Mexico during the non-breeding season, drying on the Caribbean non-breeding grounds and temperature increases on the UMGL breeding grounds were also large factors increasing vulnerability (Figure 5.85). Thus, Nashville Warbler's were affected by climate change throughout the year and throughout their range. Background risk did not have a large effect on vulnerability, suggesting that climate change may be a priority for this species. We had very little connectivity information on Nashville Warblers from banding data, including no breeding to non-breeding encounters originating from the UMGL (Figure 5.86). There was also limited information in the literature, which consisted of one study by Lovette et al. (2004) on Nashville Warbler genetic structure. The study found that populations east of the Rocky Mountains migrate to Mexico. Although this work begins to narrow the range of possibility for UMGL populations, we were unable to exclude other non-breeding regions from our analysis and maintained a broad approach. More work on this topic would help our course understanding of migratory connectivity for the species and would greatly improve our understanding of vulnerability.

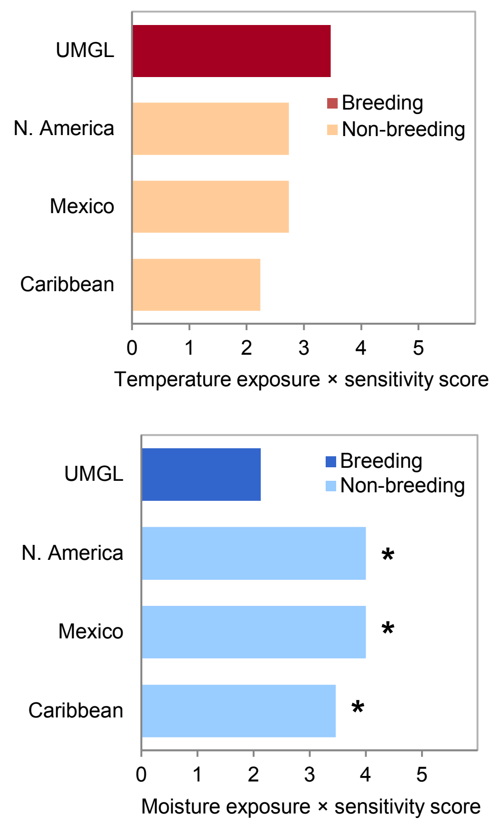


Figure 5.85. Nashville Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

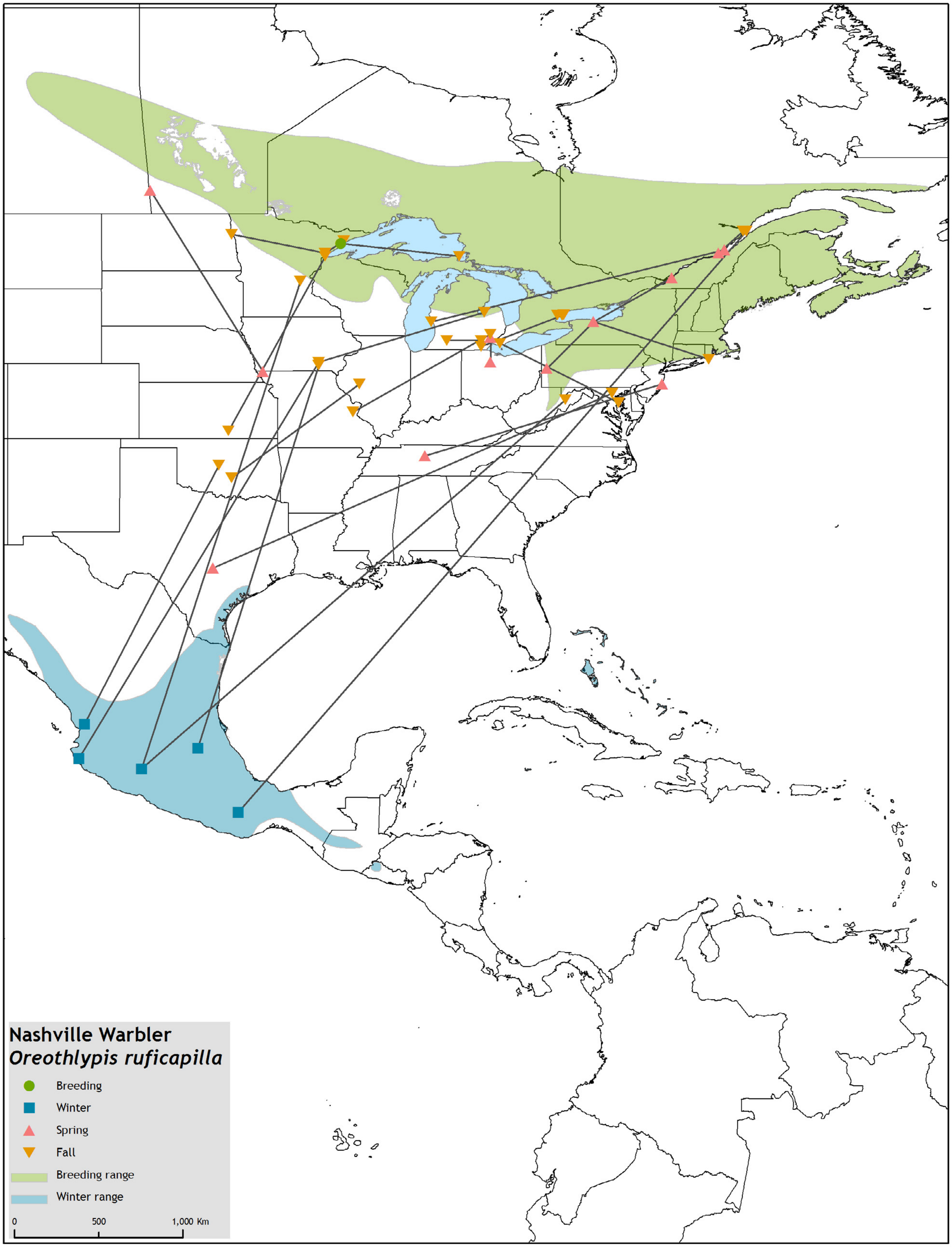


Figure 5.86. Nashville Warbler banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

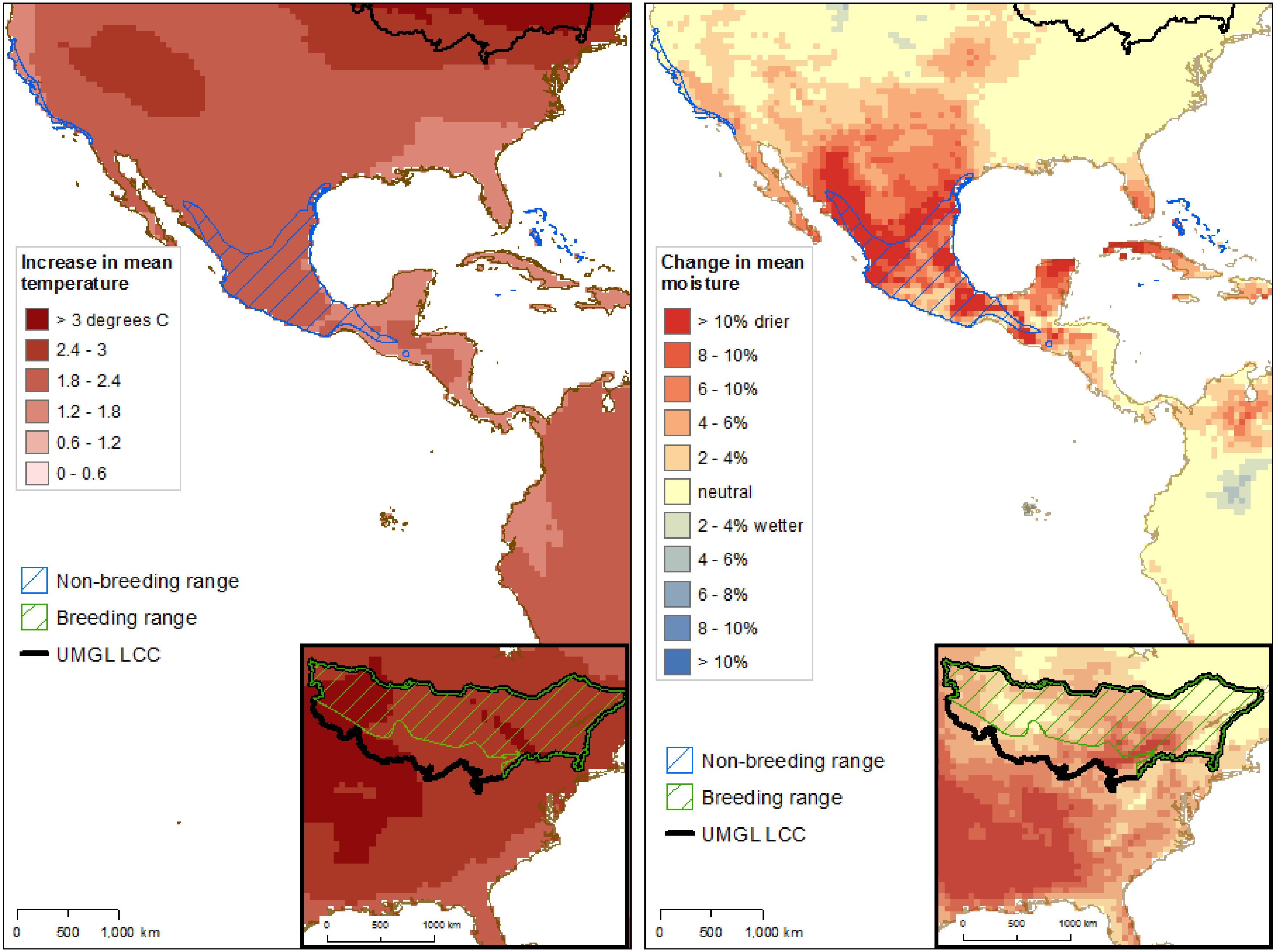


Figure 5.87. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Nashville Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

NASHVILLE WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 3.0) breeding = 2,763,151 km2; non-breeding = 921,874 km2
• PIF threats	(score = 2.3): breeding score = 2.3; non-breeding score = 2.0
• Breeding PIF conservation	(score = 2.9)
• Non-breeding PIF conservation	(score = 2.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Short-distance and long-distance migrant (mean distance = 2064 km)
• Breeding habitat niche specialization	(score = 3.9) Macro habitats second-growth woodland, deciduous and mixed woodland, boreal forest; nesting micro habitat ground (near forest edge with dense vegetation) (0 m high)
• Breeding diet niche specialization	(score = 3.7) Entirely insectivorous (adults and larvae); captured by gleaning foliage in the forest mid- and upper canopies
• Breeding site fidelity	(score = 5.0) No data available, but assumed to return to same territories year after year
• Non-breeding habitat niche specialization	(score = 3.0) Deciduous woodland (including tropical deciduous and second growth), urban gardens, cloud forest
• Non-breeding diet niche specialization	(score = 3.7) Insects (breadth of species not known)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.0) 9.8° C
• Breeding precipitation range	(score = 4.5) 31 cm
• Non-breeding thermal range	(score = 2.5) 12.3° C
• Non-breeding precipitation range	(score = 4.0) 33 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 3.6% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.0° C increase N. America (score = 3.0) 2.0° C increase Mexico (score = 3.0) 2.0° C increase Caribbean (score = 2.0) 1.6° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 4.0) 8.7% drier N. America (score = 4.0) 9.1% drier Mexico (score = 4.0) 8.9% drier Caribbean (score = 3.0) 6.0% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.0) Very little vulnerability of woodlands, which are predicted to either remain stable or increase in area (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); high vulnerability of boreal forest due to fire, pests, and succession by hardwoods (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.0) Vulnerability of arthropods in general is largely unknown, but there may be some vulnerability for native species (Chown et al. 2007); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.3) Very little vulnerability of dry scrub forest as these habitats may increase in area (Khatun et al. 2013); montane cloud forests may be somewhat to highly vulnerable depending on location (e.g. Khatun et al. 2013); no vulnerability of urban areas
• Non-breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in the tropics is largely unknown, but there may be some

5.31. American Redstart
(*Setophaga ruticilla*)

USFWS Region 3 status: common
AOU number: 6870
AOU abbreviation: AMRE

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.3	**1.4**	**3.0**	**1.7**	**2.0**	**3.1**	**2.4**	**1.8**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for American Redstart was moderate, scoring 2.3 out of 5.0. The adaptive capacity category was the largest contributor, mostly driven by a high degree of breeding site fidelity. Drying on the UMGL breeding grounds was the second largest contributor and had a large effect on vulnerability (Figure 5.88). This was because American Redstarts are particularly sensitive to moisture changes during summer months. Moisture change during the non-breeding season had less effect, primarily because redstarts appear to be less sensitive during winter months. They are also less sensitive to temperature change during both summer and winter and temperature increases had little effect on vulnerability throughout the year. The background risk subscore was low, suggesting that climate change may be a priority for American Redstarts. We had very little connectivity information from on American Redstarts from banding data (Figure 5.89), including no breeding to non-breeding encounters originating from the UMGL. However, stable isotope research suggests weak connectivity between the UMGL and Mexico, Caribbean, and C. America: breeding populations from the Midwest (including the UMGL region) wintered in Mexico (32%), the Caribbean (29%), and C. America (38%), while breeding populations from the northeast (also including UMGL) wintered in the Caribbean (84%) and C. America (16%; Norris et al. 2006). We found no evidence indicating redstarts winter in S. America, and we excluded it from our analyses. Thus, we focused on Mexico, the Caribbean, and C. America. More research on migratory connectivity will help to corroborate and fine tune these data. As we continue to fill knowledge gaps, we can increase our understanding of conservation priorities and enact more comprehensive management strategies.

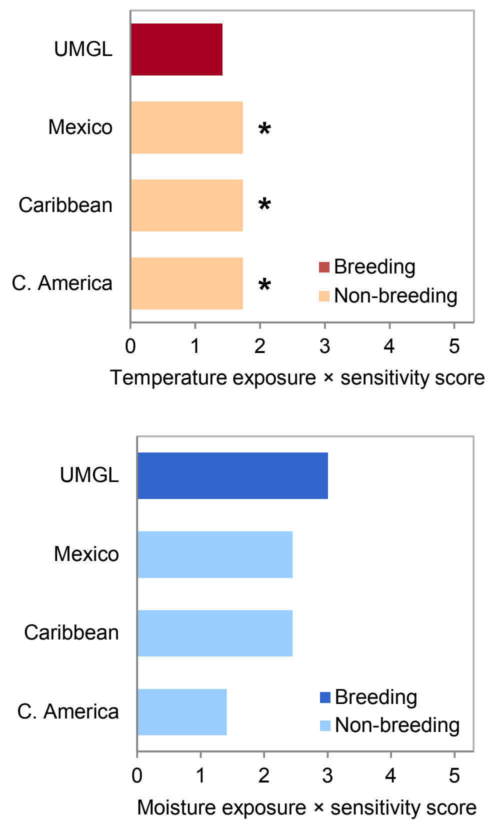


Figure 5.88. American Redstart subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

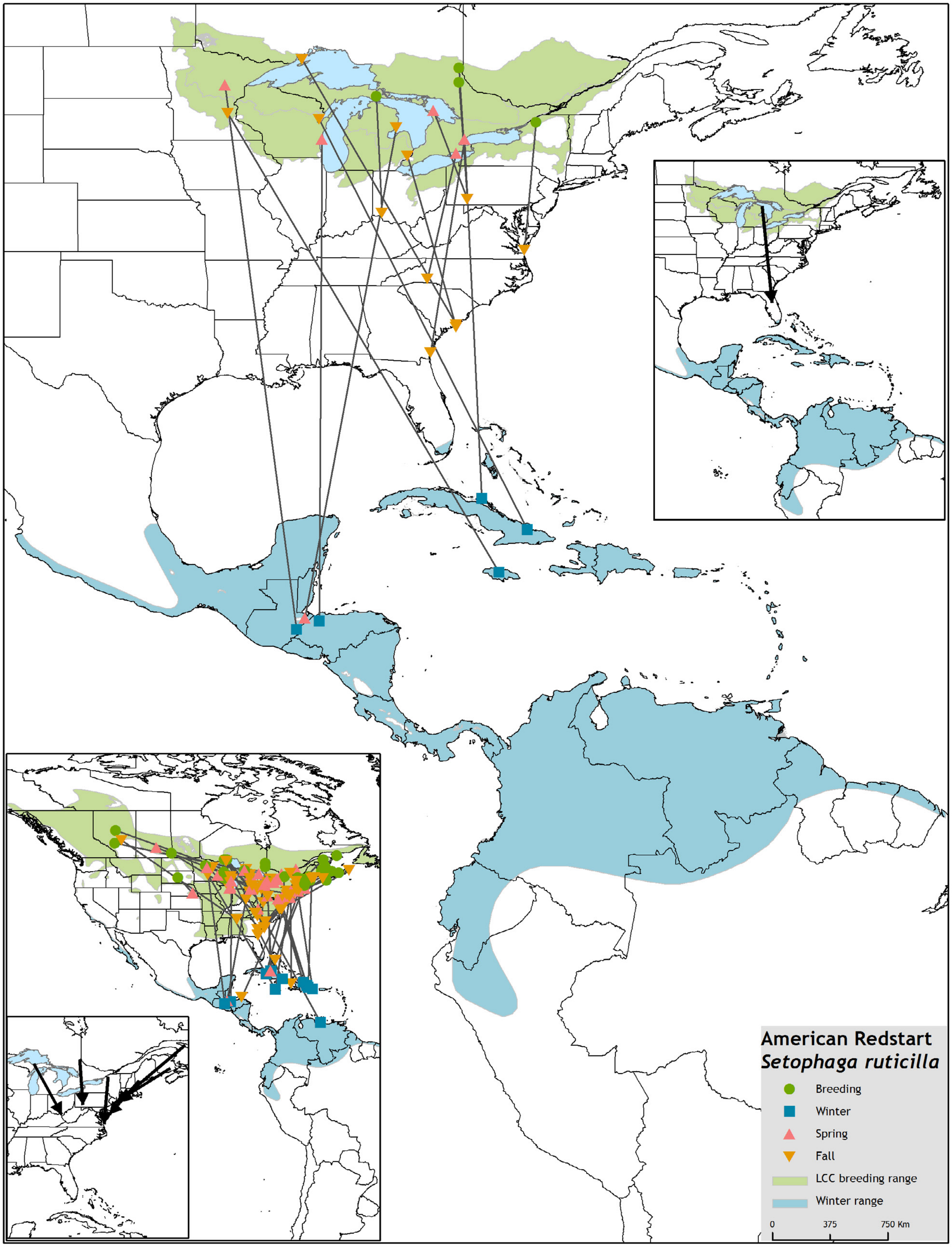


Figure 5.89. American Redstart banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green on the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Upper right inset map shows migration trajectory for UMGL populations. Bottom left inset maps show data and migration trajectories from the entire breeding range.

CLIMATE EXPOSURE

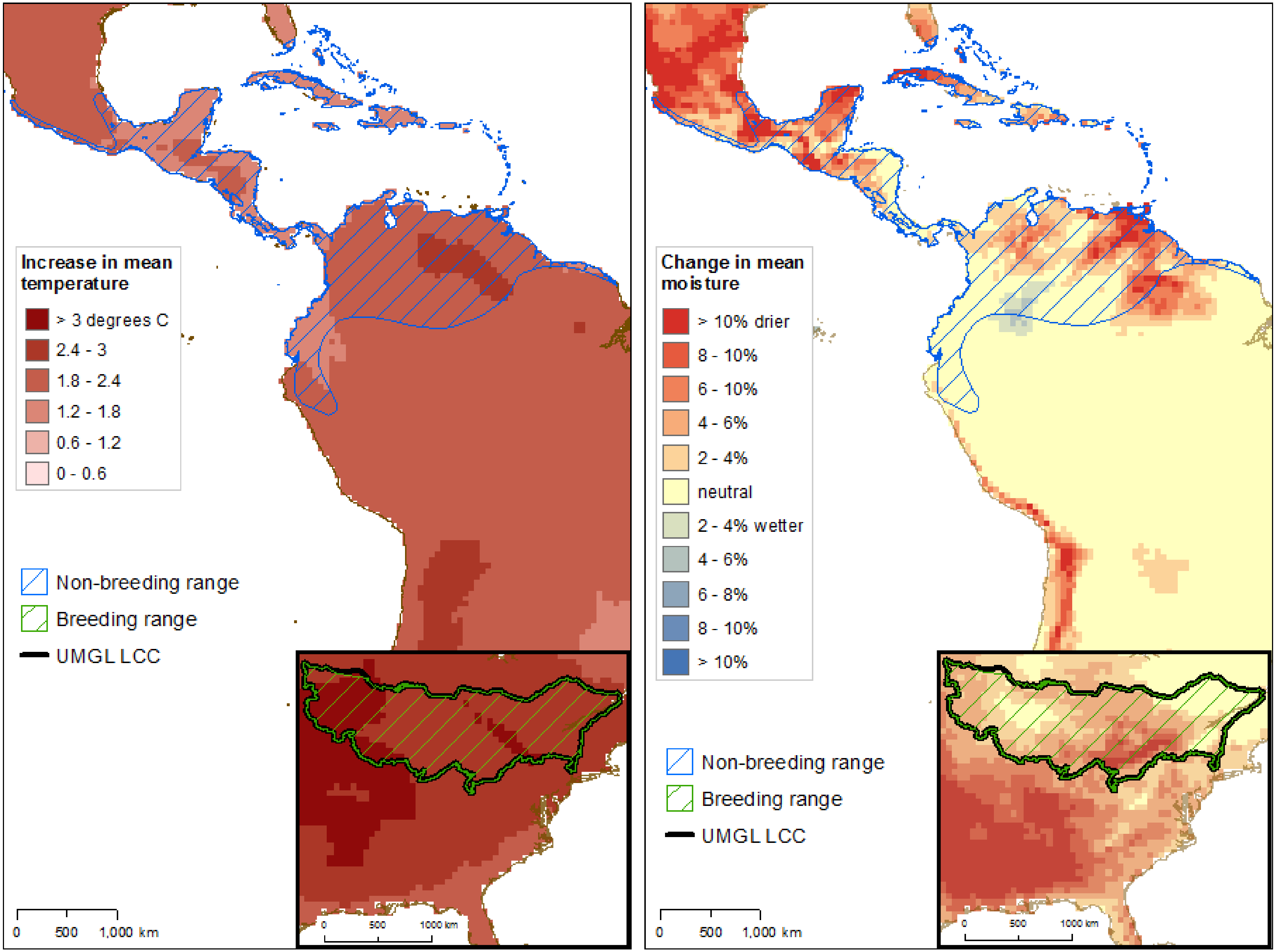


Figure 5.90. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the American Redstart's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

AMERICAN REDSTART DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 6,655,743 km2; non-breeding = 3,705,496 km2
• PIF threats	(score = 2.3): breeding score = 2.3; non-breeding score = 2.0
• Breeding PIF conservation	(score = 2.9)
• Non-breeding PIF conservation	(score = 2.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 3688 km)
• Breeding habitat niche specialization	(score = 2.5) Macro habitats deciduous forest, coniferous forest, boreal forest, second-growth forest; nesting micro habitat trees (especially deciduous, 3-6 m high)
• Breeding diet niche specialization	(score = 2.4) Arthropods; captured by hover gleaning near the ground and in the forest sub-, mid-, and upper canopy layers
• Breeding site fidelity	(score = 5.0) High (site fidelity of banded birds in summer is strong)
• Non-breeding habitat niche specialization	(score = 3.0) Primary forest (including mangroves), secondary scrub forest, coffee and citrus agriculture (low-mid elevation)
• Non-breeding diet niche specialization	(score = 2.4) Insects with considerable flexibility within the order
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0.5) 20.3° C
• Breeding precipitation range	(score = 4.5) 31 cm
• Non-breeding thermal range	(score = 1.5) 16.1° C
• Non-breeding precipitation range	(score = 2.0) 95 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.0% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.7° C increase Mexico (score = 2.0) 1.7° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.5% drier Mexico (score = 3.0) 7.3% drier Caribbean (score = 3.0) 6.4% drier C. America (score = 1.0) 3.7% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.8) Some vulnerability of deciduous forest, particularly in southern USA, though northern forests may expand (USFS 2013); high vulnerability of coniferous forest (both southern USA and boreal) due to fire, pests, and hardwood succession (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.0) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.7) Vulnerability of primary tropical forest may depend on location and forest type—stable in most areas because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013); mangrove forests very highly vulnerable due to sea level rise and of storm surges (Gilman et al. 2008); very little vulnerability of second-growth and dry scrub forest, which may increase in area (Khatun et al. 2013); zero vulnerability of agricultural or urban areas
• Non-breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in the tropics largely unknown, but there may be some

5.32. Cerulean Warbler
(Setophaga cerulea)

USFWS Region 3 status: conservation concern
AOU number: 6580
AOU abbreviation: CERW

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.9	**4.0**	**3.2**	**2.4**	**0**	**4.0**	**2.3**	**2.8**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Cerulean Warbler was moderate, scoring 2.9 out of 5.0. The adaptive capacity category was one of the largest contributors, which was driven by a combination of factors including, a high degree of breeding site fidelity, very highly specialized habitat needs during the non-breeding season, and a fairly long distance migration. The Cerulean Warbler's use of large mature forests was compounded by the vulnerability of this habitat to disturbance due to climate change, contributing to the indirect effects subscore. However, other factors (e.g. low vulnerability for temperate deciduous forest in general and for tropical humid forests) ultimately helped to reduce the indirect effects subscore. Unfortunately, we had no information on non-breeding diet, which limited our ability to assess both the adaptive capacity and indirect effects categories. More data are needed for a more comprehensive understanding of Cerulean Warbler vulnerability, and winter research should be a priority. Temperature increases and drying on the UMGL breeding grounds were other big contributors to the overall vulnerability score (Figure 5.91), partly because Cerulean Warblers are particularly sensitivity to climate change during this time of year. Climate changes on the non-breeding grounds had less effect on vulnerability. We had very little connectivity information on Cerulean Warblers from banding data, including no breeding to non-breeding encounters originating from the UMGL (Figure 5.92). However, stable isotope research from Jones et al. (2008) suggests weak connectivity between parts of the UMGL region (namely, southern Ontario) and both northern and southern portions of the non-breeding range. Although other locations in the UMGL region were not investigated, it appears that the entire non-breeding range is used by at least one Cerulean Warbler population in the UMGL. More research on migratory connectivity will continue to fill in the gaps and complete our understanding for populations from other areas.

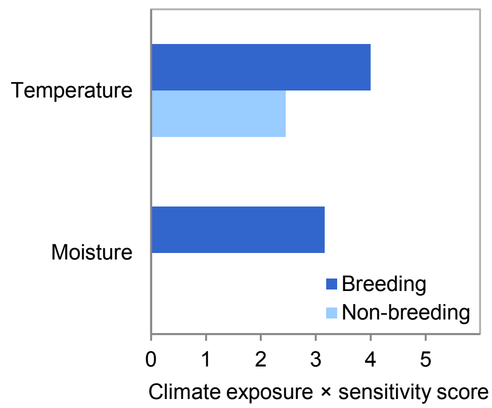


Figure 5.91. Cerulean Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

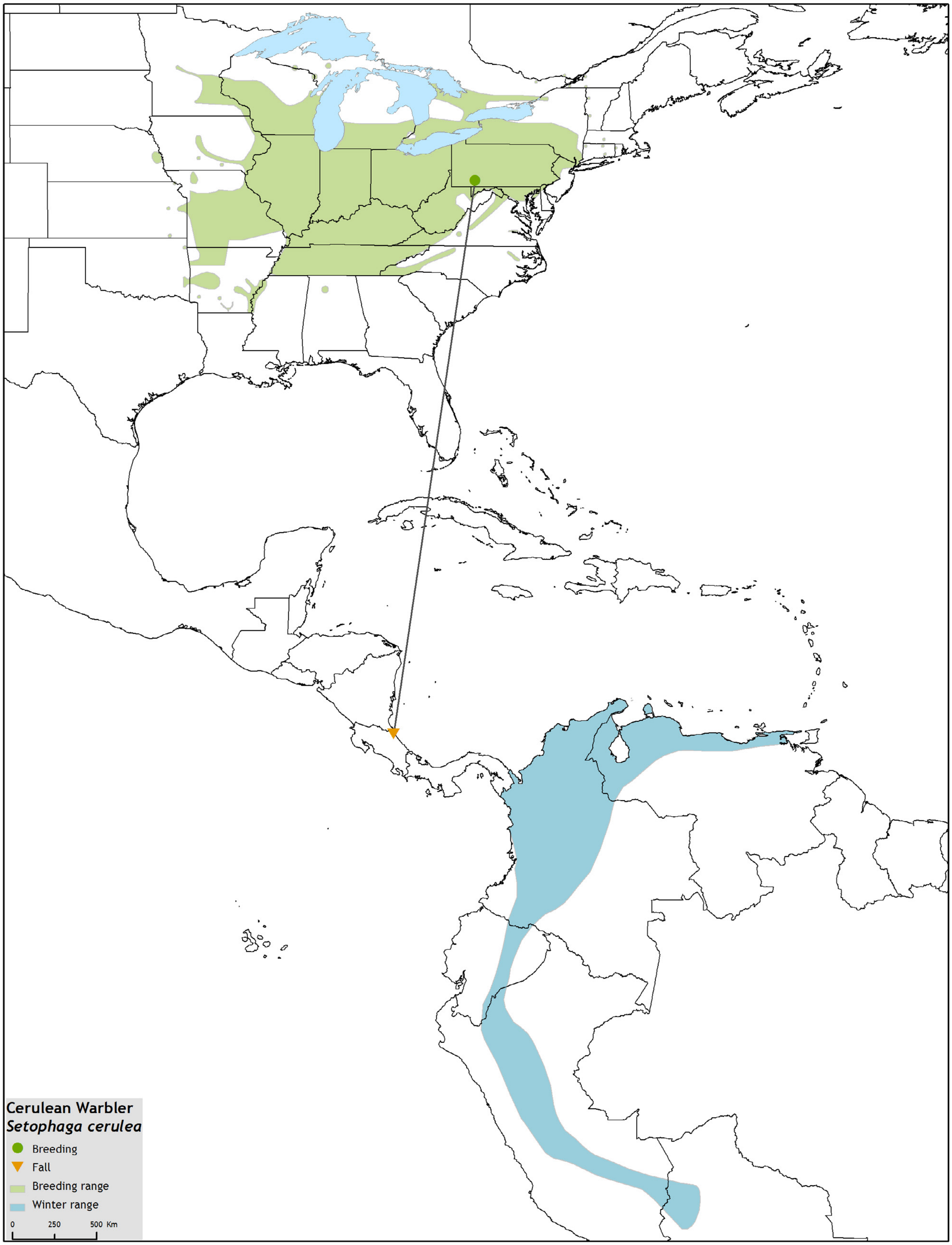


Figure 5.92. Cerulean Warbler banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

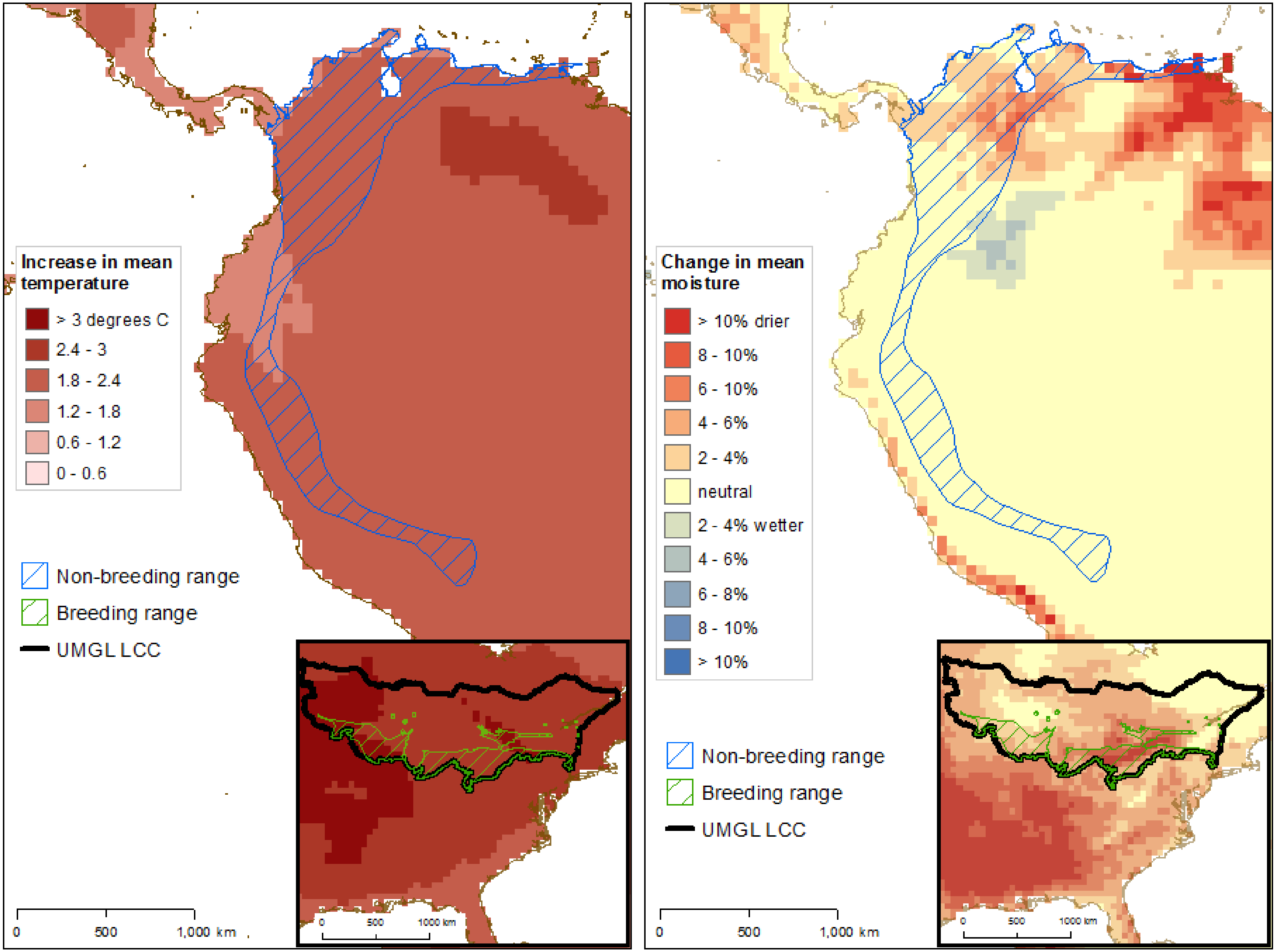


Figure 5.93. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Cerulean Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

CERULEAN WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 3.0) breeding = 1,234,266 km2; non-breeding = 971,392 km2
• PIF threats	(score = 4.3): breeding score = 4.3; non-breeding score = 4.0
• Breeding PIF conservation	(score = 3.6)
• Non-breeding PIF conservation	(score = 3.8)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 4601 km)
• Breeding habitat niche specialization	(score = 3.5) Macro habitats deciduous forest (mature and large, but may also use second-growth forest); nesting micro habitat tree mid-canopy to canopy (9-18 m high)
• Breeding diet niche specialization	(score = 3.5) Arthropods; captured by gleaning foliage in the forest mid- and upper canopies
• Breeding site fidelity	(score = 5.0) High (evidence of high fidelity but sample sizes are small)
• Non-breeding habitat niche specialization	(score = 5.0) Broadleaf/evergreen forest (though it's possible they may use some woodland habitat also)
• Non-breeding diet niche specialization	(score = unknown) No data
iii. Climate Sensitivity	
• Breeding thermal range	(score = 4.0) 7.0° C
• Breeding precipitation range	(score = 5.0) 10 cm
• Non-breeding thermal range	(score = 2.0) 14.5° C
• Non-breeding precipitation range	(score = 2.5) 88 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.7% drier
• Winter (Dec – Feb) non-breeding temperature	S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	S. America (score = 0) 2.0% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.0) Some vulnerability of deciduous forest, particularly in the southeastern USA, though northern forests may expand range (USFS 2013); coverage of large mature forest expected to decrease overall due to increased fire and pests while second-growth forests will increase (USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.0) Vulnerability of arthropods in general is largely unknown, but there may be some for native species (Chown et al. 2007); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.0) Vulnerability of broadleaf tropical forest may depend on location and forest type—lowland forests may be stable because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013); very little vulnerability of woodlands and dry scrub forest, which may increase in area (Khatun et al. 2013); no vulnerability of urban areas
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.33. Yellow Warbler *(Setophaga petechia)*

USFWS Region 3 status: common
AOU number: 6520
AOU abbreviation: YEWA

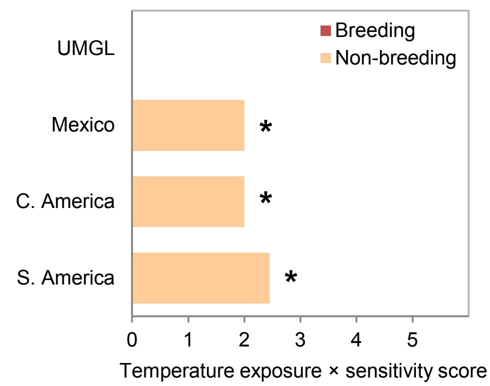
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.2	**0**	**2.4**	**2.4**	**1.6**	**3.0**	**2.7**	**1.5**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Yellow Warbler was moderate, scoring 2.2 out of 5.0. Drying on the Mexican non-breeding grounds (exposure × sensitivity) was the largest contributor. The adaptive capacity category also had a high score, which was driven by a high degree of breeding site fidelity and a fairly specialized breeding season diet. Unfortunately, we had no information on non-breeding diet, which limited our ability to assess both the adaptive capacity and indirect effects categories. More data are needed for a more comprehensive understanding of Yellow Warbler vulnerability, and winter research should be a priority. Temperature increases on the UMGL breeding grounds was not expected to have an effect on vulnerability (Figure 5.94), mostly because Yellow Warblers were not particularly sensitive to temperature change during the summer. They were sensitive, however, to temperature change during the rest of the year and to moisture changes throughout the year. Background risk had a low score, suggesting that climate change factors may be a priority for this species. We had very little connectivity information on Yellow Warblers from banding data, including no breeding to non-breeding encounters originating from the UMGL (Figure 5.95). However, stable isotope research from Boulet et al. (2006) suggests weak connectivity between the UMGL and most of the non-breeding range: breeding populations from the northeastern USA (including the UMGL region) winter in Venezuela (64%), Panama (15%), and the Yucatan (21%). We found no evidence indicating that birds winter in the Caribbean or western Mexico, and we excluded those regions from our analyses. We focused on the Gulf of Mexico (including the Yucatan Peninsula), C. America, and S. America. More research on migratory connectivity will help to corroborate these data and fill in gaps to complete our understanding of year-round conservation priorities.



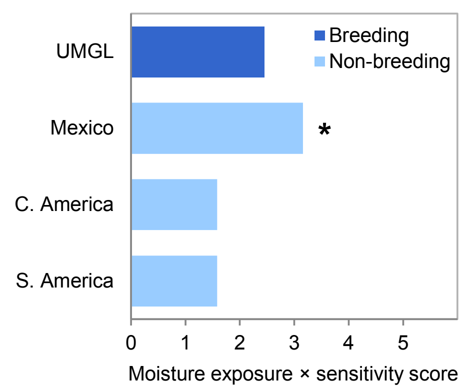


Figure 5.94. Yellow Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

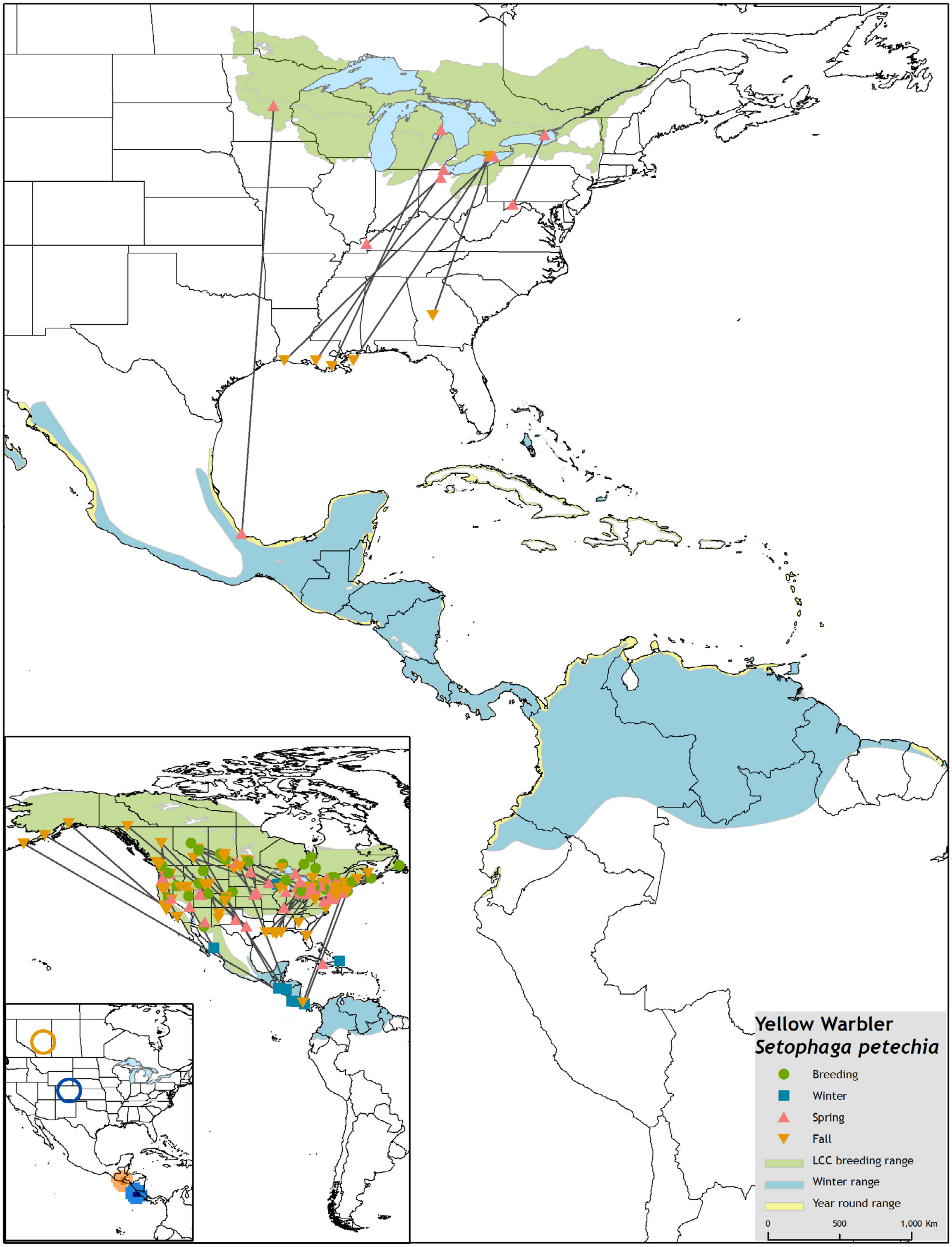


Figure 5.95. Yellow Warbler banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Inset maps show data from the entire breeding range and concentrations of stationary non-banding encounters originating from two different breeding regions.

CLIMATE EXPOSURE

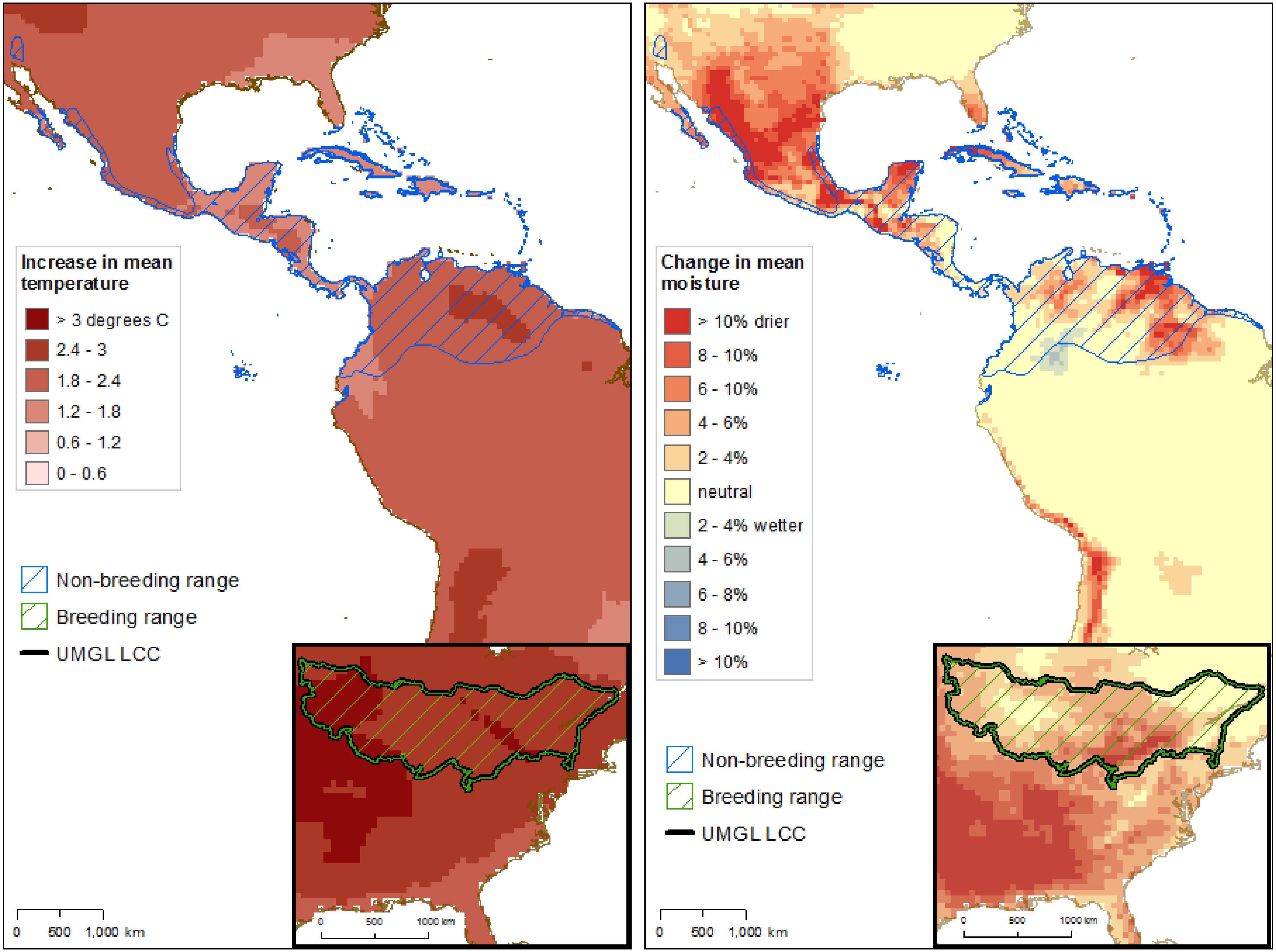


Figure 5.96. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Yellow Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

YELLOW WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 1.0) breeding = 14,182,963 km2; non-breeding = 4,830,879 km2
• PIF threats	(score = 2.5): breeding score = 2.5; non-breeding score = 2.0
• Breeding PIF conservation	(score = 2.4)
• Non-breeding PIF conservation	(score = 1.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant/resident and long-distance migrant (mean distance = 1839 km)
• Breeding habitat niche specialization	(score = 1.6) Macro habitats shrub, riparian, freshwater wetland, urban/parks, humid mangrove forests; nesting micro habitat shrubs and small trees (0.3-4 m high)
• Breeding diet niche specialization	(score = 3.5) Arthropods; captured by gleaning foliage in the mid- and upper canopies
• Breeding site fidelity	(score = 5.0) High
• Non-breeding habitat niche specialization	(score = 2.0) Woodland, scrub/second-growth, urban gardens, humid mangrove forests
• Non-breeding diet niche specialization	(score = unknown) No data
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 25.9° C
• Breeding precipitation range	(score = 3.0) 81 cm
• Non-breeding thermal range	(score = 2.0) 14.7° C
• Non-breeding precipitation range	(score = 2.5) 90 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.0% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.0° C increase Mexico (score = 2.0) 1.7° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.1° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 1.0) 3.9% drier Mexico (score = 4.0) 8.5% drier C. America (score = 1.0) 3.7% drier S. America (score = 1.0) 3.4% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.4) Overall, shrublands may be moderately vulnerable due to woodland encroachment (USDA 2012, USFS 2013), however, there will also be more forest disturbance, which may create openings for shrub habitat; very little vulnerability of woodlands, which are predicted to remain stable or increase (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); riparian habitat vulnerability may depend on location, with western riparian habitat highly vulnerable (Perry et al. 2012, USFS 2013) and eastern riparian habitat less; high vulnerability of freshwater wetlands due to drying (Goulatowitsch et al. 2009, Karl et al. 2009, USDA 2012, USFS 2013); mangrove forests very highly vulnerable due to sea level rise (Gilman et al. 2008); zero vulnerability of urban areas
• Breeding biotic interaction vulnerability	(score = 3.0) Vulnerability of arthropods in general largely unknown, but may be some for native species (Chown et al. 2007); small mammalian nest predators may increase in abundance with climate change (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.8) Very little vulnerability of woodland, second-growth, and dry scrub forest, which may increase in area (Khatun et al. 2013); very high vulnerability of mangrove forests due to sea level rise (Gilman et al. 2008); zero vulnerability of agricultural or urban areas
• Non-breeding biotic interaction vulnerability	(score = unknown) No data

5.34. Black-throated Blue Warbler (*Setophaga caerulescens*)

USFWS Region 3 status: common
AOU number: 6540
AOU abbreviation: BTBW

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.0	**3.7**	**2.2**	**2.8**	**2.8**	**3.5**	**2.1**	**3.7**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Black-throated Blue Warbler was high, scoring 3.0 out of 5.0. Background risk and temperature change on the UMGL breeding grounds (exposure × sensitivity) were the largest contributors. The adaptive capacity category was another large contributor to vulnerability, and this was driven by a supposed high degree of breeding site fidelity (though more research is needed on this subject), specialized breeding habitat needs, and a fairly specialized year-round diet. Drying on the Caribbean non-breeding grounds was another large contributor to vulnerability (Figure 5.97). Thus, it appears that Black-throated Blue Warblers are vulnerable to both climate change factors and factors unrelated to climate change. Further, changes on both the breeding and non-breeding grounds (particularly the Caribbean) were large contributors to vulnerability. We had very little connectivity information on Black-throated Blue Warblers from banding data and no breeding to non-breeding encounters originating from the UMGL (Figure 5.98). We also found limited information from the literature. Research using stable isotopes showed that non-breeding populations from the western Caribbean (especially Jamaica) go to the northern portion of the breeding range (Rubenstein et al. 2002, Royle and Rubenstein 2004). There is no information, however, for the rest of the non-breeding range. For this reason, we were unable to exclude other non-breeding regions from our analysis and maintained a broad approach. More work on migratory connectivity is needed to fill in the gaps for other regions in the Caribbean and C. America. Such research would improve our understanding of vulnerability for the species.

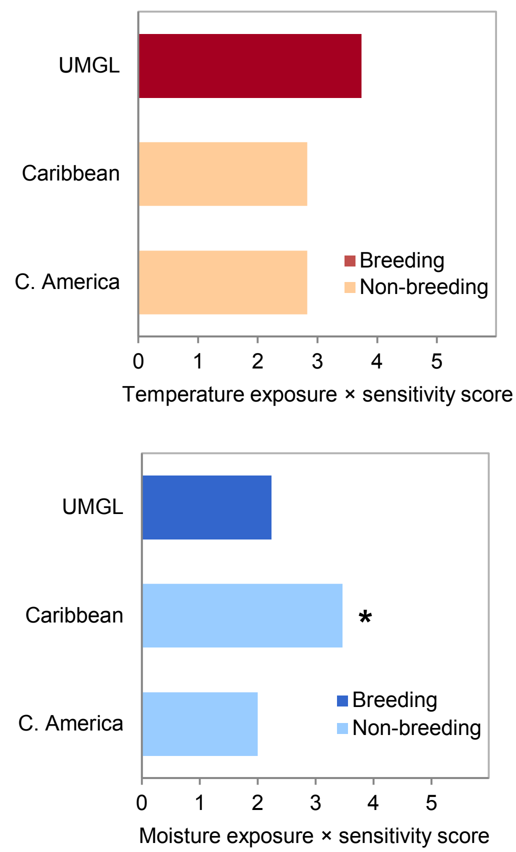


Figure 5.97. Black-throated Blue Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

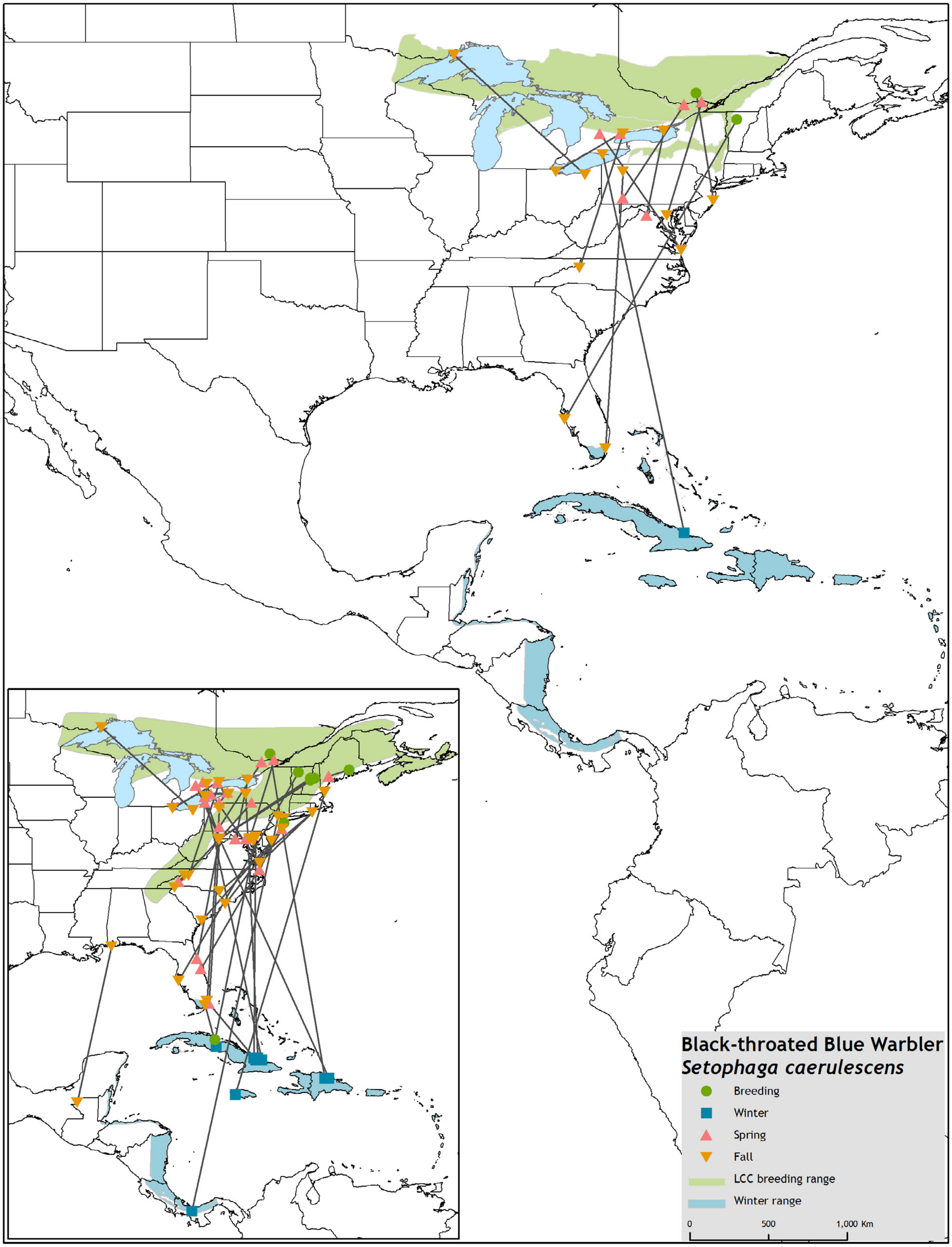


Figure 5.98. Black-throated Blue Warbler banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green on the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Inset map shows data from the entire breeding range.

CLIMATE EXPOSURE

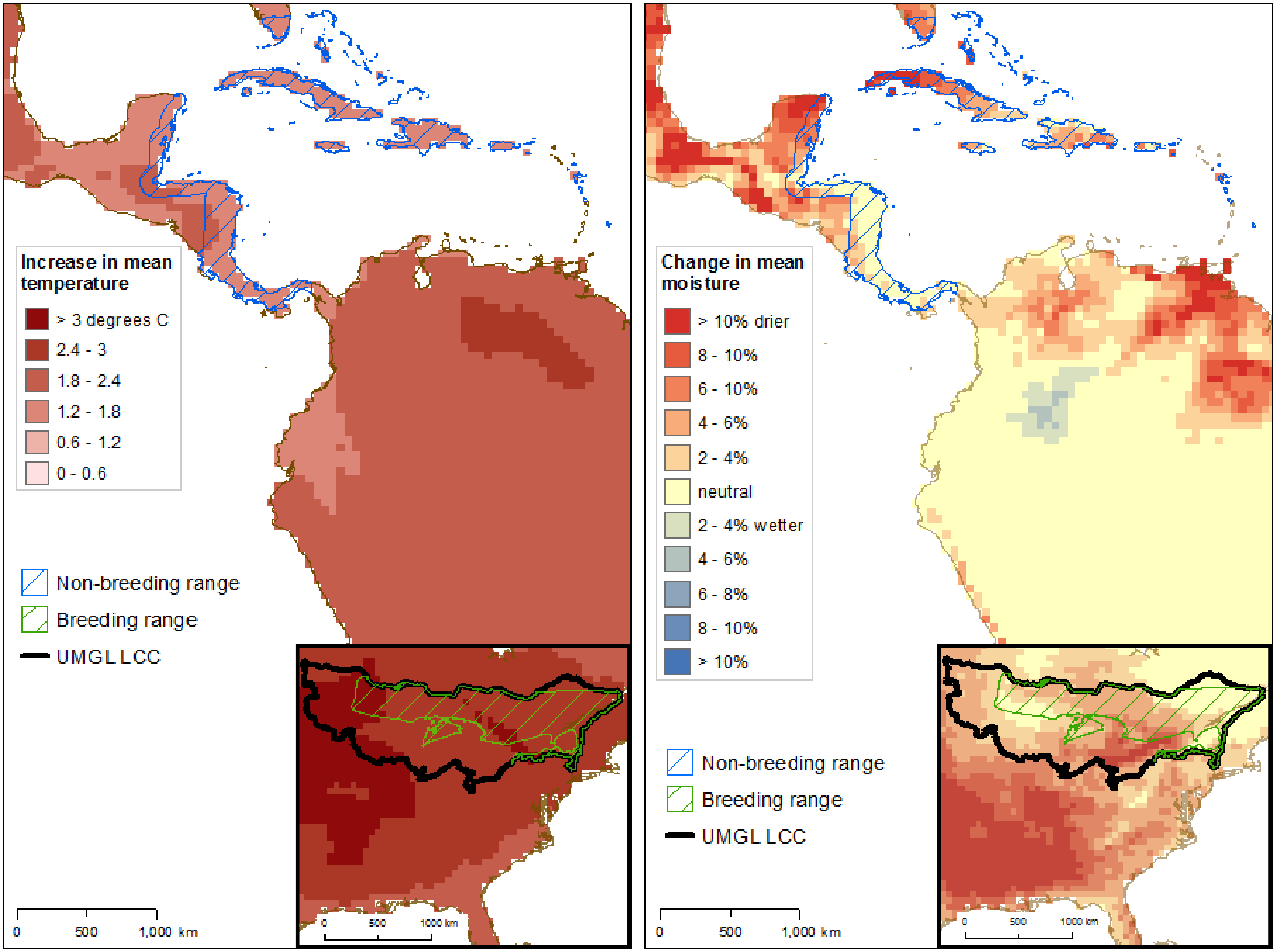


Figure 5.99. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Black-throated Blue Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

BLACK-THROATED BLUE WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 5.0) 1.00 probability (95% CI = 1.00, 1.00)
• Range size	(score = 3.0) breeding = 1,144,681 km2; non-breeding = 361,590 km2
• PIF threats	(score = 3.0): breeding score = 3.0; non-breeding score = 3.0
• Breeding PIF conservation	(score = 3.3)
• Non-breeding PIF conservation	(score = 2.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Short-distance and long-distance migrant (mean distance = 2653 km)
• Breeding habitat niche specialization	(score = 4.2) Macro habitats deciduous and mixed forest, boreal forest (especially large forests with dense shrubby undergrowth); nesting micro habitat shrubs with dense foliage (0.2-1.0 m high)
• Breeding diet niche specialization	(score = 3.5) Arthropods; captured by hover gleaning in the forest sub- and mid-canopies
• Breeding site fidelity	(score = 5.0) Not much data but may be high
• Non-breeding habitat niche specialization	(score = 2.0) Tropical forests, tropical woodland, coffee and citrus agriculture, second growth
• Non-breeding diet niche specialization	(score = 3.5) Arthropods and fruit
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.5) 7.6° C
• Breeding precipitation range	(score = 5.0) 12 cm
• Non-breeding thermal range	(score = 4.0) 4.5° C
• Non-breeding precipitation range	(score = 4.0) 52 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.8° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 3.4% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.7° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.7° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.4% drier Caribbean (score = 3.0) 6.4% drier C. America (score = 1.0) 2.6% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 3.0) Some vulnerability of deciduous, mixed forest—chiefly in southern USA, but range may expand in north (USFS 2013); high vulnerability of boreal forest due to fire, pests, hardwood succession (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013); coverage of large mature forest expected to decrease overall due to increased fire and pests while second-growth forests will increase (USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.0) Vulnerability of arthropods in general is largely unknown, but there may be some for native species (Chown et al. 2007); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 0.8) Vulnerability of broadleaf tropical forest may depend on location and forest type—lowland forests may be stable due to high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013); very little vulnerability of woodlands, second-growth, and dry scrub forest, which may increase in area (Khatun et al. 2013); no vulnerability of urban areas
• Non-breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in the tropics largely unknown, but there may be some; potential changes to abundance and phenology of fruit is largely unknown but may be very little

5.35. Prairie Warbler *(Setophaga discolor)*

photo by D Sherony

USFWS Region 3 status: conservation concern
AOU number: 6730
AOU abbreviation: PRAW

VULNERABILITY SCORES

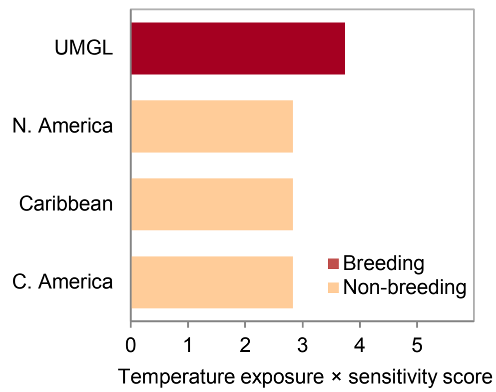
Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.7	**3.7**	**3.0**	**2.8**	**3.0**	**3.2**	**1.9**	**2.4**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Prairie Warbler was moderate, scoring 2.7 out of 5.0. Temperature change on the UMGL breeding grounds (exposure × sensitivity) and drying on the Caribbean non-breeding grounds (exposure × sensitivity) were the largest contributors to vulnerability. The adaptive capacity category was also a large contributor to vulnerability, driven primarily by a high degree of breeding site fidelity. Subscores in the indirect effects category were low to moderate, indicating that habitat and diet requirements may not be under great pressure due to climate change. Drying effects on both the UMGL breeding grounds and throughout the non-breeding range were large contributors to vulnerability (Figure 5.100). This suggests that climate change may be a factor for Prairie Warblers throughout the year. We had very little connectivity information for Prairie Warblers from banding data and no breeding to non-breeding encounters originating from the UMGL (Figure 5.101). In addition, we found no information from the literature. Consequently, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species by allowing us to focus our analysis on the most appropriate non-breeding regions.

Prairie Warblers glean foliage in the sub-canopy to upper canopy (photo by WH Majoros)



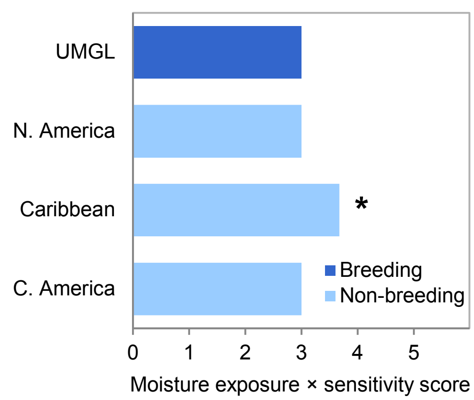


Figure 5.100. Prairie Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score ≥ 20% greater than breeding.

MIGRATORY CONNECTIVITY

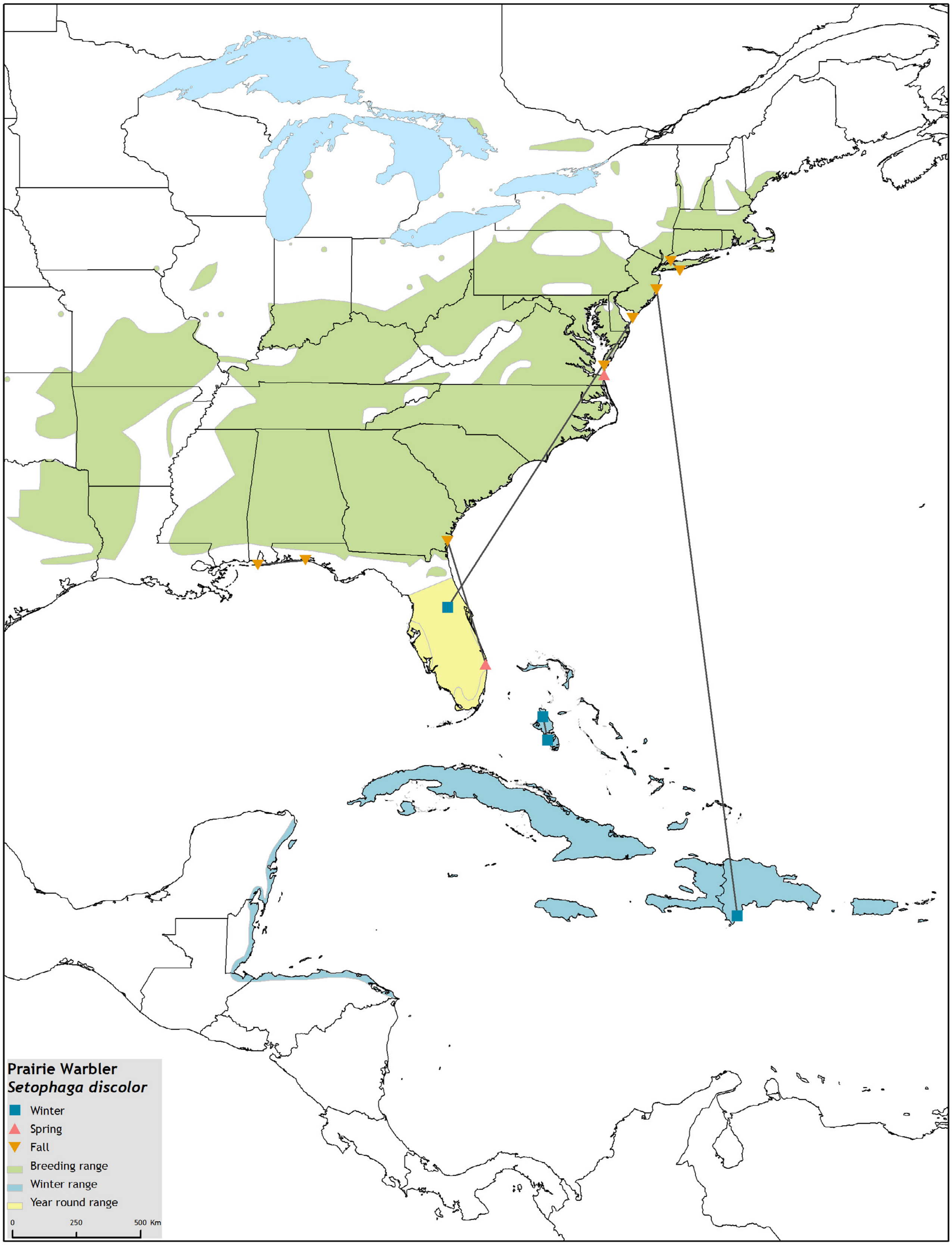


Figure 5.101. Prairie Warbler banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

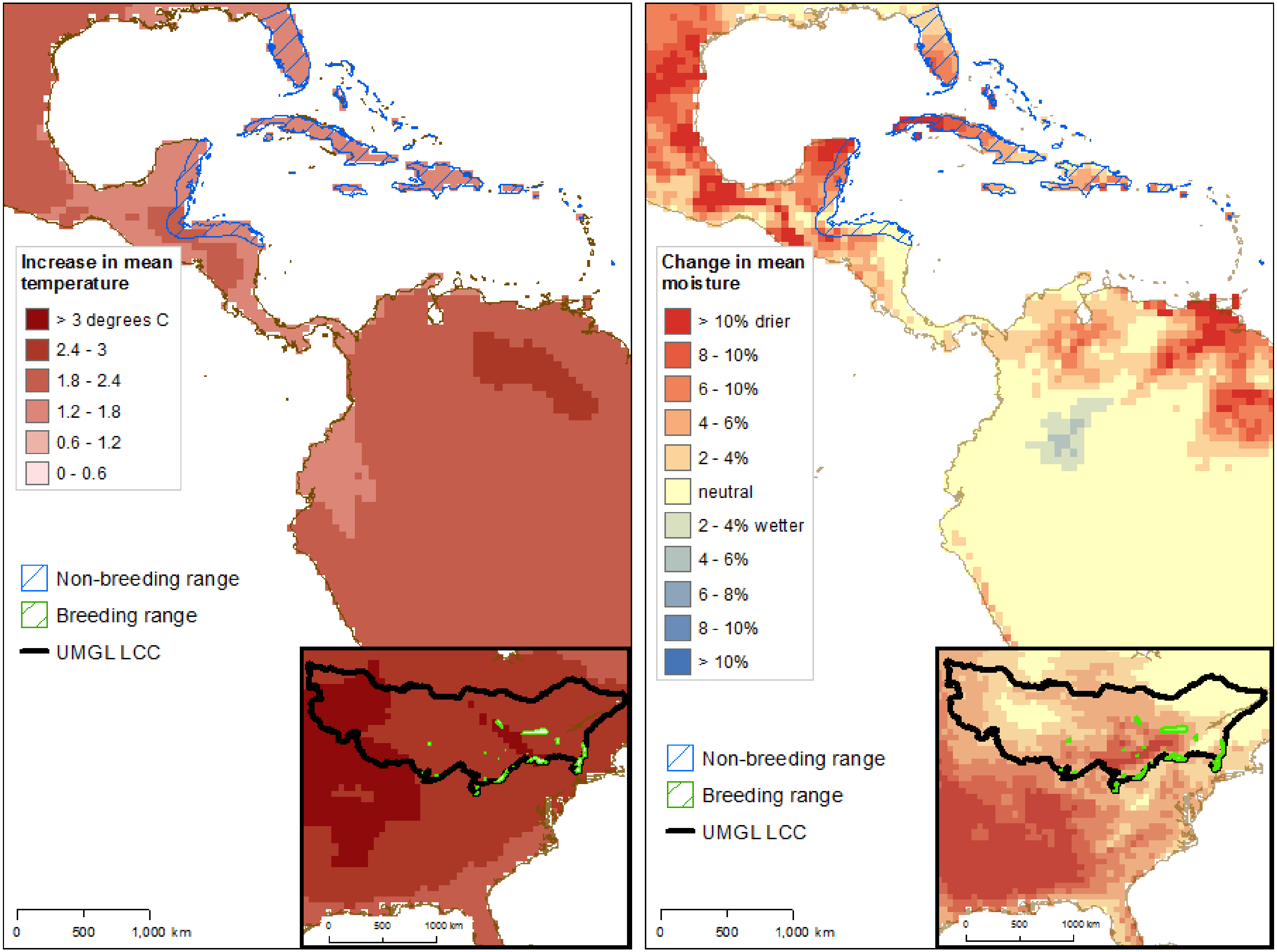


Figure 5.102. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Prairie Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

PRAIRIE WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 3.0) breeding = 1,565,057 km2; non-breeding = 336,441 km2
• PIF threats	(score = 3.3): breeding score = 3.3; non-breeding score = 2.0
• Breeding PIF conservation	(score = 3.3)
• Non-breeding PIF conservation	(score = 3.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant/resident and long-distance migrant (mean distance = 1682 km)
• Breeding habitat niche specialization	(score = 3.0) Macro habitats shrub (including coastal shrub and forest edge), woodland, mangrove forest; nesting micro habitat tree and shrub (0.3-3 m high)
• Breeding diet niche specialization	(score = 3.2) Arthropods and mollusks; captured by gleaning foliage in the forest sub-, mid-, and upper canopies
• Breeding site fidelity	(score = 5.0) High (thought that all surviving males return to same breeding territories year after year)
• Non-breeding habitat niche specialization	(score = 2.0) Agriculture (brushy fields, pastures, coffee), second-growth forest (scrub and edges), broadleaf/evergreen forest (including mangroves), urban gardens
• Non-breeding diet niche specialization	(score = 3.2) Mostly insects, some fruit (considered a generalist, eating what's available)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.5) 8.1° C
• Breeding precipitation range	(score = 4.5) 28 cm
• Non-breeding thermal range	(score = 4.0) 6.9° C
• Non-breeding precipitation range	(score = 4.5) 31 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.8° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.4% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.6° C increase N. America (score = 2.0) 1.6° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.7° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.5% drier N. America (score = 2.0) 5.1% drier Caribbean (score = 3.0) 6.3% drier C. America (score = 2.0) 4.4% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.3) Overall, shrublands may be moderately vulnerable due to woodland encroachment (USDA 2012, USFS 2013), however, there will also be more forest disturbance, creating openings for shrub habitat; very little vulnerability of woodlands, which are predicted to remain stable or to increase (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); mangrove forests very highly vulnerable due to sea level rise and storm surges, (Gilman et al. 2008)
• Breeding biotic interaction vulnerability	(score = 2.3) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); no information on potential changes for mollusk populations; small mammalian nest predators may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.3) Very little vulnerability of second-growth and dry scrub forest, which may increase in area (Khatun et al. 2013); vulnerability of broadleaf tropical forest may depend on location and forest type—lowland forests may be stable because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013) while mangrove forests are vulnerable to sea level rise and storm surges (Gilman et al. 2008); zero vulnerability of agricultural or urban areas
• Non-breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in the tropics largely unknown, but there may be some; potential changes to abundance and phenology of fruit is largely unknown but may be very little

5.36. Canada Warbler *(Cardellina canadensis)*

USFWS Region 3 status: conservation concern
AOU number: 6860
AOU abbreviation: CAWA

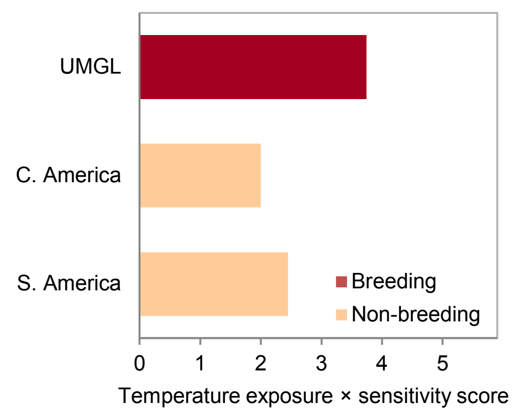
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.8	**3.7**	**2.2**	**2.4**	**1.4**	**4.0**	**2.6**	**2.3**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Canada Warbler was moderate, scoring 2.8 out of 5.0. The adaptive capacity category was a very large contributor, which was driven by a combination of factors, including a high degree of breeding site fidelity, highly specialized non-breeding and breeding diets, and a long-distance migration. The Canada Warbler's reliance on wooded wetland habitat during the breeding season was compounded by the highly vulnerable nature of this habitat to climate change. However, other factors, such as non-breeding habitat, were not as vulnerable and helped to reduce the indirect effects category subscore. Temperature increases on the UMGL breeding grounds was another large contributor to vulnerability (Figure 5.103), partly because Canada Warblers are sensitive to temperature changes during summer. Climate change on the non-breeding grounds was expected to have very little to moderate effects on vulnerability, depending on location and variable (Figure 5.103). Thus, climate change on the breeding grounds appears to be a bigger priority compared to climate change on the non-breeding grounds. We had very little connectivity information for Canada Warblers from banding data and no breeding to non-breeding encounters originating from the UMGL (Figure 5.104). In addition, we found no information from the literature. Consequently, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species by allowing us to focus our analysis on the most appropriate non-breeding regions.



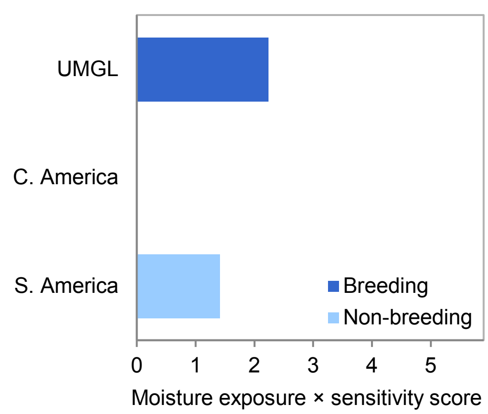


Figure 5.103. Canada Warbler subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

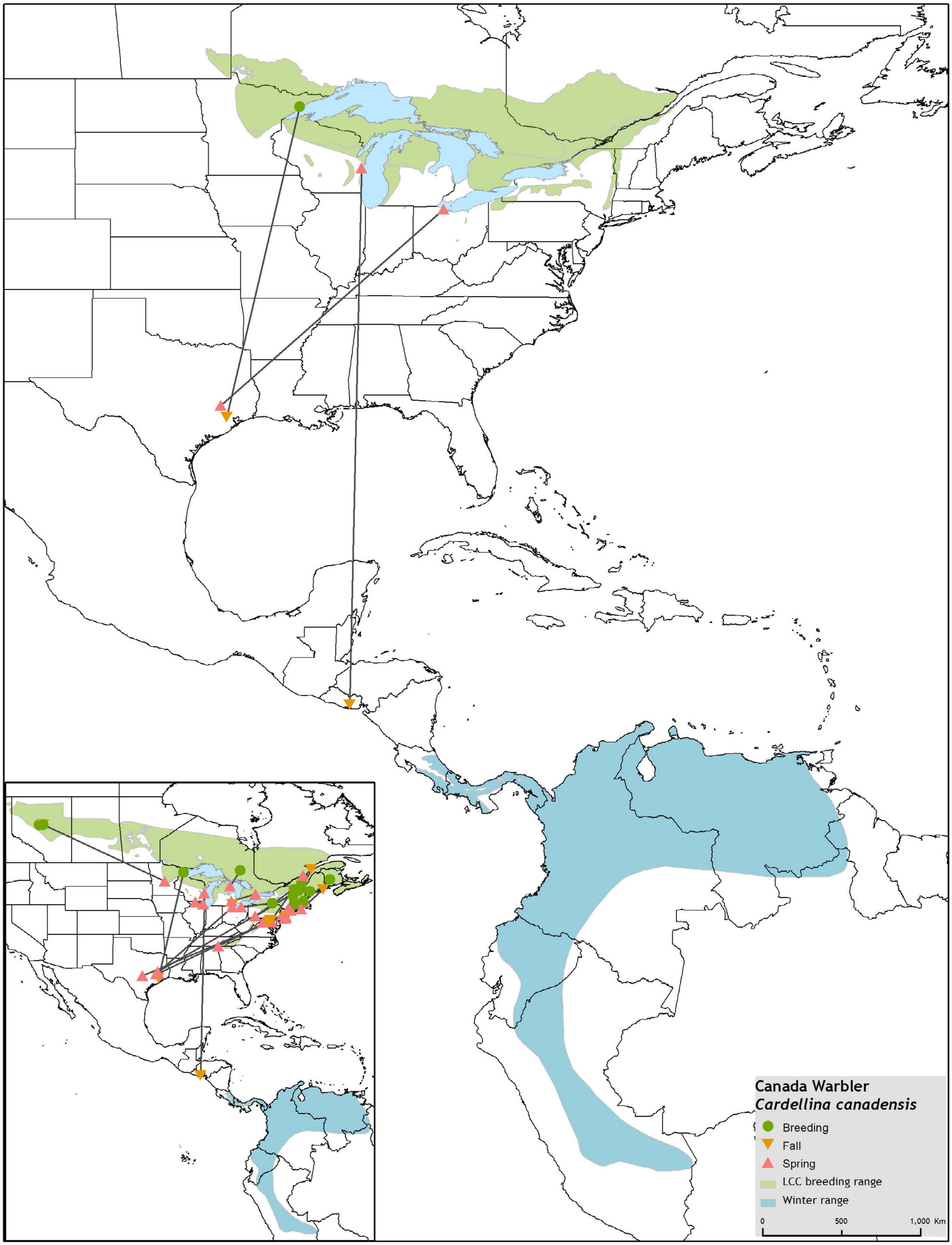


Figure 5.104. Canada Warbler banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Inset map shows data from the entire breeding range.

CLIMATE EXPOSURE

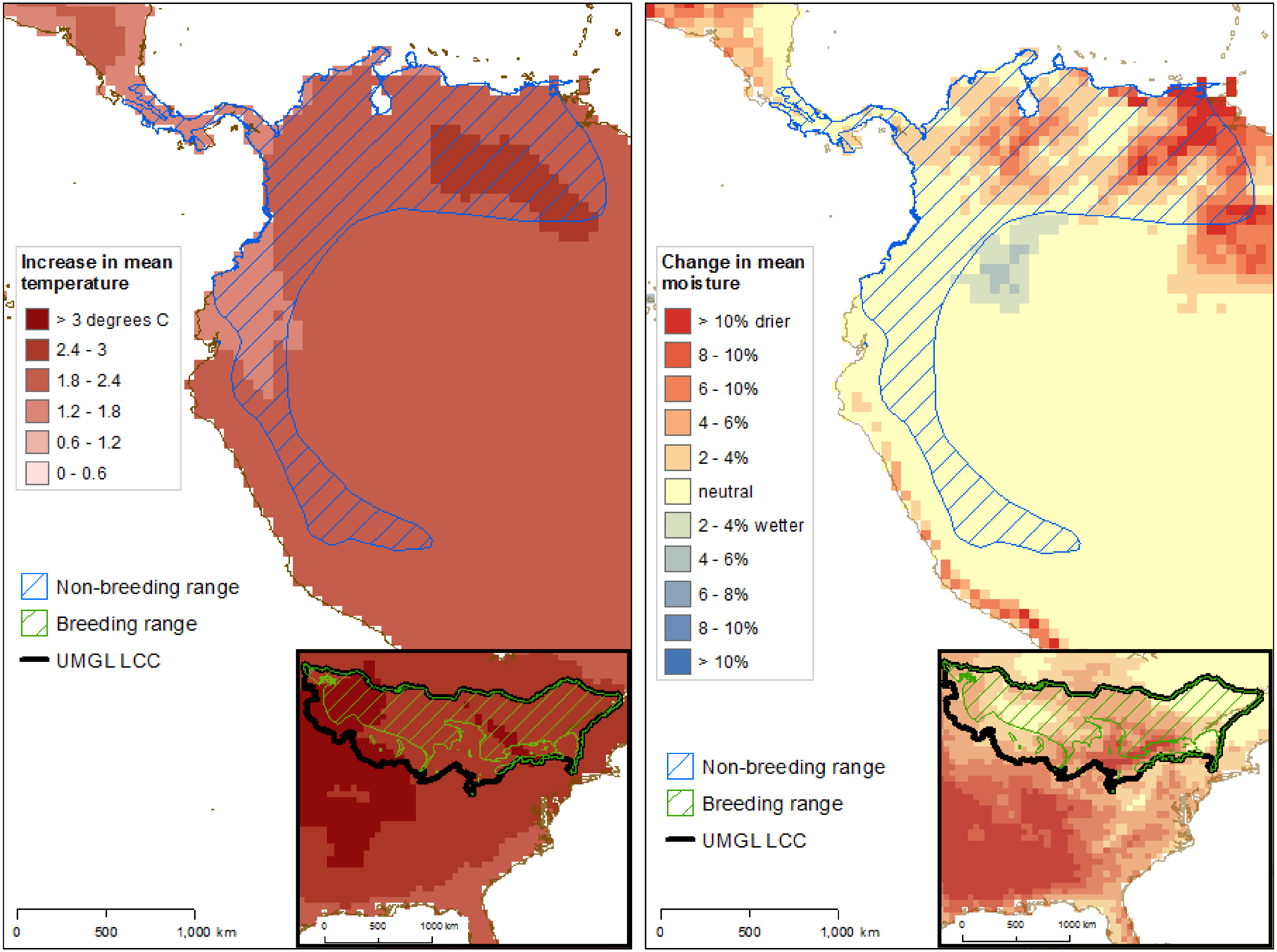


Figure 5.105. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Canada Warbler's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

CANADA WARBLER DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 2,756,662 km2; non-breeding = 1,492,354 km2
• PIF threats	(score = 4.0): breeding score = 3.1; non-breeding score = 4.0
• Breeding PIF conservation	(score = 4.2)
• Non-breeding PIF conservation	(score = 3.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 4.0) Long-distance migrant (mean distance = 5330 km)
• Breeding habitat niche specialization	(score = 3.7) Macro habitats mixed forest, wooded wetland; nesting micro habitat on ground and low vegetation (0-0.2 m high)
• Breeding diet niche specialization	(score = 3.9) Flying insects, spiders; captured by hover gleaning in the shrub and forest sub-canopy
• Breeding site fidelity	(score = 5.0) High (no details available)
• Non-breeding habitat niche specialization	(score = 3.0) Wet forest (including submontane), second-growth/edges, coffee agriculture
• Non-breeding diet niche specialization	(score = 4.5) Insects (no details available)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.5) 7.9° C
• Breeding precipitation range	(score = 5.0) 18 cm
• Non-breeding thermal range	(score = 2.0) 13.8° C
• Non-breeding precipitation range	(score = 2.0) 109 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 3.7% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.1° C increase C. America (score = 2.0) 1.7° C increase S. America (score = 3.0) 2.1° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 1.0) 2.7% drier C. America (score = 0) 1.6% drier S. America (score = 1.0) 2.8% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.0) High vulnerability of mixed northern forests due to loss of conifers (Bachelet et al. 2001, Gonzalez et al. 2010); high vulnerability of wooded wetlands due to drying and changing vegetation (Karl et al. 2009, Goulatowitsch et al. 2009, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.0) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 1.3) Vulnerability of broadleaf/humid forest may depend on location and forest type—stable in many areas because of high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013), but Brazil and eastern Amazon may be exception (Freeley et al. 2010, Gonzalez et al. 2010); very little vulnerability of second-growth, which may increase (Khatun et al. 2013); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in the tropics largely unknown, but there may be some

5.37. Field Sparrow
(*Spizella pusilla*)

USFWS Region 3 status: conservation concern
AOU number: 5630
AOU abbreviation: FISP

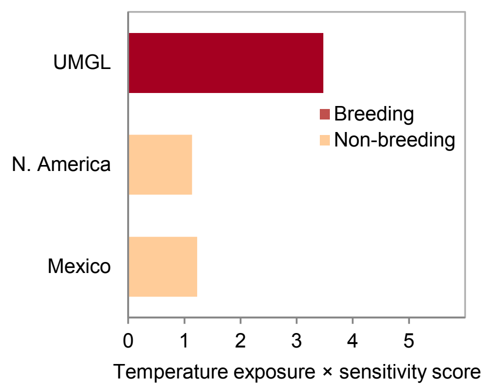
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.2	3.5	2.8	1.2	2.0	3.3	1.0	2.0

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Field Sparrow was moderate, scoring 2.2 out of 5.0. Drying on the Mexican non-breeding grounds (exposure × sensitivity) was the largest contributor to vulnerability (Figure 5.106), which was driven by both the sparrow's very high sensitivity to moisture change during winter and the prediction that there will be a very large change in moisture in Mexico during winter (9.2% drier by 2050 compared to current levels). Temperature increases on the UMGL breeding grounds (exposure × sensitivity) was also a large contributor to vulnerability (Figure 5.106), mostly driven by predicted temperature change during summer. The adaptive capacity category was another large contributor to vulnerability, driven by specialization during the non-breeding season in both habitat and diet. Fortunately, the sparrow's requirements during that time (agricultural fields, forest edges, and grass seeds) were not expected to be particularly vulnerable to climate change. This helped to lower the indirect effects subscore. Nevertheless, climate-change factors outscored background risk, suggesting that climate change may be a priority for the species. In addition, it appears that temperature change on the UMGL breeding grounds and moisture change on the Mexican non-breeding grounds may work synergistically to increase vulnerability. We had very little connectivity information for Field Sparrows from banding data and only three breeding to non-breeding encounters originating from the UMGL (Figure 5.107). In addition, we found no information from the literature. Consequently, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species by allowing us to focus our analysis on the most appropriate non-breeding regions.



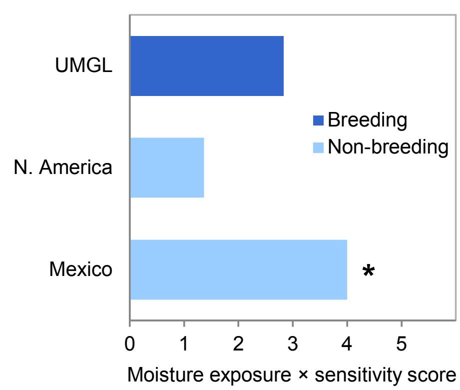


Figure 5.106. Field Sparrow subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score 20% greater than breeding.

MIGRATORY CONNECTIVITY

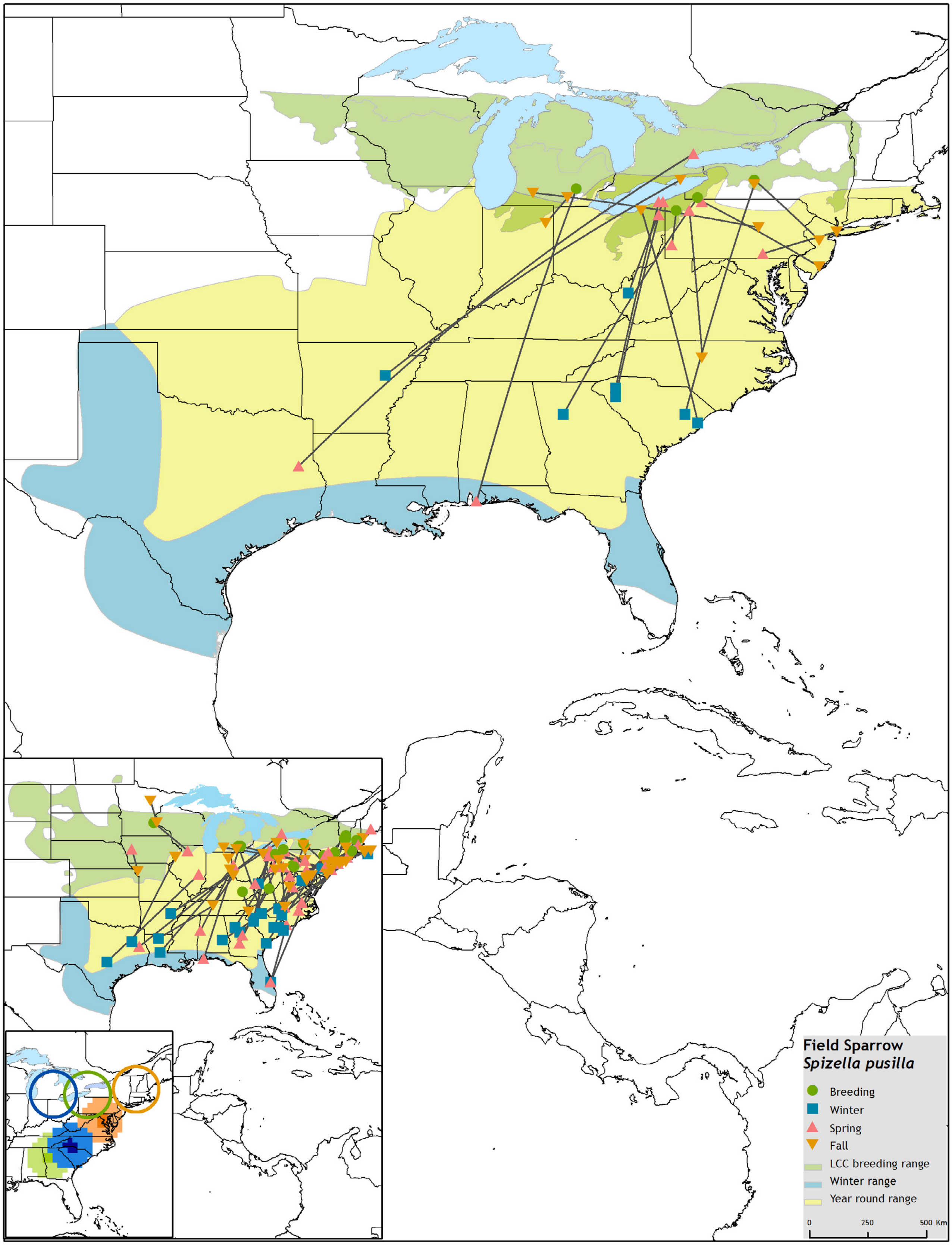


Figure 5.107. Field Sparrow banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were only three breeding to stationary non-breeding encounters from the UMGL. Inset maps show data from the entire breeding range and concentrations of stationary non-breeding encounters originating from three different breeding regions.

CLIMATE EXPOSURE

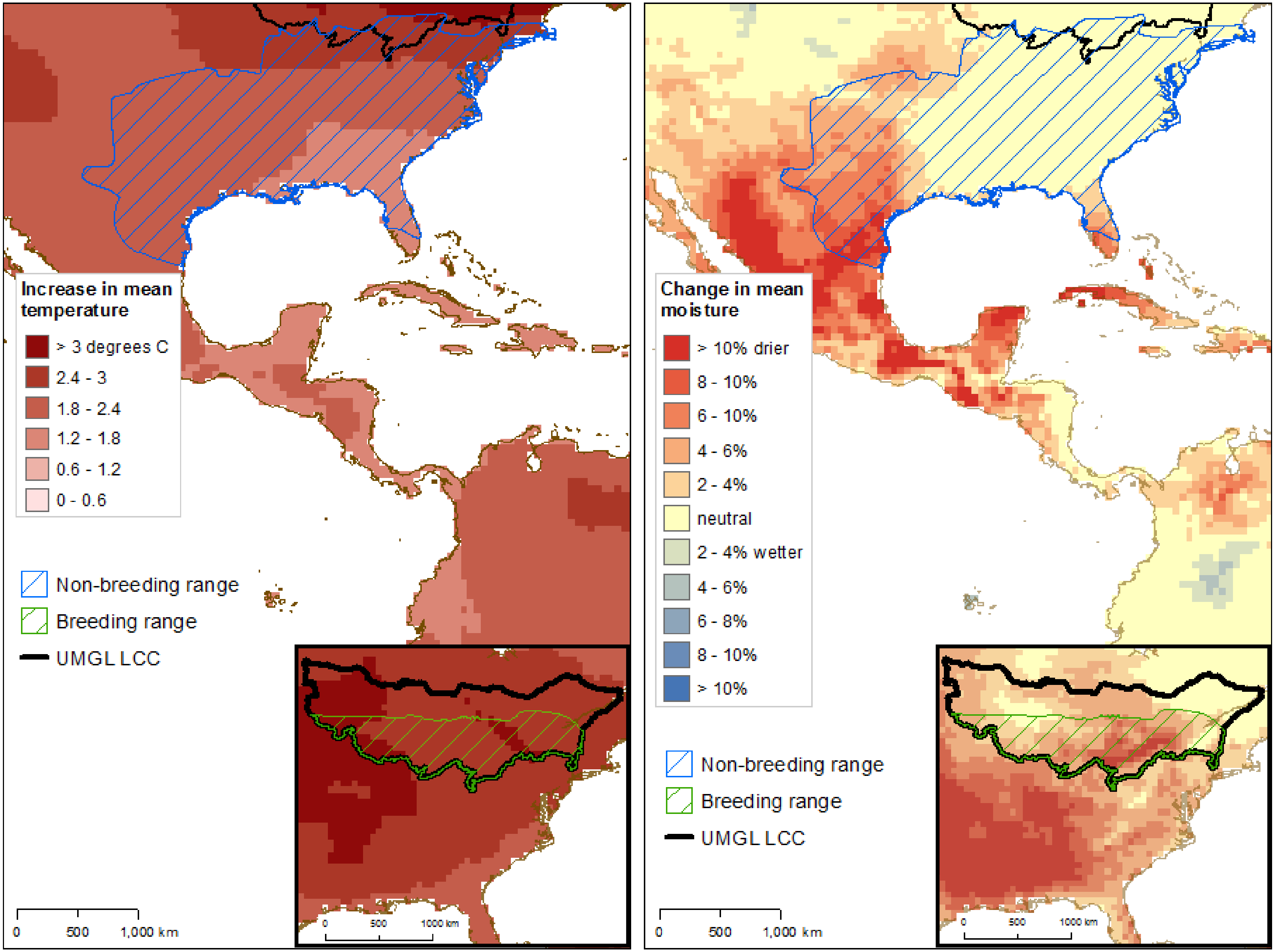


Figure 5.108. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Field Sparrow's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

FIELD SPARROW DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 3,993,359 km2; non-breeding = 3,185,005 km2
• PIF threats	(score = 3.1) breeding score = 3.1; non-breeding score = 3.0
• Breeding PIF conservation	(score = 3.8)
• Non-breeding PIF conservation	(score = 3.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 2.0) Non-migrant, short-distance migrant (mean distance = 976 km)
• Breeding habitat niche specialization	(score = 3.2) Macro habitats shrubby pasture and second growth scrub, woodland openings; nesting micro habitat ground, grass, or shrub (0-1 m high)
• Breeding diet niche specialization	(score = 3.2) Arthropods and seeds; captured by gleaning the ground and low vegetation
• Breeding site fidelity	(score = 3.5) Some fidelity to medium fidelity (data are inconsistent, though breeding habitat is ephemeral and species is probably able to rapidly colonize new areas)
• Non-breeding habitat niche specialization	(score = 4.0) Old agricultural fields and pasture, forest edges
• Non-breeding diet niche specialization	(score = 3.7) Seeds (small, mostly grasses)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.0) 11.4° C
• Breeding precipitation range	(score = 4.0) 33 cm
• Non-breeding thermal range	(score = 0.5) 20.2° C
• Non-breeding precipitation range	(score = 4.0) 39 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 5.0% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.1° C increase N. America (score = 3.0) 1.9° C increase Mexico (score = 3.0) 2.2° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 1.0) 2.4% drier N. America (score = 1.0) 2.7% drier Mexico (score = 4.0) 9.2% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.0) Zero vulnerability of pastures; second-growth scrub and woodland openings are expected to expand due to increased fire and pests (USFS 2013)
• Breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); potential changes to abundance and phenology of seeds largely unknown but may be very little—especially in agricultural areas
• Non-breeding habitat vulnerability	(score = 0.5) Zero vulnerability of agricultural areas; forest edges may expand due to increased fire and pests (USFS 2013)
• Non-breeding biotic interaction vulnerability	(score = 1.0) Potential changes to abundance and phenology of seeds largely unknown (see above)

5.38. Vesper Sparrow
(*Pooecetes gramineus*)

USFWS Region 3 status: common
AOU number: 5400
AOU abbreviation: VESP

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.2	**2.4**	**2.8**	**1.7**	**2.8**	**3.2**	**1.0**	**2.1**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Vesper Sparrow was moderate, scoring 2.2 out of 5.0. Drying on the Mexican non-breeding grounds (exposure × sensitivity) was by far the largest contributor (Figure 5.109), which was driven by both the sparrow's very high sensitivity to moisture change during winter and the prediction that there will be a very large change in moisture in Mexico during winter (8.7% drier by 2050 compared to current levels). Drying on the UMGL breeding grounds and temperature change throughout the year had less effect (Figure 5.109). The adaptive capacity category was also a large contributor to vulnerability, driven primarily by habitat specialization during the breeding season. Fortunately, this habitat (grasslands and agricultural fields) was not expected to be particularly vulnerable to climate change. This helped to lower the indirect effects subscore, although we found no information regarding vulnerability of tropical grasslands, which limited our assessment of this category. More research of the non-breeding grounds is needed to complete our understanding of vulnerability for Vesper Sparrows. Ultimately, it appears that climate change on the non-breeding grounds (particularly moisture change in Mexico) may be the primary concern for this species. We had very little connectivity information for Vesper Sparrows from banding data and only one breeding to non-breeding encounter originating from the UMGL (Figure 5.110). In addition, we found no information from the literature. Consequently, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species by allowing us to focus our analysis on the most appropriate non-breeding regions.

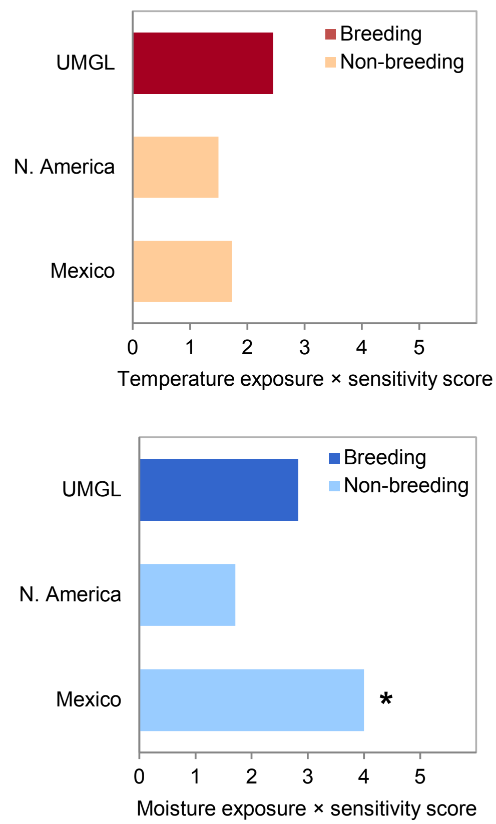


Figure 5.109. Vesper Sparrow subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score 20% greater than breeding.

MIGRATORY CONNECTIVITY

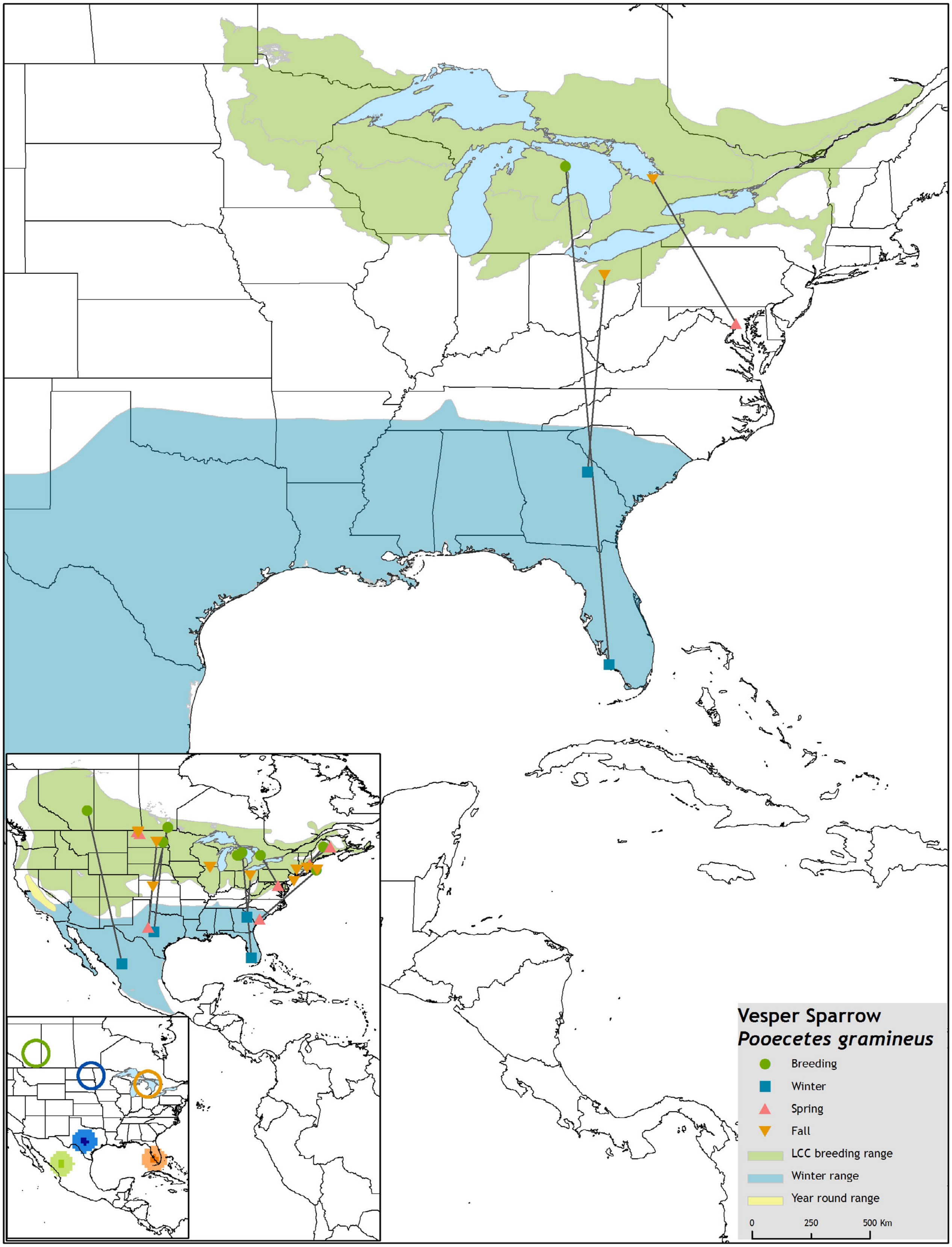


Figure 5.110. Vesper Sparrow banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There was only one breeding to stationary non-breeding encounter from the UMGL. Inset maps show data from the entire breeding range and concentrations of stationary non-breeding encounters originating from three different breeding regions.

CLIMATE EXPOSURE

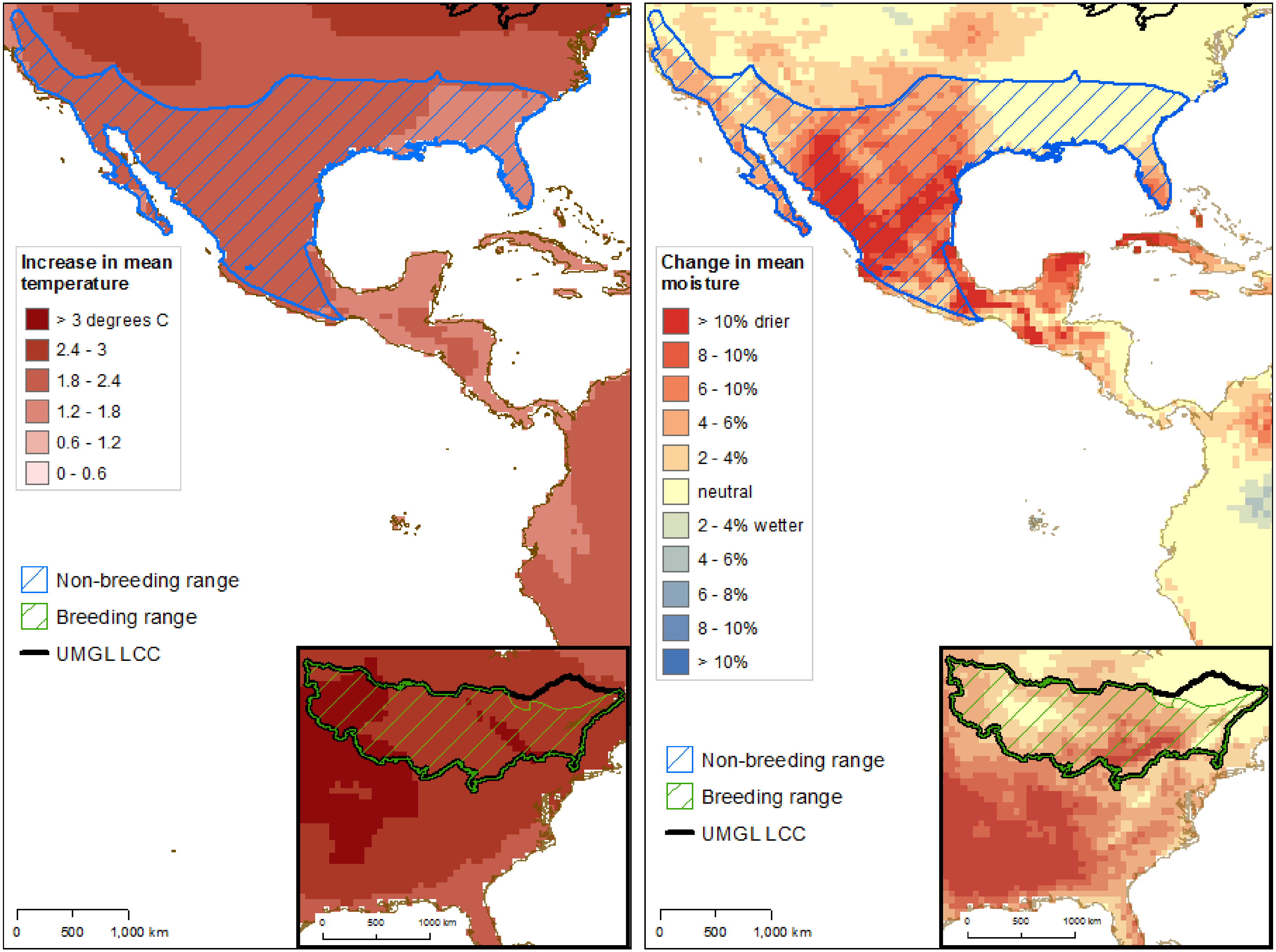


Figure 5.111. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Vesper Sparrow's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

VESPER SPARROW DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 6,346,442 km2; non-breeding = 3,636,009 km2
• PIF threats	(score = 3.2) breeding score = 3.2; non-breeding score = 3.0
• Breeding PIF conservation	(score = 3.4)
• Non-breeding PIF conservation	(score = 2.8)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant, short-distance migrant, long-distance migrant (mean distance = 2282 km)
• Breeding habitat niche specialization	(score = 3.9) Macro habitats dry grassland with shrubs (including prairie, desert grassland, shrub steppe grassland, montane grassland), old field agriculture and pasture; nesting micro habitat on ground under thick vegetation (0 m high)
• Breeding diet niche specialization	(score = 3.2) Seeds and arthropods; captured by gleaning the ground and low grass
• Breeding site fidelity	(score = 3.0) Some (moves in response to rain and can rapidly colonize new habitat)
• Non-breeding habitat niche specialization	(score = 3.0) Grassland, weedy agricultural, brushy second growth (scrub)
• Non-breeding diet niche specialization	(score = 3.2) Seeds (grasses, weeds, grains), arthropods
iii. Climate Sensitivity	
• Breeding thermal range	(score = 1.5) 16.0° C
• Breeding precipitation range	(score = 4.0) 34 cm
• Non-breeding thermal range	(score = 1.0) 17.9° C
• Non-breeding precipitation range	(score = 4.0) 45 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.4% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase N. America (score = 2.0) 1.8° C increase Mexico (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.6% drier N. America (score = 1.0) 3.5% drier Mexico (score = 4.0) 8.7% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 0.5) Very little vulnerability of grasslands, especially dry grasslands (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); zero vulnerability of agricultural fields and pastures
• Breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); potential changes to abundance and phenology of seeds largely unknown but may be very little
• Non-breeding habitat vulnerability	(score = 0.7) Not much information is available on the vulnerability of tropical grasslands due to climate change; very little vulnerability of second-growth scrub forest as these habitats may increase in area (Khatun et al. 2013); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in the tropics largely unknown, but there may be some; potential changes to abundance and phenology of seeds largely unknown but may be very little

5.39. Savannah Sparrow (*Passerculus sandwichensis*)

USFWS Region 3 status: common
AOU number: 5420
AOU abbreviation: SAVS

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.0	**0**	**2.8**	**0**	**2.8**	**3.4**	**1.8**	**1.5**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Savannah Sparrow was moderate, scoring 2.0 out of 5.0. Drying on the Mexican non-breeding grounds (exposure × sensitivity) was the largest contributor, followed by drying on the Caribbean non-breeding grounds (Figure 5.112). This was driven by both the sparrow's very high sensitivity to moisture change during winter and predictions that there will be large to very large changes in moisture in Mexico and the Caribbean during winter (8.3% and 7.2% drier, respectively, by 2050). The adaptive capacity category was another large contributor to vulnerability and was driven primarily by a high degree of breeding site fidelity. Neither temperature change during the breeding nor non-breeding season had much effect on vulnerability (Figure 5.112), primarily because Savannah Sparrows were not sensitive to temperature change throughout the year. Ultimately, it appears that climate change on the non-breeding grounds (particularly moisture change in Mexico and the Caribbean) may be the primary concern for this species. We had very little connectivity information for Savannah Sparrows from banding data and only three breeding to non-breeding encounters from the UMGL (Figure 5.113). In addition, we found no information from the literature. Consequently, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species by allowing us to focus our analysis on the most appropriate non-breeding regions.

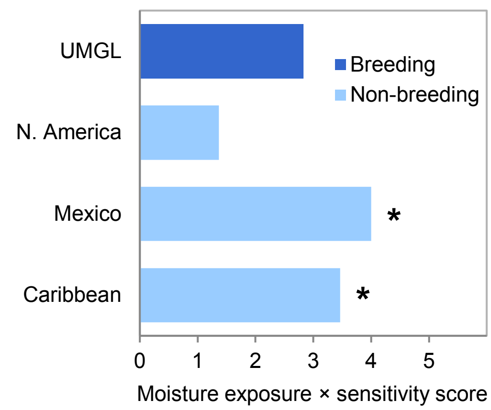


Figure 5.112. Savannah Sparrow subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). Temperature results not shown as all scores equaled zero. *Non-breeding score 20% greater than breeding.

Savannah Sparrows always nest on the ground under grasses (photo by DGE Robertson)

MIGRATORY CONNECTIVITY

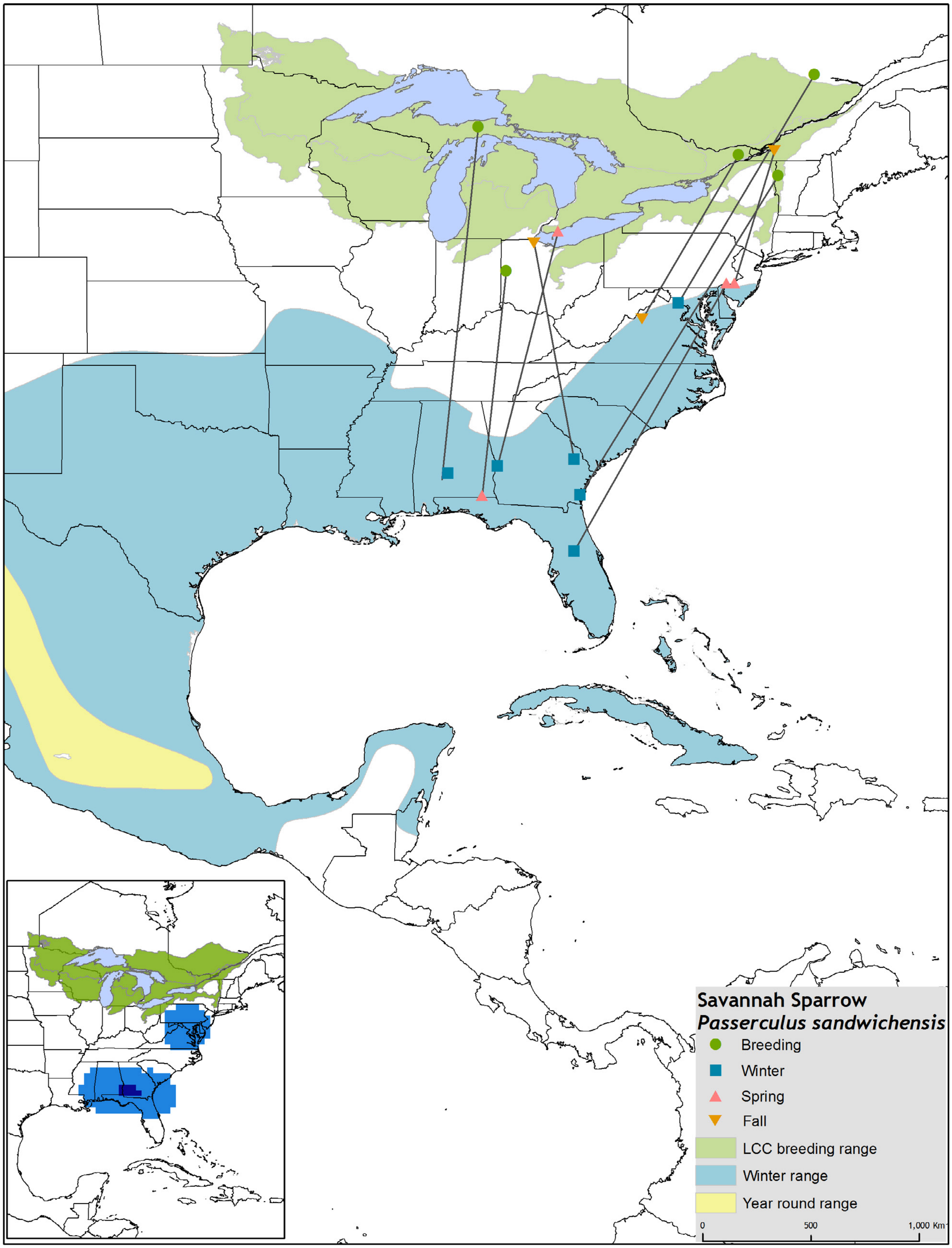


Figure 5.113. Savannah Sparrow banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were only three breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of stationary non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

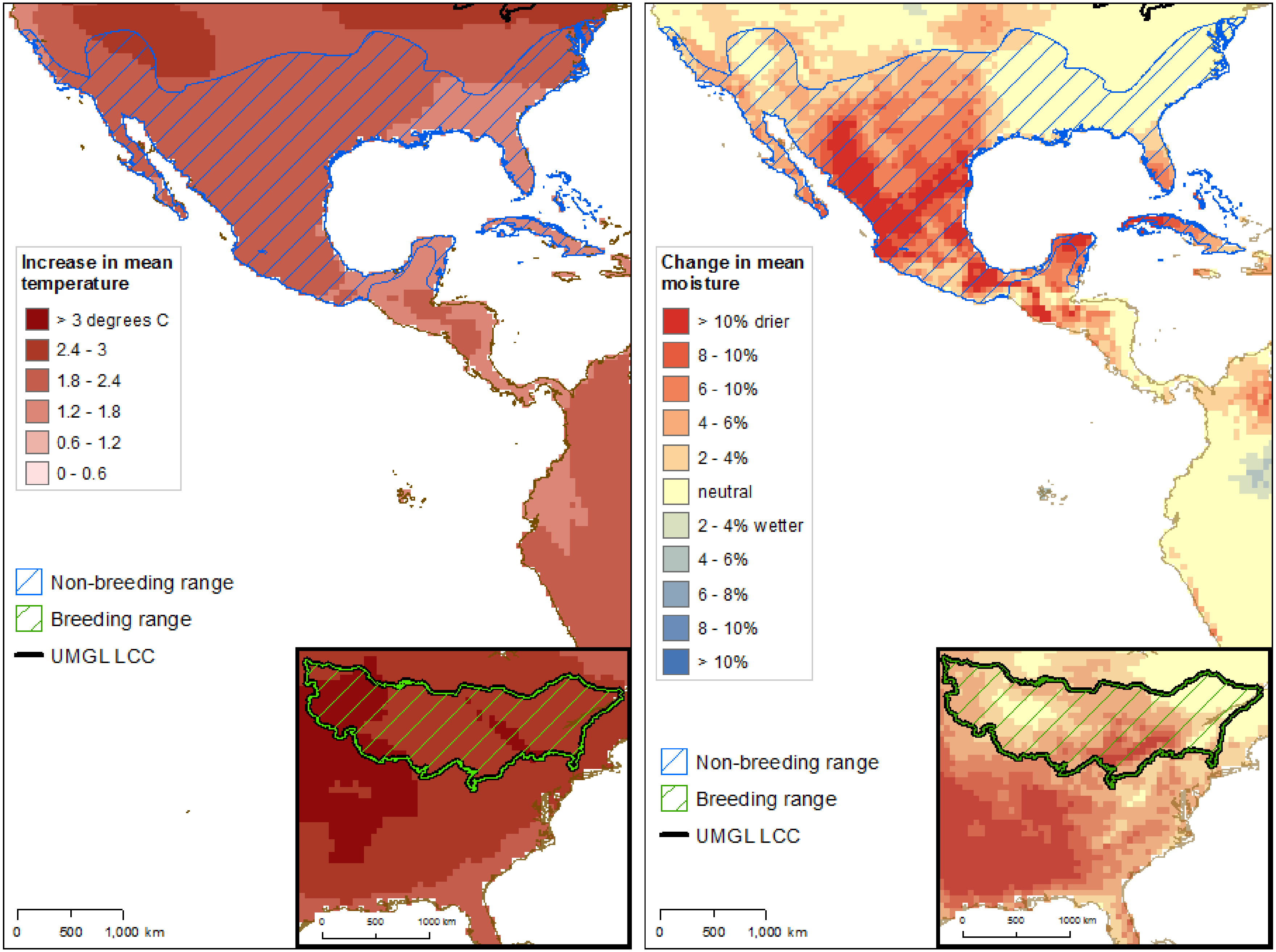


Figure 5.114. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Savannah Sparrow's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

SAVANNAH SPARROW DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 1.0) breeding = 13,727,335 km2; non-breeding = 4,716,806 km2
• PIF threats	(score = 2.4) breeding score = 2.4; non-breeding score = 2.0
• Breeding PIF conservation	(score = 3.4)
• Non-breeding PIF conservation	(score = 2.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Non-migrant, short-distance migrant, long-distance migrant (mean distance = 1930 km)
• Breeding habitat niche specialization	(score = 3.2) Macro habitats grassland, tundra, freshwater wetland, pasture; nesting micro habitat on ground in grass (0 m high)
• Breeding diet niche specialization	(score = 3.2) Arthropods and seeds; captured by gleaning the ground and low vegetation
• Breeding site fidelity	(score = 5.0) High (strong philopatry has led to substantial geographic variation)
• Non-breeding habitat niche specialization	(score = 3.0) Grasslands, agricultural fields and pasture, saltwater wetland
• Non-breeding diet niche specialization	(score = 2.8) Seeds (also fruit and inverts when available)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 23.2° C
• Breeding precipitation range	(score = 4.0) 54 cm
• Non-breeding thermal range	(score = 0) 24.2° C
• Non-breeding precipitation range	(score = 4.0) 43 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.0% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.0° C increase N. America (score = 3.0) 2.0° C increase Mexico (score = 3.0) 2.0° C increase Caribbean (score = 2.0) 1.6° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.2% drier N. America (score = 1.0) 3.2% drier Mexico (score = 4.0) 8.3% drier Caribbean (score = 3.0) 7.2% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.5) Very little vulnerability of grasslands although specific components may change or disappear (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); all sources agree that tundra habitat is very highly vulnerable (Bachelet et al. 2001, Gonzalez et al. 2010); high vulnerability of freshwater wetlands due to drying and re-vegetation (Karl et al. 2009, Goulatowitsch et al. 2009, USDA 2012, USFS 2013); zero vulnerability of pastures
• Breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); potential changes to abundance and phenology of seeds largely unknown but may be very little
• Non-breeding habitat vulnerability	(score = 2.0) Very little vulnerability of grasslands (see above); very high vulnerability on saltwater wetlands due to sea level rise (IPCC 2014); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 1.3) Potential changes to abundance and phenology of seeds and fruit largely unknown but may be very little; vulnerability of arthropods in the tropics largely unknown, but there may be some

5.40. Indigo Bunting (*Passerina cyanea*)

USFWS Region 3 status: common
AOU number: 5980
AOU abbreviation: INBU

VULNERABILITY SCORES

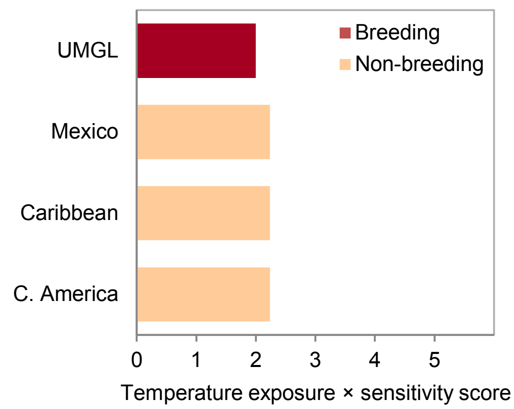
Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.0	2.0	2.8	2.2	3.5	2.6	1.0	1.7

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Indigo Bunting was moderate, scoring 2.0 out of 5.0. Drying on the Mexican and Caribbean non-breeding grounds (exposure × sensitivity) was by far the largest contributor (Figure 5.115). This was driven by both the bunting's very high sensitivity to moisture change during winter and predictions that there will be large changes in moisture on the Mexican and Caribbean non-breeding grounds (7.4% and 6.2% drier, respectively, by 2050). Drying on the UMGL breeding grounds and temperature change throughout the year had less effect (Figure 5.115). All other categories had low to moderate effects on vulnerability. Ultimately, it appears that climate change on the non-breeding grounds (particularly moisture change in Mexico and the Caribbean) may be the primary concern for this species. We had very little connectivity information for Indigo Buntings from banding data and only three breeding to non-breeding encounters originating from the UMGL (Figure 5.116). In addition, we found no information from the literature. Consequently, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species by allowing us to focus our analysis on the most appropriate non-breeding regions.

Indigo Buntings have a variable breeding site tenacity



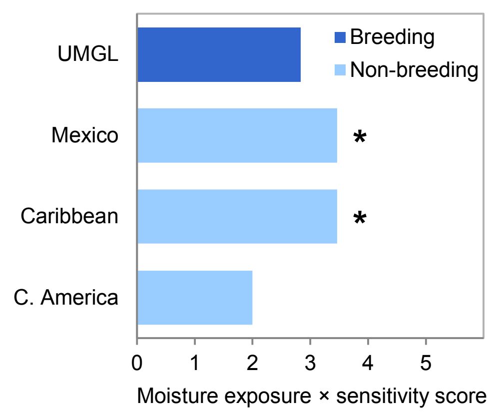


Figure 5.115. Indigo Bunting subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score 20% greater than breeding.

MIGRATORY CONNECTIVITY

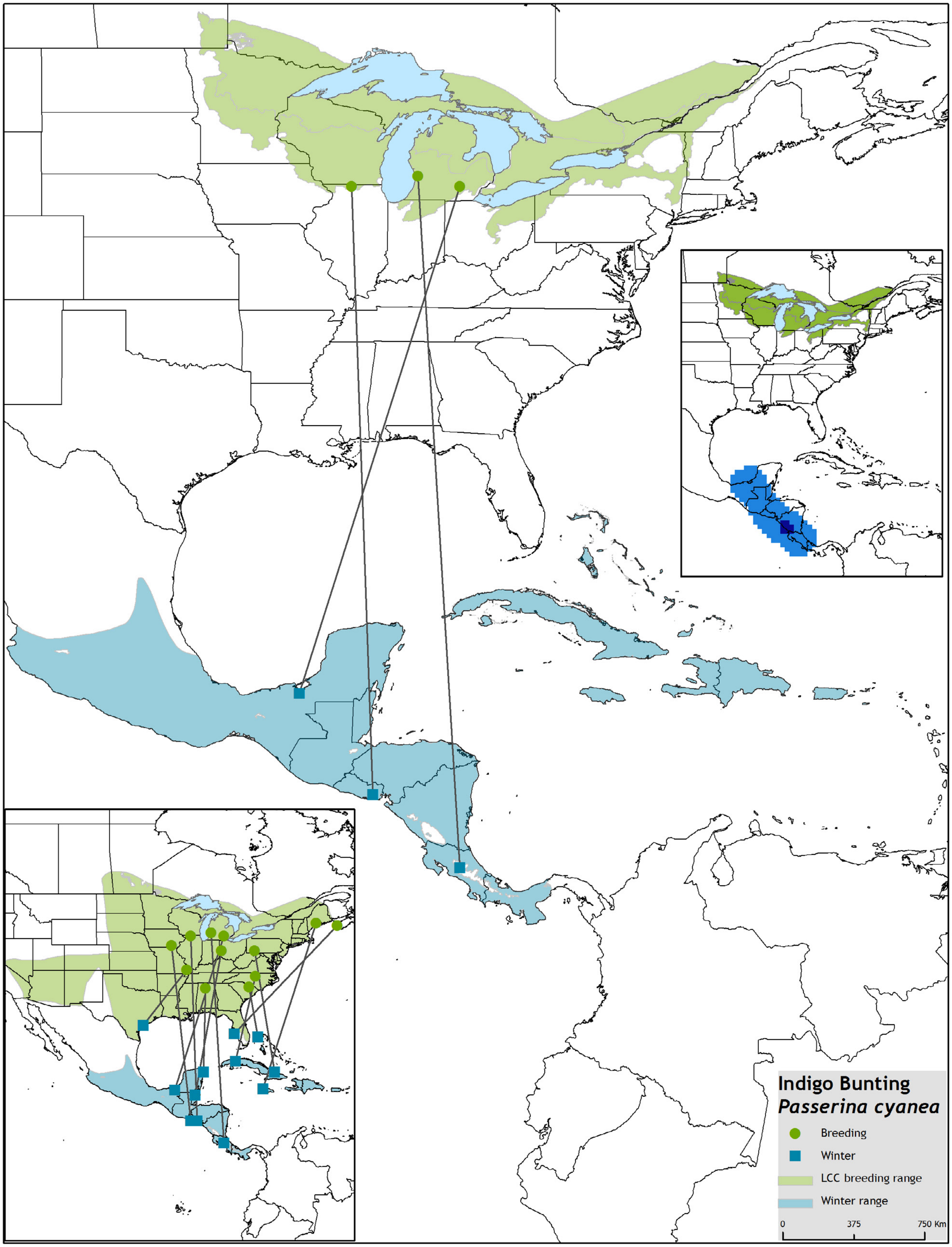


Figure 5.116. Indigo Bunting banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were only three breeding to stationary non-breeding encounters from the UMGL. Inset map on upper right shows concentrations of stationary non-breeding encounters originating from the UMGL. Inset map on lower left shows data from the entire breeding range.

CLIMATE EXPOSURE

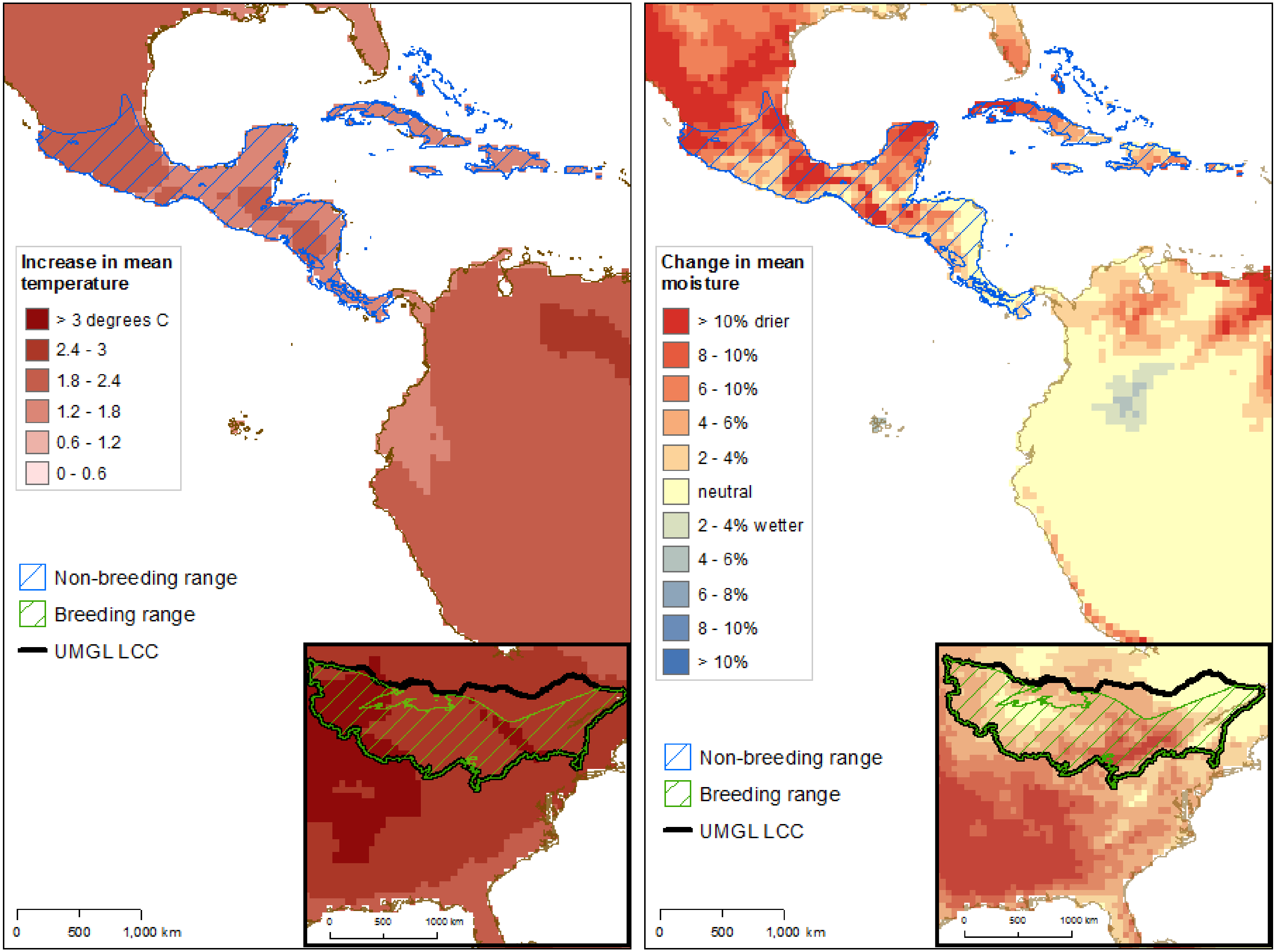


Figure 5.117. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Indigo Bunting's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

INDIGO BUNTING DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 5,858,023 km2; non-breeding = 1,413,101 km2
• PIF threats	(score = 2.1): breeding score = 2.1; non-breeding score = 2.0
• Breeding PIF conservation	(score = 2.3)
• Non-breeding PIF conservation	(score = 2.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 2374 km)
• Breeding habitat niche specialization	(score = 2.2) Macro habitats shrub (including scrubby second growth), weedy fields, edges and clearings, parks and orchards; nesting micro habitat shrubs and forbs (0.3-4.5 m high)
• Breeding diet niche specialization	(score = 2.4) Arthropods, seeds, fruit; captured by gleaning the ground, low vegetation, and sub-canopy
• Breeding site fidelity	(score = 3.0) Some (some individuals return to same site year after year, others do not, also late-arriving females may have bred elsewhere)
• Non-breeding habitat niche specialization	(score = 3.0) Grassland, agriculture and pasture, second growth scrub
• Non-breeding diet niche specialization	(score = 2.1) Primarily seeds (wide variety from grasses, forbs, trees), also fruit, buds, insects
iii. Climate Sensitivity	
• Breeding thermal range	(score = 1.0) 17.1° C
• Breeding precipitation range	(score = 4.0) 51 cm
• Non-breeding thermal range	(score = 2.5) 12.0° C
• Non-breeding precipitation range	(score = 4.0) 56 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.3% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 2.0) 1.8° C increase Mexico (score = 2.0) 1.8° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 3.0) 6.1% drier Mexico (score = 3.0) 7.4% drier Caribbean (score = 3.0) 6.2% drier C. America (score = 1.0) 3.8% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 0.8) Overall, shrublands may be moderately vulnerable due to woodland encroachment (USDA 2012, USFS 2013); forest edges may increase due to fire, pests, and disease (USFS 2013); zero vulnerability of agricultural fields, orchards, and parks
• Breeding biotic interaction vulnerability	(score = 1.3) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); potential changes to abundance and phenology of seeds and fruit largely unknown but may be very little
• Non-breeding habitat vulnerability	(score = 0.7) Not much information is available on vulnerability of tropical grasslands due to climate change; very little vulnerability of second-growth scrub forest as these habitats may increase in area (Khatun et al. 2013); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 1.3) Vulnerability of arthropods in the tropics largely unknown, but there may be some; potential changes to abundance and phenology of seeds and fruit largely unknown but may be very little

5.41. Dickcissel
(Spiza americana)

USFWS Region 3 status: conservation concern
AOU number: 6040
AOU abbreviation: DICK

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.6	**3.5**	**3.2**	**3.2**	**2.6**	**3.4**	**0.9**	**3.0**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Dickcissel was moderate, scoring 2.6 out of 5.0. Temperature increases on the UMGL breeding grounds (exposure × sensitivity) was the largest contributor, which was driven by a high sensitivity to temperature change during summer and the prediction that mean summer temperature will be 3.0° C hotter by 2050. The adaptive capacity category was also a large contributor, driven by year-round habitat specialization and an entirely grainivorous diet during the non-breeding season. Fortunately, grassland and agricultural habitat used during the breeding season was not expected to be particularly vulnerable to climate change. This helped to lower the indirect effects subscore. However, we could not find information regarding vulnerability of tropical grasslands, and this limited our assessment of indirect effects. More research of the non-breeding grounds is needed to complete our understanding of Dickcissel vulnerability. Other large contributors to vulnerability included temperature change on the S. American non-breeding grounds, drying on the UMGL breeding grounds and the Mexican non-breeding grounds (Figure 5.118), and background risk. This suggests that both climate-change and factors unrelated to climate change may be priorities for conservation. Further, it appears that climate change on UMGL breeding grounds, S. American non-breeding grounds, and Mexican non-breeding grounds may work synergistically to increase Dickcissel vulnerability. We have very little connectivity information for Dickcissels from banding data and no breeding to non-breeding encounters from the UMGL (Figure 5.119). In addition, we found no information from the literature. Consequently, we were unable to deduce possible migratory connectivity with the UMGL, and we maintained a broad approach in our analysis. Work on this topic would improve our understanding of vulnerability for the species by allowing us to focus our analysis on the most appropriate non-breeding regions.

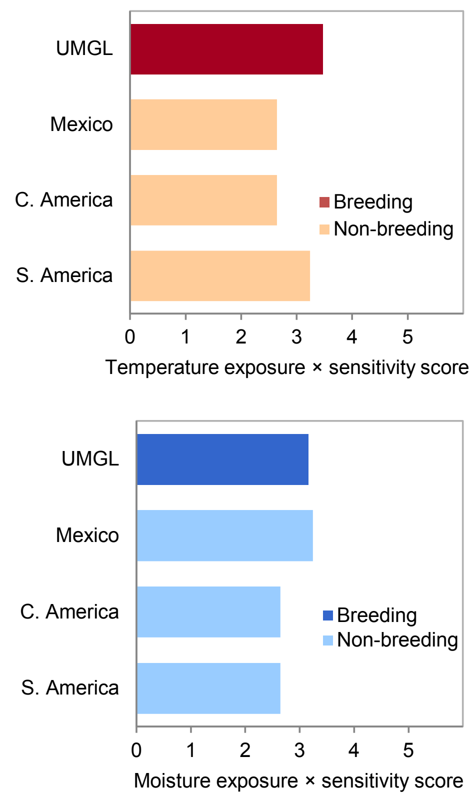


Figure 5.118. Dickcissel subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

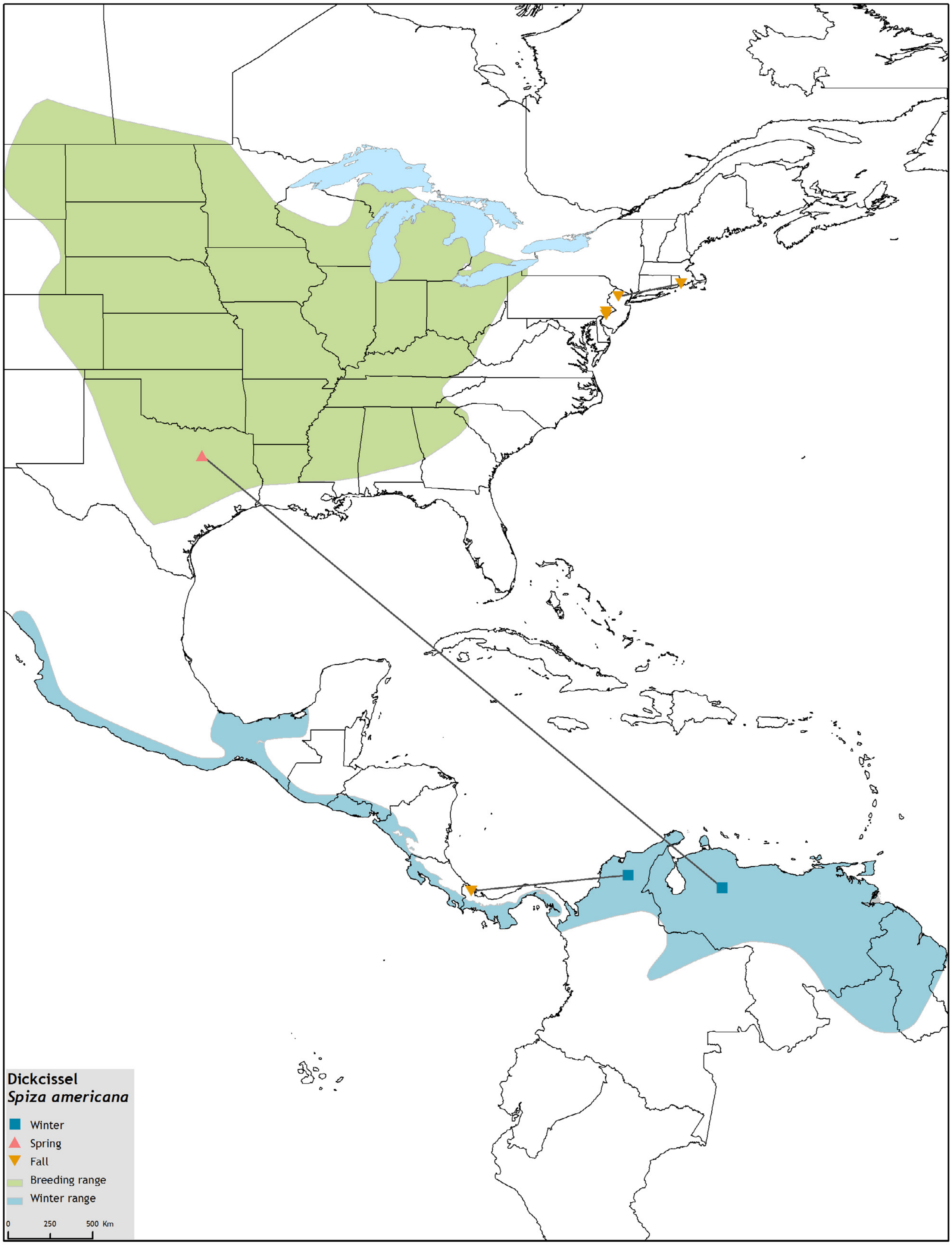


Figure 5.119. Dickcissel banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green. There were no breeding to stationary non-breeding encounters from the UMGL.

CLIMATE EXPOSURE

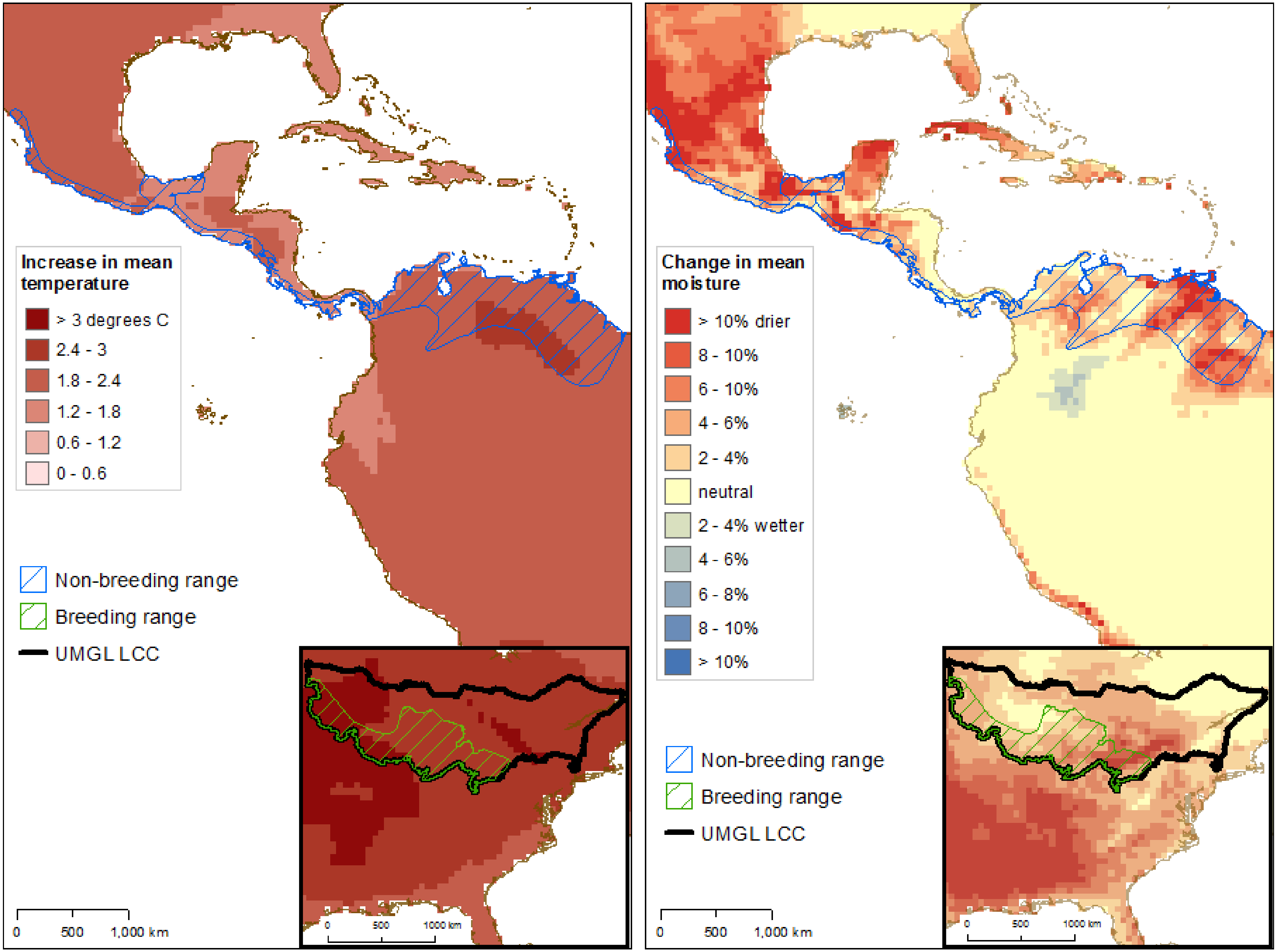


Figure 5.120. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Dickcissel's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

DICKCISSEL DATA

i. Background Risk	
• Quasi-extinction risk	(score = 3.0) 0.19 probability (95% CI = 0.01, 0.75)
• Range size	(score = 2.0) breeding = 3,458,339 km2; non-breeding = 1,074,777 km2
• PIF threats	(score = 4.0) breeding score = 3.2; non-breeding score = 4.0
• Breeding PIF conservation	(score = 3.0)
• Non-breeding PIF conservation	(score = 2.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 3024 km)
• Breeding habitat niche specialization	(score = 4.2) Macro habitats grassland (including prairie), old agricultural fields and pastures; nesting micro habitat low vegetation (0-0.5 m high)
• Breeding diet niche specialization	(score = 3.2) Arthropods and seeds; captured by gleaning the ground and grass
• Breeding site fidelity	(score = 2.0) No fidelity to some fidelity (in core of range fidelity is high but on edges it's low, described as erratic and somewhat nomadic)
• Non-breeding habitat niche specialization	(score = 4.0) Grassland (llanos), agriculture
• Non-breeding diet niche specialization	(score = 3.7) Seeds (mostly grasses)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 3.0) 11.4° C
• Breeding precipitation range	(score = 5.0) 23 cm
• Non-breeding thermal range	(score = 3.5) 8.3° C
• Non-breeding precipitation range	(score = 3.5) 59 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.9% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 2.1° C increase Mexico (score = 2.0) 1.8° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.2° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 5.4% drier Mexico (score = 3.0) 6.9% drier C. America (score = 2.0) 4.2% drier S. America (score = 2.0) 5.4% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 0.5) Very little vulnerability of grasslands although specific components may change or disappear, particularly in wet prairies (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); zero vulnerability of agriculture
• Breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); potential changes to abundance and phenology of seeds largely unknown but may be very little—especially in agricultural areas
• Non-breeding habitat vulnerability	(score = 0.5) Not much information is available on vulnerability of tropical grasslands due to climate change but it may be very little; zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 1.0) Potential changes to abundance and phenology of seeds largely unknown (see above)

5.42. Bobolink
(Dolichonyx oryzivorus)

USFWS Region 3 status: conservation concern
AOU number: 4940
AOU abbreviation: BOBO

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.6	**3.2**	**3.0**	**3.9**	**0**	**4.1**	**1.2**	**2.5**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Bobolink was moderate, scoring 2.6 out of 5.0. The adaptive capacity category was the largest contributor, which was driven by a combination of factors, including a very long distance migration, a very high degree of breeding site fidelity, and highly specialized habitat requirements during the breeding season. Fortunately, grassland and agricultural habitat on the breeding grounds was not expected to be particularly vulnerable to climate change and helped to lower the indirect effects subscore as well as total vulnerability. However, we have no information regarding vulnerability of tropical grasslands and many aspects of the Bobolink diet. This increased our uncertainty of the indirect effects category, and more research of the non-breeding grounds is needed. Other large contributors to vulnerability included temperature change on the S. American non-breeding grounds, temperature change on the UMGL breeding grounds, and moisture change on the UMGL breeding grounds (Figure 5.121). Bobolinks were particularly sensitive to temperature change during winter, and this was part of the reason S. American temperature had such a large effect. Bobolinks were also sensitive to moisture change during this time of year, but because their S. American non-breeding range is not expected to undergo much drying during winter, the effect was very small. The background risk subscore was moderate, suggesting that climate-change factors may be a priority for the species. Further, it appears that climate change on the UMGL breeding grounds and S. American non-breeding rounds may work synergistically to increase Bobolink vulnerability. We had very little connectivity information for Bobolinks from banding data, including no breeding to non-breeding encounters originating from UMGL (Figure 5.122). In addition, we found no information from the literature specific to UMGL. Consequently, we were unable to deduce possible migratory connectivity and included the entire S. American non-breeding range in analyses. Because the non-breeding range is small, however, our analyses remained somewhat specific. Nevertheless, work on this topic would help conservationists focus on non-breeding areas most critical to Bobolinks from UMGL and would help refine understanding of vulnerability.

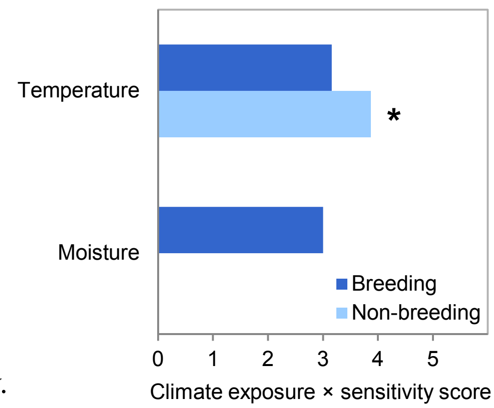


Figure 5.121. Bobolink subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb). *Non-breeding score 20% greater than breeding.

MIGRATORY CONNECTIVITY

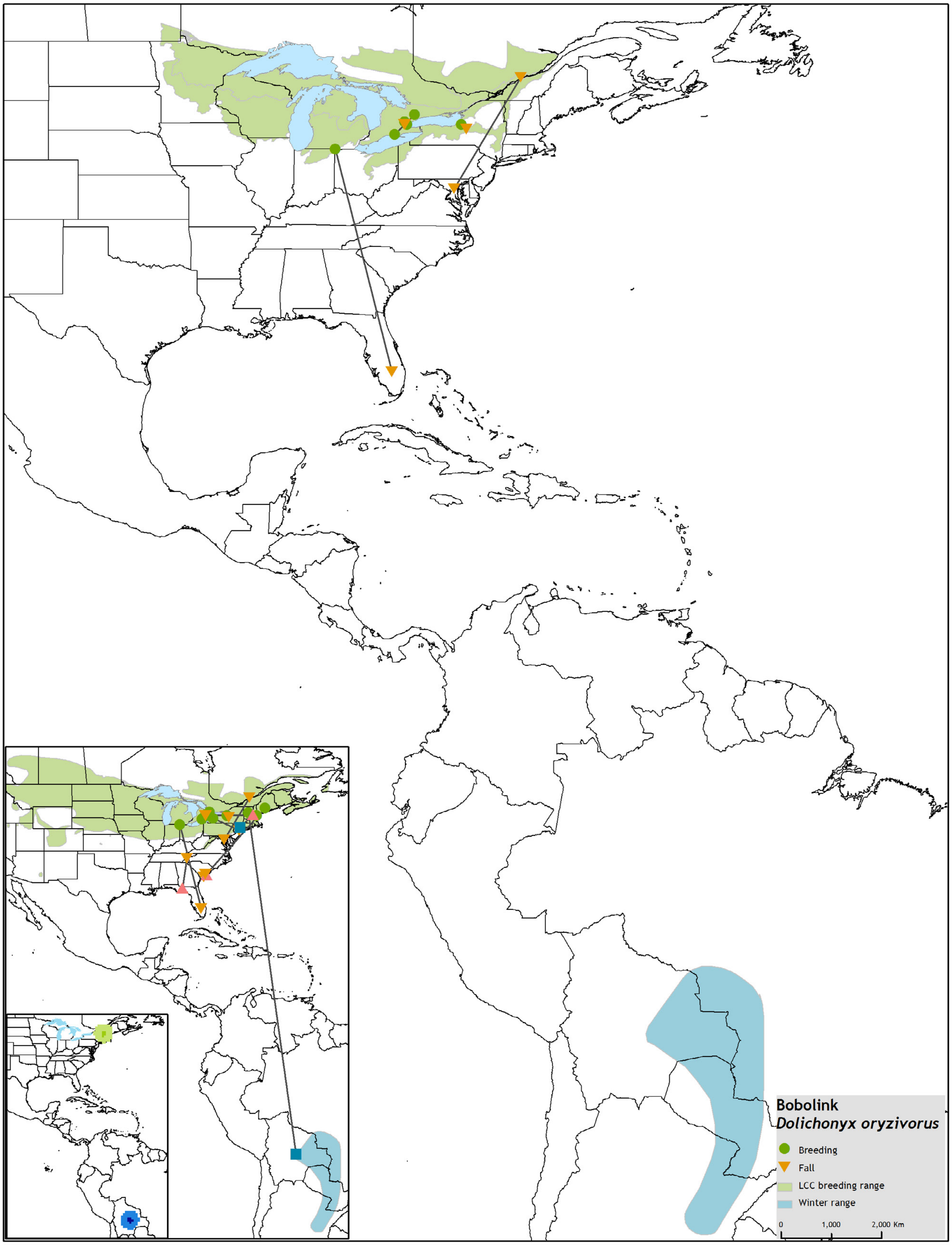


Figure 5.122. Bobolink banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Inset maps show data from the entire breeding range and concentration of breeding to stationary non-breeding data originating from the northeastern USA.

CLIMATE EXPOSURE

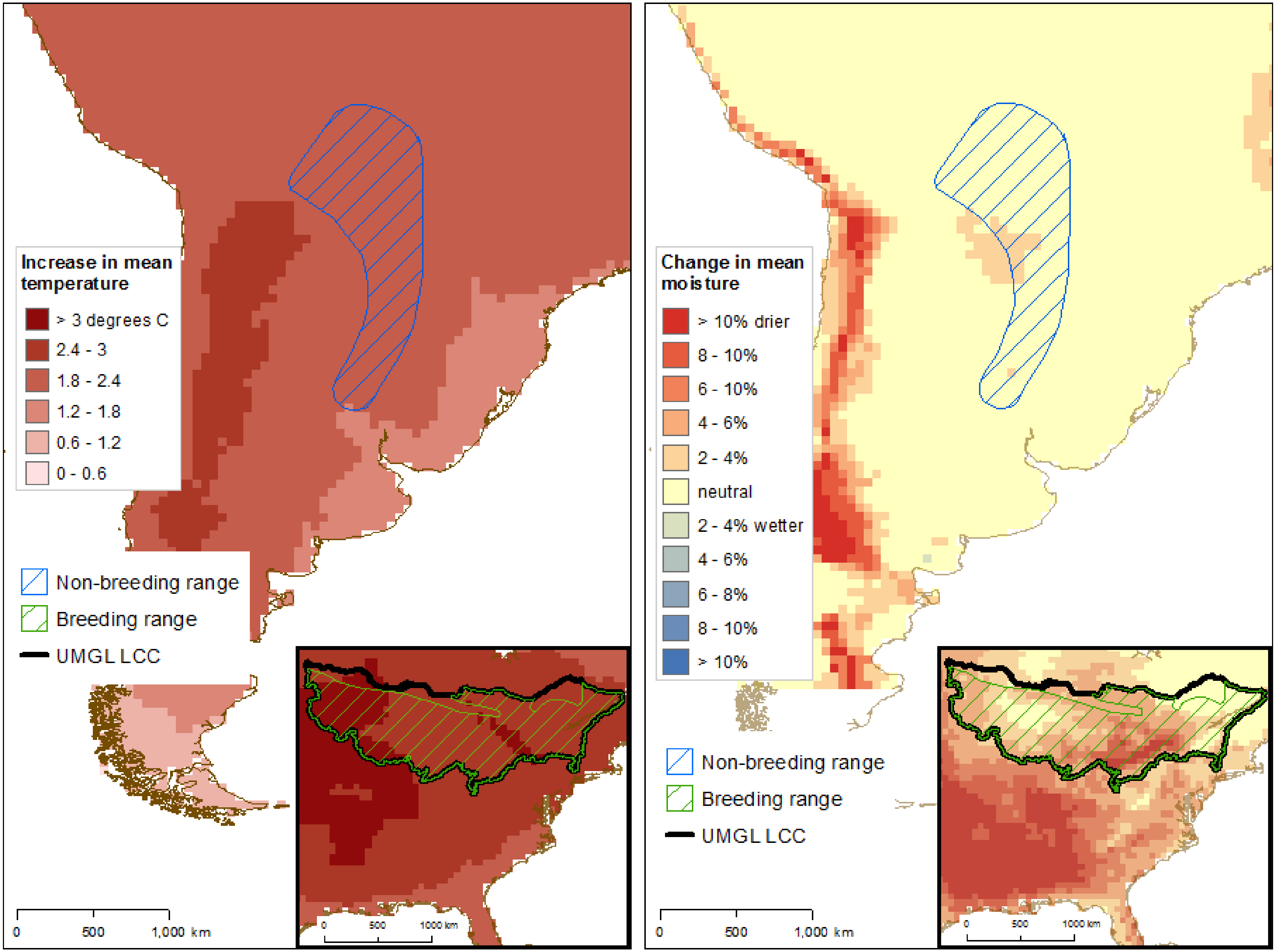


Figure 5.123. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Bobolink's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

BOBOLINK DATA

i. Background Risk	
• Quasi-extinction risk	(score = 3.0) 0.23 probability (95% CI = 0.003, 0.78)
• Range size	(score = 3.0) breeding = 3,873,291 km2; non-breeding = 900,390 km2
• PIF threats	(score = 3.5) breeding score = 3.5; non-breeding score = 3.0
• Breeding PIF conservation	(score = 4.1)
• Non-breeding PIF conservation	(score = 3.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 5.0) Long-distance migrant (mean distance = 7300 km)
• Breeding habitat niche specialization	(score = 4.5) Macro habitats grassland (including prairie), agriculture (old hay fields and large fields); nesting micro habitat ground at base of forbs (0 m high)
• Breeding diet niche specialization	(score = 3.5) Arthropods and seeds; captured by gleaning low vegetation
• Breeding site fidelity	(score = 5.0) High
• Non-breeding habitat niche specialization	(score = 3.0) Grassland (pampas), freshwater wetland, agriculture
• Non-breeding diet niche specialization	(score = 3.9) Seeds (many species of grasses, grain crops, and weeds)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.5) 12.3° C
• Breeding precipitation range	(score = 4.5) 30 cm
• Non-breeding thermal range	(score = 5.0) 3.1° C
• Non-breeding precipitation range	(score = 4.0) 36 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.3% drier
• Winter (Dec – Feb) non-breeding temperature	S. America (score = 3.0) 2.2° C increase
• Winter (Dec – Feb) non-breeding moisture	S. America (score = 0) 0.8% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 0.5) Very little vulnerability of grasslands although specific components may change or disappear, particularly in wet prairies (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); zero vulnerability of agriculture
• Breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); potential changes to abundance and phenology of seeds largely unknown but may be very little—especially in agricultural areas
• Non-breeding habitat vulnerability	(score = 1.7) Not much information is available on vulnerability of tropical grasslands due to climate change, but there may be very little; vulnerability of tropical freshwater wetlands may be high due to drying and re-vegetation; zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 1.0) Potential changes to abundance and phenology of seeds largely unknown but may be very little—especially in agricultural areas

5.43. Red-winged Blackbird
(Agelaius phoeniceus)

USFWS Region 3 status: common
AOU number: 4980
AOU abbreviation: RWBL

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
1.5	0	2.0	0	0	2.5	1.7	1.3

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Red-winged Blackbird was low, scoring 1.5 out of 5.0. The adaptive capacity category was the largest contributor, which was driven by a somewhat specialized diet throughout the year. Red-winged Blackbirds utilize wetland habitat during both breeding and non-breeding seasons, and this habitat was expected to be highly vulnerable to climate change. However, they also use several other habitat types that were not considered vulnerable, resulting in a low subscore for the indirect effects category. Red-winged Blackbirds were not particularly sensitive to temperature change during either breeding or non-breeding seasons. Consequently, temperature change on both the UMGL breeding grounds and the non-breeding grounds was not expected to have much effect on vulnerability. Drying on the non-breeding grounds was also not expected to have much effect, mostly because eastern N. American winters were only expected to be 1.2% drier by 2050 compared to current conditions. In contrast, moisture change on the UMGL breeding grounds was expected to have a moderate effect on vulnerability. The subscore for background risk was low, suggesting that adaptive capacity and moisture change during the breeding season may be a priority for Red-winged Blackbirds. We had 325 banding-encounter locations originating from the UMGL region for Red-winged Blackbirds (Figure 5.124). Most points were located in the southeastern USA (90%) and some in the northeastern USA (10%). This suggests most UMGL populations are migratory, but relatively short-distance migrants and winter in the eastern USA. We did not find any data to support connectivity with the southwestern USA, Mexico, or the Caribbean, and we excluded these regions from our vulnerability analysis. We did not find any information specific to the UMGL in the literature. Consequently, the USGS banding data are some of the first to endeavor into this complex topic. Further research will greatly improve our knowledge of the species and full-life cycle biology.

Red-winged Blackbird female at nest

MIGRATORY CONNECTIVITY

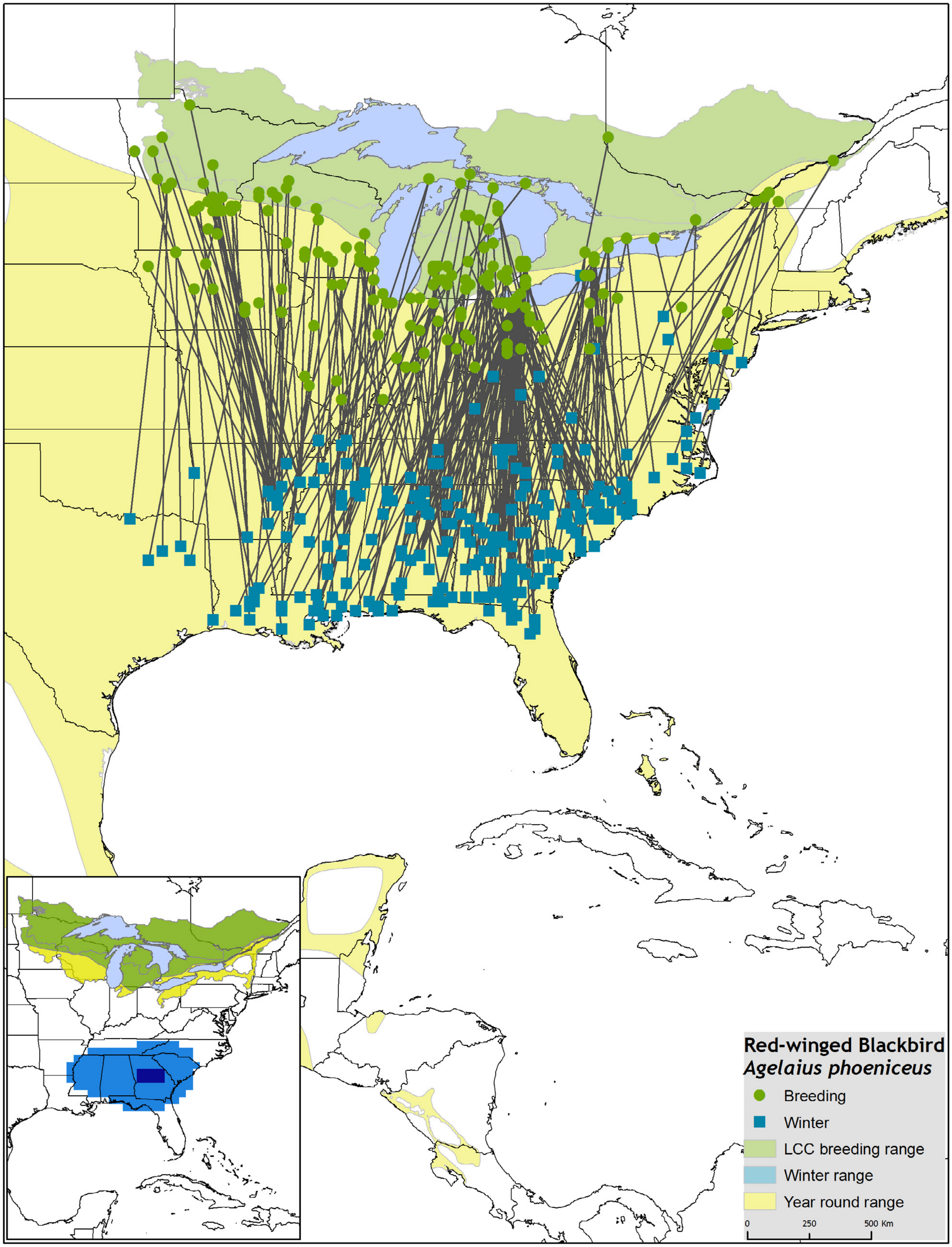


Figure 5.124. Red-winged Blackbird banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were 325 breeding to stationary non-breeding encounters from the UMGL, all of which were in the eastern USA. Inset map shows concentration of breeding to stationary non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

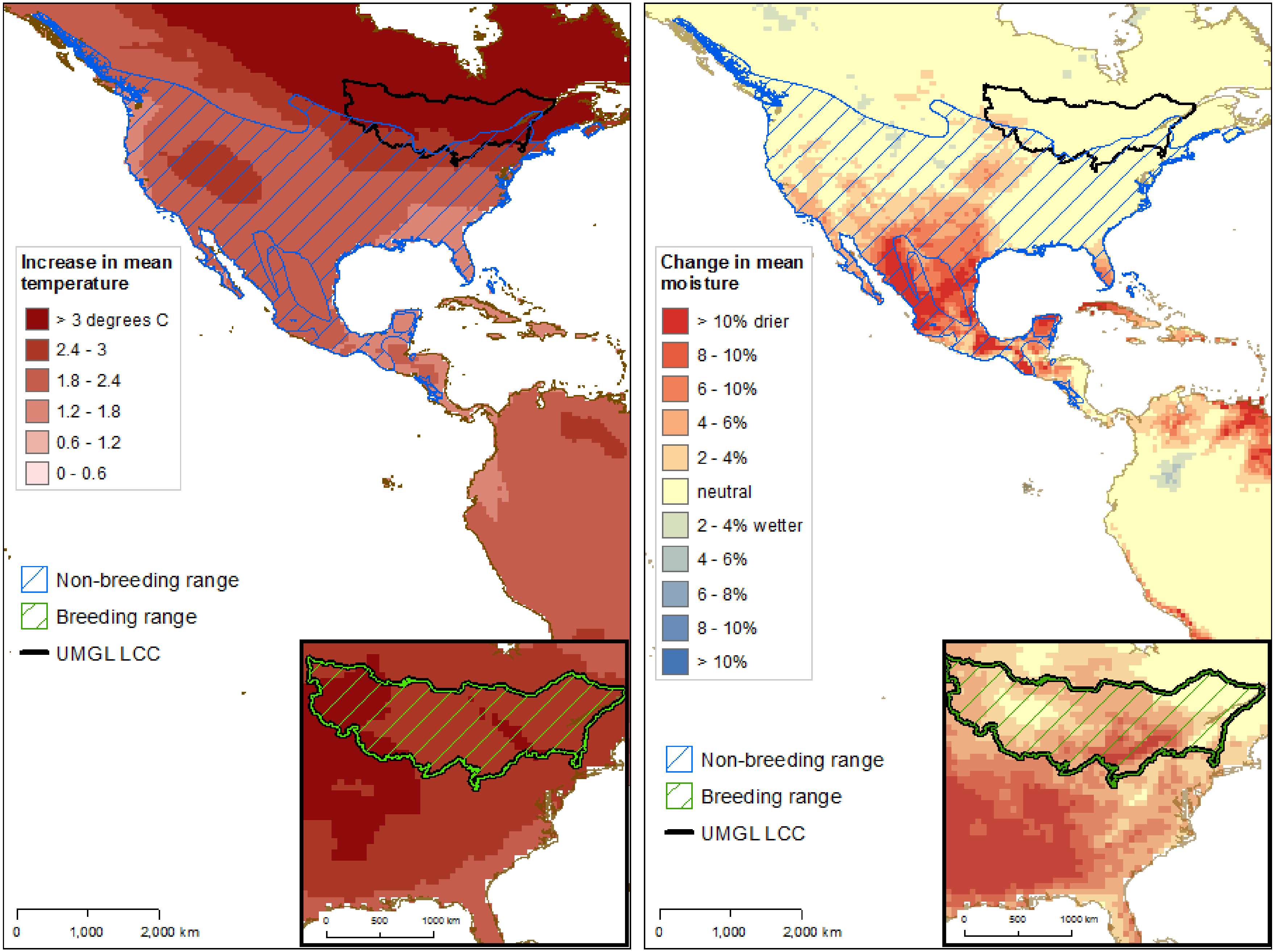


Figure 5.125. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Red-winged Blackbird's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

RED-WINGED BLACKBIRD DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 3,458,339 km2; non-breeding = 1,074,777 km2
• PIF threats	(score = 4.0) breeding score = 3.2; non-breeding score = 4.0
• Breeding PIF conservation	(score = 2.9)
• Non-breeding PIF conservation	(score = 2.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 2.0) Non-migrant, short-distance migrant, long-distance migrant (mean distance = 1263 km)
• Breeding habitat niche specialization	(score = 1.4) Macro habitats freshwater wetland, saltwater wetland, grassland, deciduous thickets, agriculture, parks; nesting micro habitat grasses/forbs, shrubs, and trees (0.3-2.5 m high)
• Breeding diet niche specialization	(score = 3.2) Arthropods and seeds; captured by gleaning the ground and wetland edges
• Breeding site fidelity	(score = 3.0) Some (evidence of females switching marshes between years)
• Non-breeding habitat niche specialization	(score = 2.0) Freshwater wetland, saltwater wetland, deciduous thicket, agriculture
• Non-breeding diet niche specialization	(score = 3.5) Seeds (diversity of grain crops, weeds, and forbs)
iii. Climate Sensitivity	
• Breeding thermal range	(score = 0) 25.6° C
• Breeding precipitation range	(score = 2.0) 110 cm
• Non-breeding thermal range	(score = 0) 35.6° C
• Non-breeding precipitation range	(score = 2.5) 90 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.0% drier
• Winter (Dec – Feb) non-breeding temperature	N. America (score = 3.0) 2.3° C increase
• Winter (Dec – Feb) non-breeding moisture	N. America (score = 0) 1.2% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 2.0) High vulnerability on freshwater wetlands due to drying and re-vegetation (Karl et al. 2009, Goulatowitsch et al. 2009, USDA 2012, USFS 2013); very high vulnerability on saltwater wetlands due to sea level rise (IPCC 2014); very little vulnerability of grasslands although specific components may change or disappear, particularly in wet prairies (Goulatowitsch et al. 2009, USDA 2012, USFS 2013); zero vulnerability of agriculture and park lands
• Breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); potential changes to abundance and phenology of seeds largely unknown but may be very little—especially in agricultural areas
• Non-breeding habitat vulnerability	(score = 2.3) High vulnerability on freshwater wetlands (see above); very high vulnerability on saltwater wetlands (see above); zero vulnerability of agriculture and park lands
• Non-breeding biotic interaction vulnerability	(score = 1.0) Potential changes to abundance and phenology of seeds largely unknown (see above)

5.44. Rusty Blackbird *(Euphagus carolinus)*

USFWS Region 3 status: conservation concern
AOU number: 5090
AOU abbreviation: RUBL

VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
3.0	2.8	2.1	1.2	0	4.0	3.1	3.3

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Rusty Blackbird was high, scoring 3.0 out of 5.0. The adaptive capacity category was the largest contributor, which was driven by a combination of factors, including a supposed high breeding site fidelity (though more research is needed on this topic), highly specialized habitat requirements throughout the year, and a highly specialized diet during the breeding season. The Rusty Blackbird's use of wet coniferous and mixed forests may be further exacerbated by the probability that these habitats may be highly vulnerable to climate change. In addition, their breeding diet of aquatic insects may also be highly vulnerable to climate change. Although, these factors increased the indirect effects subscore, non-breeding diet helped to ameliorate it. Rusty Blackbirds were highly sensitive to moisture change throughout the year, but moisture exposure was not expected to be very great on either the UMGL breeding grounds or the non-breeding grounds (3.5% and 1.2% drier, respectively). Although temperature exposure was expected to be great on the UMGL breeding grounds, Rusty Blackbirds were only moderately sensitive to temperature change during summer (they were not sensitive to temperature change during winter). Consequently, temperature exposure had a moderate effect on vulnerability during the breeding season and very little effect during the non-breeding season (Figure 5.126). The subscore for background risk was high, suggesting that both climate change and factors unrelated to climate change may be a priority for the species. We had very little connectivity information for Rusty Blackbirds from banding data, including just two breeding to non-breeding encounters originating from the UMGL (Figure 5.127). Both points went to the southeastern USA (Arkansas and Alabama). Research on stable isotopes links blackbird populations from parts of the UMGL to the Atlantic coastal plan, including South Carolina and Virginia (Hobson et al. 2010). Thus, we focused on eastern N. America for our analysis of non-breeding climate exposure. More research will help to fine tune these data and expand our knowledge of populations from other areas of the UMGL, thereby increasing our understanding of Rusty Blackbird conservation.

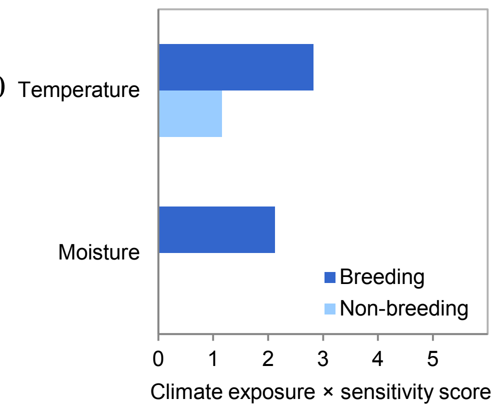


Figure 5.126. Rusty Blackbird subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

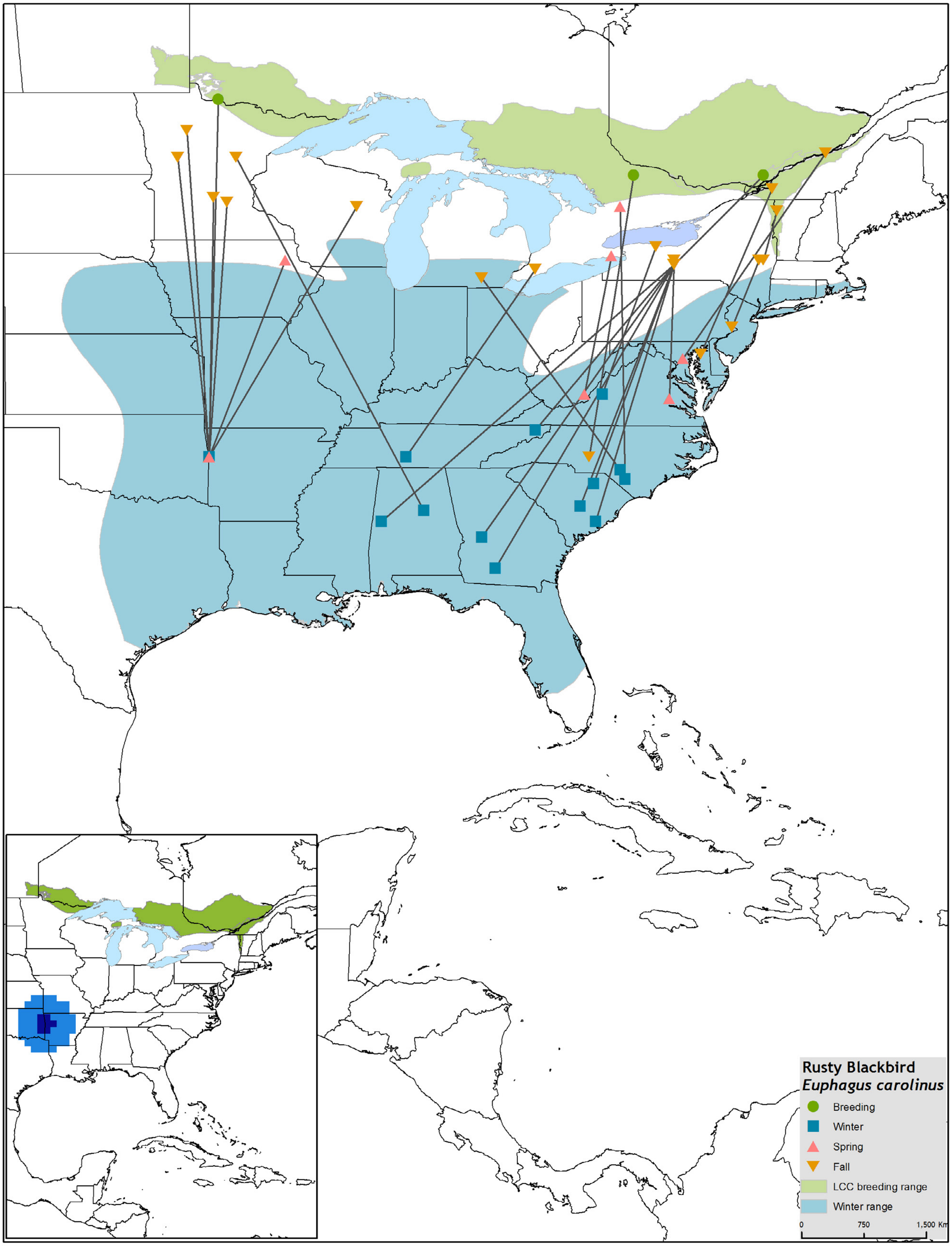


Figure 5.127. Rusty Blackbird banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were two breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentration of breeding to stationary non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

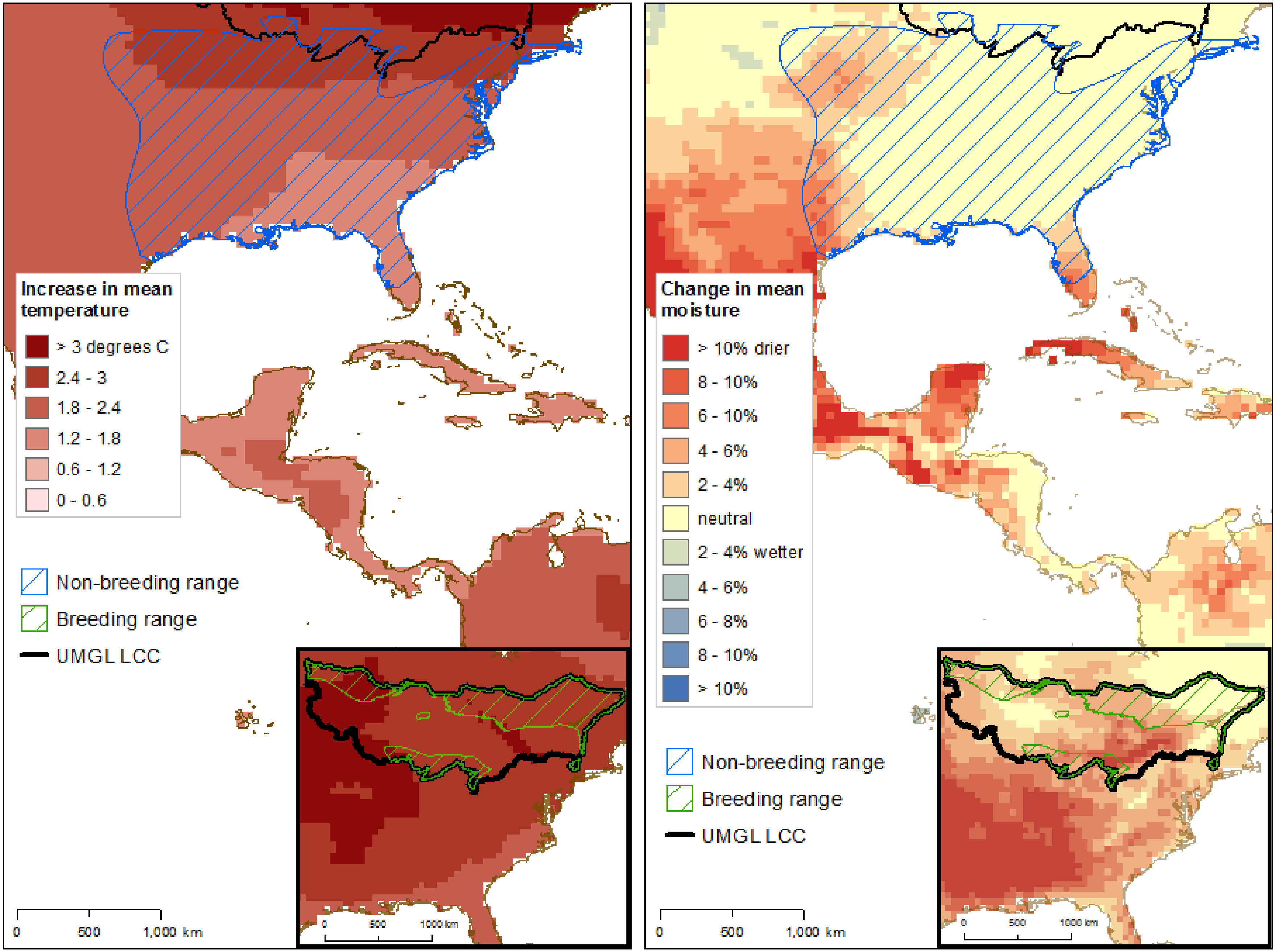


Figure 5.128. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Rusty Blackbird's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

RUSTY BLACKBIRD DATA

i. Background Risk	
• Quasi-extinction risk	(score = 5.0) 1.00 probability (95% CI = 1.00, 1.00)
• Range size	(score = 2.0) breeding = 7,237,426 km2; non-breeding = 2,643,685 km2
• PIF threats	(score = 3.0) breeding score = 2.8; non-breeding score = 3.0
• Breeding PIF conservation	(score = 2.8)
• Non-breeding PIF conservation	(score = 3.0)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Short-distance migrant (mean distance = 2333 km)
• Breeding habitat niche specialization	(score = 3.7) Macro habitats wet coniferous and mixed forest (may also use riparian zones); nesting micro habitat trees and shrubs near water (0.5-2.5 m high)
• Breeding diet niche specialization	(score = 4.2) Arthropods (especially aquatic arthropods and grasshoppers), seeds and nuts; captured by gleaning the ground
• Breeding site fidelity	(score = 5.0) No data available, but may be high
• Non-breeding habitat niche specialization	(score = 5.0) Wet woodlands
• Non-breeding diet niche specialization	(score = 3.2) Nuts and seeds (e.g. acorn, beech, pine, grain crops, weeds), fruit, wide variety of invertebrates
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.0) 14.5° C
• Breeding precipitation range	(score = 4.5) 28 cm
• Non-breeding thermal range	(score = 0.5) 20.2° C
• Non-breeding precipitation range	(score = 4.0) 37 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.8° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 1.0) 3.5% drier
• Winter (Dec – Feb) non-breeding temperature	N. America (score = 3.0) 2.2° C increase
• Winter (Dec – Feb) non-breeding moisture	N. America (score = 0) 1.2% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 4.0) High vulnerability of coniferous forest due to fire, pests, and hardwood succession (Bachelete et al. 2001, Goulatowitsch et al. 2009, Gonzalez et al. 2010, Joyce and Rehfeldt 2013, USFS 2013); high vulnerability of wet forests due to drying (Karl et al. 2009, Goulatowitsch et al. 2009, USFS 2013)
• Breeding biotic interaction vulnerability	(score = 3.0) Potential changes to abundance and phenology of nuts and seeds largely unknown but may be very little; masting of nuts may be resilient (mean temperature is not expected to affect mast frequency, though annual variability probably will, Kelley et al. 2012); moderate to very high vulnerability of aquatic arthropods, depending on whether it's a cold or warm-water species (Flebbe et al. 2006, Heino et al. 2009, Karl et al. 2009, Li et al. 2013); small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 4.0) High vulnerability of wet woodlands due to drying (USFS 2013)
• Non-breeding biotic interaction vulnerability	(score = 1.3) Potential changes to abundance and phenology of nuts and fruit largely unknown (see above); vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007)

5.45. Orchard Oriole
(Icterus spurius)

USFWS Region 3 status: conservation concern
AOU number: 5060
AOU abbreviation: OROR

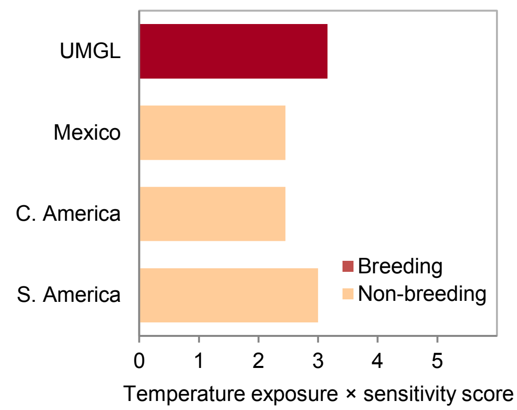
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.3	**3.2**	**2.8**	**3.0**	**2.4**	**3.0**	**1.3**	**2.0**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Orchard Oriole was moderate, scoring 2.3 out of 5.0. Temperature increases (exposure × sensitivity) on the UMGL breeding grounds was the largest contributor, mostly driven by a predicted rise in temperature of 3.0° C. Temperature increases on the S. American non-breeding grounds and drying on the Mexican non-breeding grounds also had large effects on vulnerability (Figure 5.129). The adaptive effects category was another large contributor, which was driven primarily by a supposed high degree of breeding site fidelity (though more research is needed on this topic). The habitat and diet requirements of Orchard Orioles were not expected to be particularly vulnerable to climate change, resulting in a low subscore for the indirect effects category. Background risk was moderate, suggesting that both climate change and factors unrelated to climate change may both be important. We had very little connectivity information for Orchard Orioles from banding data, including no breeding to non-breeding encounters originating from the UMGL (Figure 5.130). In addition, we found no information from the literature that was specific to the UMGL. Consequently, we were unable to deduce possible migratory connectivity, and we included the entire non-breeding range in our analysis. Work on this topic would help conservationists focus on non-breeding areas that are most critical to orioles from the UMGL and would help refine our understanding of vulnerability for the species.



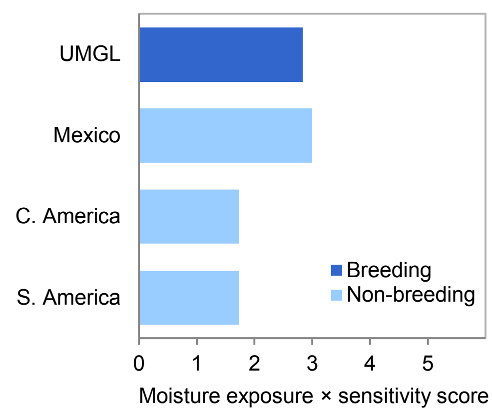


Figure 5.129. Orchard Oriole subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

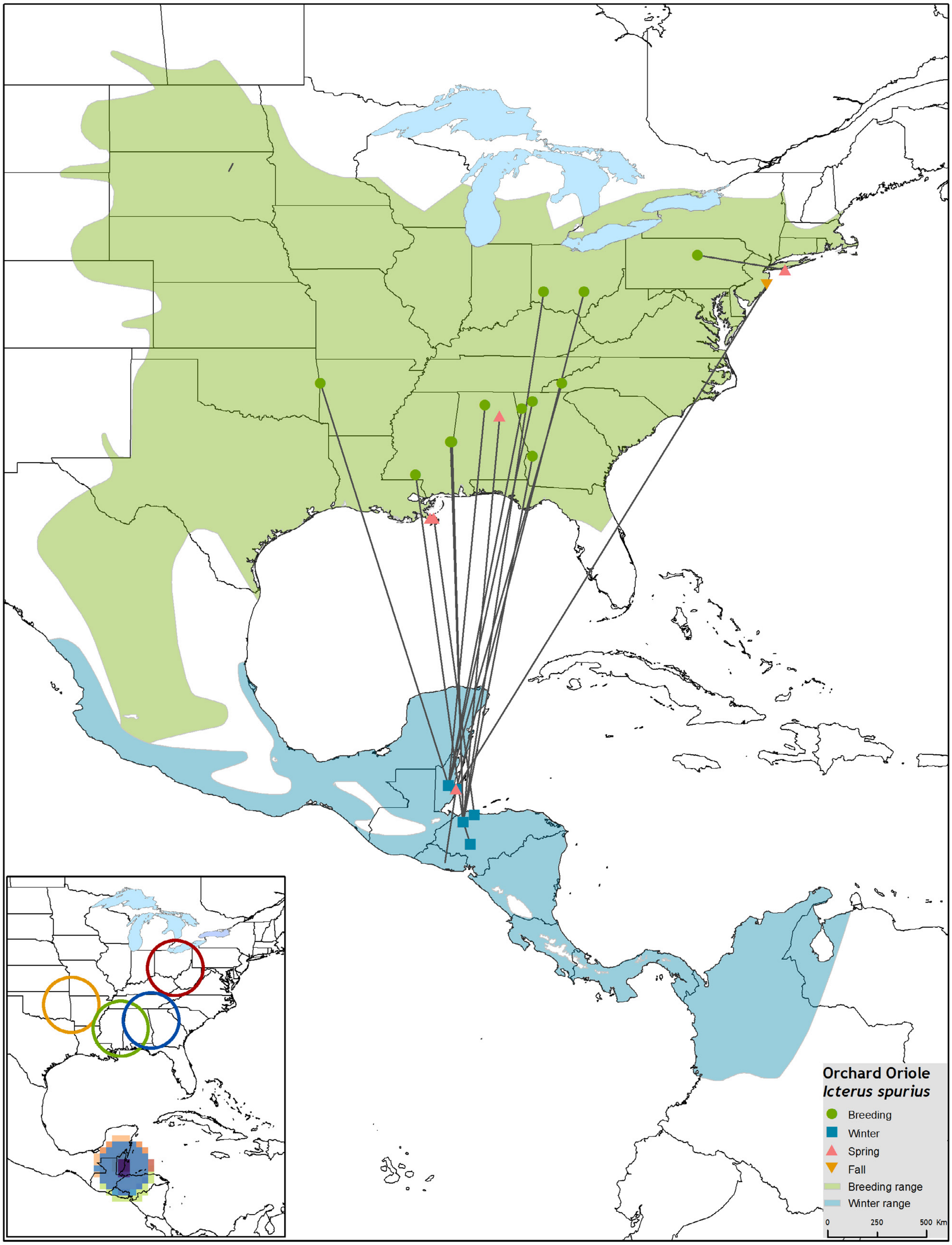


Figure 5.130. Orchard Oriole banding data from USGS Bird Banding Laboratory. The entire breeding range is shown in green in the main map. There were no breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentrations of breeding to stationary non-breeding encounters originating from four different breeding regions.

CLIMATE EXPOSURE

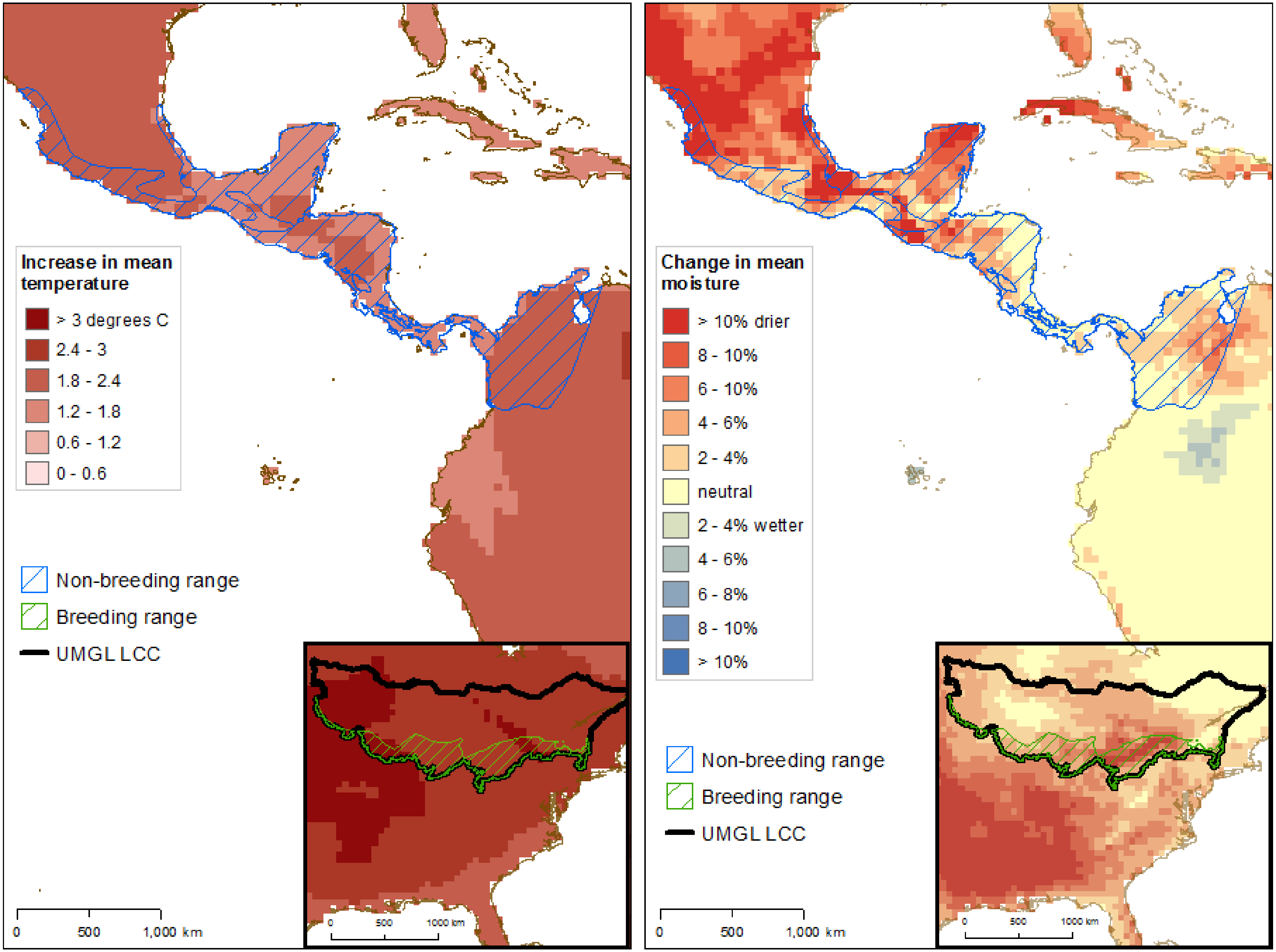


Figure 5.131. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Orchard Oriole's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

ORCHARD ORIOLE DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 4,788,158 km2; non-breeding = 1,424,755 km2
• PIF threats	(score = 3.0) breeding score = 3.0; non-breeding score = 2.0
• Breeding PIF conservation	(score = 2.3)
• Non-breeding PIF conservation	(score = 2.3)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Long-distance migrant (mean distance = 2346 km)
• Breeding habitat niche specialization	(score = 3.0) Macro habitats riparian, woodland, parks; nesting micro habitat trees (1-15 m high)
• Breeding diet niche specialization	(score = 2.4) Arthropods, fruit, nectar; captured by gleaning foliage near the ground and in the forest sub-canopy and mid-canopy
• Breeding site fidelity	(score = 5.0) No data available, but may be high
• Non-breeding habitat niche specialization	(score = 2.0) Woodland, tropical deciduous/scrub forest, agriculture and plantation, tropical evergreen/broadleaf forest
• Non-breeding diet niche specialization	(score = 2.4) Fruit, nectar, insects
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.5) 11.9° C
• Breeding precipitation range	(score = 4.0) 43 cm
• Non-breeding thermal range	(score = 3.0) 11.3° C
• Non-breeding precipitation range	(score = 3.0) 73 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 3.0° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 6.0% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.9° C increase Mexico (score = 2.0) 1.8° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.5% drier Mexico (score = 3.0) 7.1% drier C. America (score = 1.0) 3.4% drier S. America (score = 1.0) 2.9% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.2) Riparian vulnerability may depend on location with western riparian habitat highly vulnerable (Perry et al. 2012, USFS 2013) and eastern riparian habitat less vulnerable; very little vulnerability of woodlands, which are predicted to either remain stable or increase (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); zero vulnerability of park lands
• Breeding biotic interaction vulnerability	(score = 2.0) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); potential changes to abundance and phenology of fruit and nectar is largely unknown but may be very little; small mammalian nest predators are another potential biotic interaction, and these may increase in abundance with climate change, especially in warmer temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 0.8) Very little vulnerability of dry scrub forests and woodlands as these habitats may increase in area (Khatun et al. 2013); vulnerability of broadleaf/humid tropical forest may depend on location and forest type—stable in many areas due to high heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013); zero vulnerability of agricultural areas
• Non-breeding biotic interaction vulnerability	(score = 1.3) Potential changes to abundance and phenology of fruit and nectar largely unknown but may be very little; vulnerability of arthropods in the tropics largely unknown, but there may be some

5.46. Baltimore Oriole
(Icterus galbula)

USFWS Region 3 status: common
AOU number: 5070
AOU abbreviation: BAOR

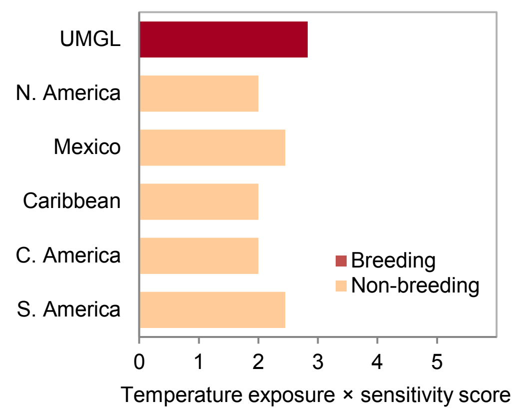
VULNERABILITY SCORES

Total Vulnerability	Breeding climate effect subscore		NB climate effect subscore		Adaptive capacity subscore	Indirect effects subscore	Background risk subscore
	Temperature change	Moisture change	Temperature change	Moisture change			
2.1	**2.8**	**3.2**	**2.4**	**2.4**	**2.9**	**1.2**	**1.8**

(maximum score of 5 for all columns)

SUMMARY

Total vulnerability for Baltimore Oriole was moderate, scoring 2.1 out of 5.0. Drying (exposure × sensitivity) on the UMGL breeding grounds was the largest contributor, mostly driven by a very high sensitivity to moisture change. Drying on the Mexican and Caribbean non-breeding grounds also had large effects on vulnerability (Figure 5.132). The adaptive effects category was driven primarily by a high degree of breeding site fidelity. Similar to the Orchard Oriole, the Baltimore Oriole's habitat and diet requirements were not expected to be particularly vulnerable to climate change. In fact, one aspect of their diet, large and toxic caterpillars, may increase. This resulted in a low subscore to the indirect effects category. Background risk was low, suggesting that climate change may be a priority. Further, it appears that moisture exposure throughout the year may be the biggest concern for this species. We had very little connectivity information for Baltimore Orioles from banding data, including just six breeding to non-breeding encounters originating from the UMGL (Figure 5.133). Most of these birds went to C. America while one went to Florida. We found no information from the literature that was specific to the UMGL. Consequently, we were unable to deduce possible migratory connectivity, and we included the entire non-breeding range in our analysis. Work on this topic would help conservationists focus on non-breeding areas that are most critical to orioles from the UMGL and would help refine our understanding of vulnerability for the species.



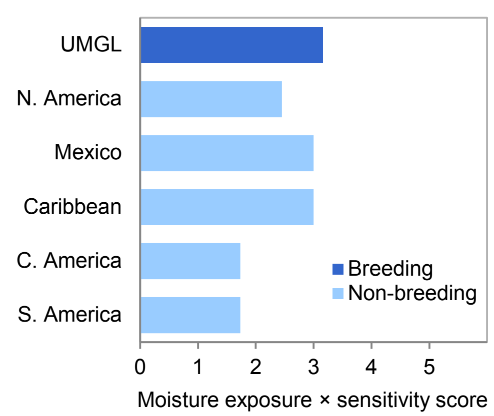


Figure 5.132. Baltimore Oriole subscores for climate exposure × sensitivity, breeding (Jun – Aug) and non-breeding regions (Dec – Feb).

MIGRATORY CONNECTIVITY

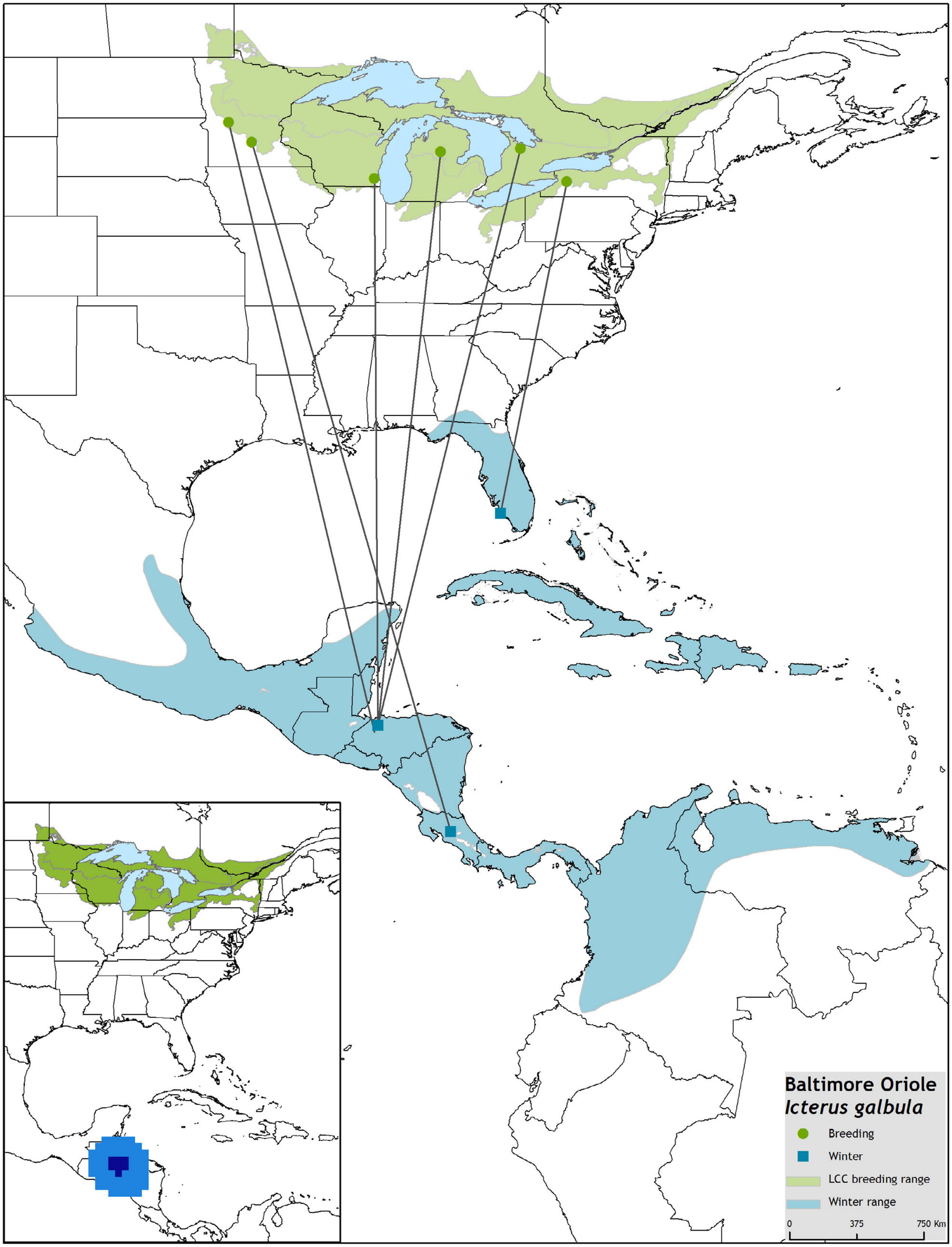


Figure 5.133. Baltimore Oriole banding data from USGS Bird Banding Laboratory. The UMGL breeding range is shown in green in the main map. There were only six breeding to stationary non-breeding encounters from the UMGL. Inset map shows concentration of stationary non-breeding encounters originating from the UMGL.

CLIMATE EXPOSURE

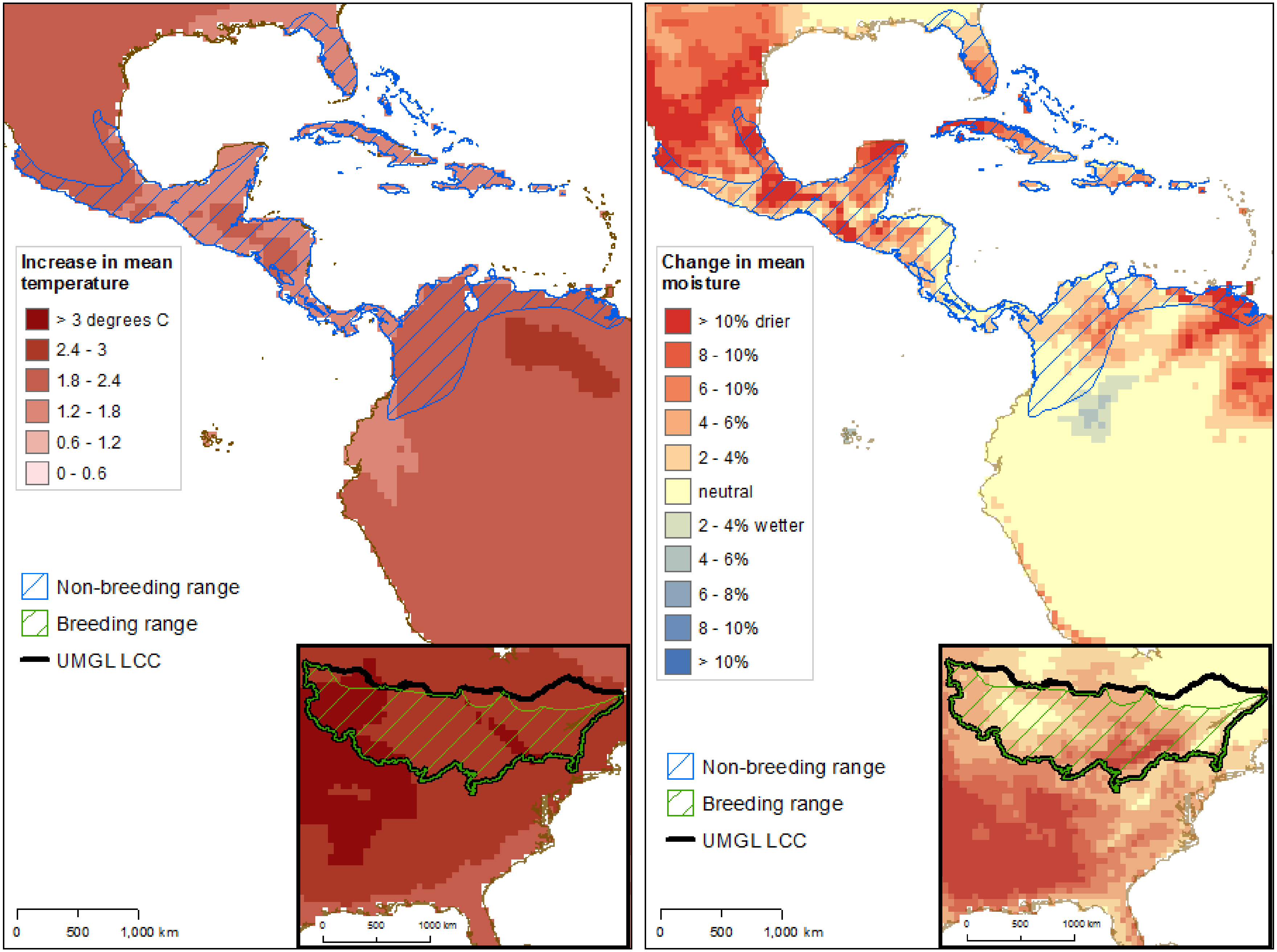


Figure 5.134. Mid-century (2040-2069) climate exposure during winter (Dec – Feb) on the Baltimore Oriole's non-breeding grounds (main maps) and during summer (Jun – Aug) on its breeding grounds in the Upper Midwest Great Lakes LCC (inset maps).

BALTIMORE DATA

i. Background Risk	
• Quasi-extinction risk	(score = 1.0) 0 probability (95% CI = 0, 0)
• Range size	(score = 2.0) breeding = 4,701,864 km2; non-breeding = 2,202,185 km2
• PIF threats	(score = 3.0) breeding score = 3.0; non-breeding score = 2.0
• Breeding PIF conservation	(score = 3.4)
• Non-breeding PIF	(score = 2.5)
ii. Adaptive Capacity	
• Migration strategy	(score = 3.0) Short-distance migrant, long-distance migrant (mean distance = 3177 km)
• Breeding habitat niche specialization	(score = 3.2) Macro habitats deciduous woodland edges, riparian, parks; nesting micro habitat trees (4.5-9 m high)
• Breeding diet niche specialization	(score = 2.4) Arthropods (including large, toxic, pest caterpillars), fruit, nectar; captured by gleaning foliage near the ground and in the forest sub-canopy and mid-canopy
• Breeding site fidelity	(score = 5.0) High (reports of strong site fidelity)
• Non-breeding habitat niche specialization	(score = 1.0) Humid/semi-humid woodland, urban gardens, arid scrub and second growth, shade coffee agriculture, broadleaf/evergreen forest, semi-arid forest
• Non-breeding diet niche specialization	(score = 2.4) Nectar, small fruits, insects
iii. Climate Sensitivity	
• Breeding thermal range	(score = 2.5) 14.7° C
• Breeding precip. range	(score = 5.0) 23 cm
• Non-breeding thermal range	(score = 2.0) 14.4° C
• Non-breeding precip. range	(score = 3.0) 73 cm
iv. Climate Exposure (mid-century predictions)	
• Summer (Jun – Aug) UMGL temperature	(score = 4.0) 2.9° C increase
• Summer (Jun – Aug) UMGL moisture	(score = 2.0) 4.4% drier
• Winter (Dec – Feb) non-breeding temperature	Entire non-breeding range (score = 3.0) 1.8° C increase N. America (score = 2.0) 1.6° C increase Mexico (score = 3.0) 1.8° C increase Caribbean (score = 2.0) 1.6° C increase C. America (score = 2.0) 1.8° C increase S. America (score = 3.0) 2.0° C increase
• Winter (Dec – Feb) non-breeding moisture	Entire non-breeding range (score = 2.0) 4.8% drier N. America (score = 2.0) 4.2% drier Mexico (score = 3.0) 7.0% drier Caribbean (score = 3.0) 6.2% drier C. America (score = 1.0) 3.7% drier S. America (score = 1.0) 3.6% drier
v. Indirect Effects	
• Breeding habitat vulnerability	(score = 1.2) Riparian vulnerability may depend on location with vulnerability higher in the west (Perry et al. 2012, USFS 2013); very little vulnerability of woodlands, which are predicted to remain stable or increase (Bachelet et al. 2001, Goulatowitsch et al. 2009, USFS 2013); zero vulnerability of park lands
• Breeding biotic interaction vulnerability	(score = 1.5) Vulnerability of arthropods in general largely unknown, but there may be some for native species (Chown et al. 2007); large toxic pest caterpillars expected to increase with climate change; potential changes to abundance and phenology of fruit and nectar largely unknown but may be very little; small mammalian nest predators may increase in abundance with climate change, especially in warm temperate regions (Karl et al. 2009, Johnston et al. 2012, Korpela et al. 2013)
• Non-breeding habitat vulnerability	(score = 0.7) Very little vulnerability of dry scrub forests, which may increase (Khatun et al. 2013); vulnerability of broadleaf/humid forest may depend on location and type—stable in places due to heat tolerance (Mahi et al. 2008, Gonzalez et al. 2010, Huntingford et al. 2013); no vulnerability of agriculture or urban areas
• Non-breeding biotic interaction vulnerability	(score = 1.3) Potential changes to abundance and phenology of fruit and nectar largely unknown but may be very little; vulnerability of arthropods in tropics largely unknown, but there may be some

6. References

Angert, A.L., L.G. Crozier, L.J. Rissler, S.E. Gilman, J.J. Tewksbury, and A.J. Chunco. 2011. Do species' traits predict recent shifts at expanding range edges? Ecology Letters 14: 677-689.

Association of Fish and Wildlife Agencies (AFWA). 2009. Voluntary Guidance for States to Incorporate Climate Change into State Wildlife Action Plans and Other Management Plans. The Voice of Fish and Wildlife Agencies, Washington D.C.

Bachelet, D., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2001. Climate Change Effects on Vegetation Distribution and Carbon Budget in the United States. Ecosystems 4: 164-185.

Both, C., and M.E. Visser. 2001. Adjustment to climate change is constrained by arrival date in a long-distance migrant bird. Nature 411: 296-299.

Boulet, M., H.L. Gibbs, and K.A. Hobson. 2006. Integrated Analysis of Genetic, Stable Isotope, and Banding Data Reveal Migratory Connectivity and Flyways in the Northern Yellow Warbler (Dendroica petechia; Aestiva group). Ornithological Monographs 61: 29-78.

Bronte, C.R., M.H. Hoff, O.T. Gorman, W.E. Thogmartin, P.J. Schneebergerup, and T.N. Todd. 2010. Decline of the Shortjaw Cisco in Lake Superior: The Role of Overfishing and Risk of Extinction. Transactions of the American Fisheries Society 139: 735-748.

Cahill, A.E., M.E. Aiello-Lammens, M.C. Fisher-Reid, X. Hua, C.J. Karanewsky, H.Y. Ryu, G.C. Sbeglia, F. Spagnolo, J.B. Waldron, O. Warsi, and J.J. Wiens. 2012. How does climate change cause extinction? Proc. R. Soc. B 280: 1750.

Chown, S.L., S. Slabber, M.A. McGeoch, C. Janion, and H.P. Leinaas. 2007. Phenotypic plasticity mediates climate change responses among invasive and indigenous arthropods. Proc. R. Soc. B. 274. DOI: 10.1098/rspb.2007.0772.

Cohen, E.B., J.A. Hostetler, A. Royle, and P.P. Marra. 2014. Estimating migratory connectivity of birds when re-encounter probabilities are heterogeneous. Ecology and Evolution 3: 1659-1670.

Cohen, E.B., Z. Németh, T. J. Zenzal Jr., K. Paxton, R. Diehl, E.H. Paxton, and F.R. Moore. 2015. Spring resource phenology and timing of songbird migration across the Gulf of Mexico. Pp. 54-74 in E. M. Wood and J. L. Kellermann (editors). Phenological synchrony and bird migration: changing climate and seasonal resources in North America. Studies in Avian Biology (no. 47).

COSEWIC. 2009. Canadian wildlife species at risk. Committee on the Status of Endangered Wildlife in Canada, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, Canada. [online] URL: www.cosewic.gc.ca/eng/sct5/index_e.cfm.

Dawson, T.P., S.T. Jackson, J.I. House, I.C. Prentice, and G.M. Mace. 2011. Beyond Predictions: Biodiversity Conservation in a Changing Climate. Science 332: 53-60.

DeMaster, D. (chair), R. Angliss, J. Cochrane, P. Mace, R. Merrick, M. Miller, S. Rumsey, B. Taylor, G. Thompson, and R. Waples. 2004. Recommendations to NOAA Fisheries: ESA Listing Criteria by the Quantitative Working Group, 10 June 2004. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-67, 85 p.

Dugger, K.M., J. Faaborg, W.J. Arendt, and K.A. Hobson. 2004. Understanding survival and abundance of overwintering warblers: does rainfall matter? The Condor 106:744-760.

Dunn, P.O., and D.W. Winkler. 1999. Climate change has affected the breeding date of tree swallows throughout North America. Proc. R. Soc. Lond. B 266: 1437.

Dunn, P.O., D.W. Winkler, L.A. Whittingham, S.J. Hannon, and R.J. Robertson. 2011. A test of the mismatch hypothesis: How is timing of reproduction related to food abundance in an aerial insectivore? Ecology 92: 450-461.

ESRI. 2010. ArcGIS. Version 9.3.1. ESRI Inc. (USA), Redlands, CA

Ewert, N.D., K.R. Hall, R.J. Smith, and P.G. Rodewald (in review). Landbird stopover in the Great Lakes region: Integrating habitat use and climate change in conservation. Studies in Avian Biology.

Fagan, W.F., and E.E. Holmes. 2006. Quantifying the extinction vortex. Ecology Letters 9: 51-60.

Feeley, K.J., Y. Malhi, P. Xelazowski, and M.R. Silman. 2010. The relative importance of deforestation, precipitation change, and temperature sensitivity in determining the future distributions and diversity of Amazonian plant species. Global Change Biology 18: 2636-2647.

Finch, D.M. (ed.). 2012. Climate change in grasslands, shrublands, and deserts of the interior American West: a review and needs assessment. Gen. Tech. Rep. RMRS-GTR-285. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 139 p.

Flebbe, P.A., L.D. Roghair, and J.L. Bruggink. 2006. Spatial Modeling to Project Southern Appalachian Trout Distribution in a Warmer Climate. Transactions of the American Fisheries Society. 135: 1371-1382.

Fuller, M.R., W.S. Seegar, and L.S. Schueck. 1998. Routes and Travel Rates of Migrating Peregrine Falcons Falco peregrinus and Swainson's Hawks (Buteo swainsoni) in the Western Hemisphere. Journal of Avian Biology 29: 433-440.

Galatowitsch, S., L. Frelich, and L. Phillips-Mao. 2009. Regional climate change adaptation strategies for biodiversity conservation in a midcontinental region of North America. Biological Conservation 142: 2021-2022.

Gardali, T., N.E. Seavy, R.T. DiGaudio, and L.A. Comrack. 2012. A Climate Change Vulnerability Assessment of California’s At-Risk Birds. PLoS ONE 7(3): e29507.

Geyer, J., I. Kiefer, S. Kreft, V. Chavez, N. Salafsky, F. Jeltsch, and P.L. Ibisch. 2011. Classification of climate-change-induced stresses on biological diversity. Conservation Biology 25: 708-715.

Gienapp, P., M. Lof, T.E. Reed, J. McNamara, S. Verhulst, and M.E. Visser. 2012. Predicting demographically sustainable rates of adaptation: can great tit breeding time keep pace with climate change? Phil. Trans. R. Soc. B 368.

Gill, F. B. 1995. Ornithology, 2nd ed. W. H. Freeman, New York, NY. 720 p.

Gilman, E.L., J. Ellison, N.C. Duke, and C. Field. 2008. Threats to mangroves from climate change and adaptation options: A review. Aquatic Botany 89: 237-250.

Glick, P., B.A. Stein, and N.A. Edelson, editors. 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation, Washington, D.C.

Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. Global Ecol. Biogeogr. 19: 755-768.

Heino, J., R. Virkkala, and H. Toivonen. 2009. Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. Biol. Rev. 84: 39-54.

Hobson, K.A., R. Greenberg, S.L. Van Wilgenburg, and C. Mettke-Hofmann. 2010. Migratory Connectivity in the Rusty Blackbird: Isotopic Evidence from Feathers of Historical and Contemporary Specimens. The Condor 112: 778-788.

Hobson, K.A., S.H. deMent, S.L. Van Wilgenburg, and L.I. Wassenaar. 2009. Origins of American Kestrels Wintering at Two Southern U.S. Sites: An Investigation Using Stable-Isotope (δD, δ18O) Methods. Journal of Raptor Research 43: 325-337.

Holmes, R.T. 2007. Understanding population change in migratory songbirds: long-term and experimental studies of Neotropical migrants in breeding and wintering areas. Ibis 149: 2-13.

Huntingford, C., P. Zelazowski. D. Galbraith, L.M. Mercado, S. Sitch, R. Fisher, M. Lomas, A.P. Walker, C.D. Jones, B.B.B. Booth, Y. Malhi, D. Hemming, G. Kay, P. Good, S.L. Lewis, O.L. Phillis, O.K. Atkin, J. Lloyd, E. Gloor, J. Zaragoza-Castells, P. Meir, R. Betts, P.P. Harris, C. Nobre, J. Marengo, and P.M. Cox. 2013. Simulated resilience of tropical rainforests to CO2-induced climate change. Nature Geoscience 6: 268-273.

Huppop, O., and W. Winkel. 2006. Climate change and timing of spring migration in the long-distance migrant Ficedula hypoleuca in central Europe: the role of spatially different temperature changes along migration routes. Journal of Ornithology 147: 344-353.

Hurlbert, A.H., and Z. Liang. 2012. Spatiotemporal Variation in Avian Migration Phenology: Citizen Science Reveals Effects of Climate Change. PLoS ONE 7(2): e31662.

IPCC SRES. 2000. IPCC SRES, 2000: Special Report on Emissions Scenarios: Summary for Policymakers. A special report of IPCC Working Group III [O. Davidson and B. Metz (co-chairs)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2007. IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2014. IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jiguet, F., A.-S. Gadot, R. Julliard, S.E. Newson, and D. Couvet. 2007. Climate envelope, life history traits and the resilience of birds facing global change. Global Change Biology 13: 1672-1684.

Jiguet, F., R. Julliard, C.D. Thomas, O. Dehorter, S.E. Newson, and D. Couvet. 2006. Thermal range predicts bird population resilience to extreme high temperatures. Ecology Letters 9: 1321-1330.

Johnston, K.M., K. A. Freund, and O.J. Schmitz. 2012. Projected range shifting by montane mammals under climate change: implications for Cascadia's National Parks. Ecosphere 3 (11): 97.

Jones, J., D.R. Norris, M.K. Girvan, J.J. Barg, T.K. Kyser, and A.J. Robertson. 2008. Migratory connectivity and rate of population decline in a vulnerable songbird. The Condor 110: 538-544.

Jonzen, N., A. Linden, T. Ergon, E. Knudsen, J.O. Vik, D. Rubolini, D. Piacentini, C. Brinch, F. Spina, L. Karlsson, M. Stervander, A. Andersson, J. Waldenstrom, A. Lehikoinen, E. Edvardsen, R. Solvang, and N. Chr. Stenseth. 2006. Rapid Advance of Spring Arrival Dates in Long-Distance Migratory Birds. Science 312: 1959-1961.

Joyce, D.G., and G.E. Rehfeldt. 2013. Climatic niche, ecological genetics, and impact of climate change on eastern white pine (Pinus strobus L.): Guidelines for land managers. Forest Ecology and Management 295: 173-192.

Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press, Cambridge, NY.

Kearney, M., R. Shine, and W.P. Porter, 2009. The potential for behavioral thermoregulation to buffer "cold-blooded" animals against climate warming. Proceedings of the National Academy of Sciences 106: 3835-3840.

Kelley, D., A. Geldenhuis, A. James, E.P. Holland, M.J. Plank, R.E. Brockie, P.E. Cowan, G.A. Harper, W.G. Lee, M.J. Maitland, A.F. Mark, J.A. Mills, P.R. Wilson, and A.E. Byrom. 2012. Of mast and mean: differential-temperature cue makes mast seeding insensitive to climate change. Ecology Letters 16: 90-98.

Kelly, J.F., K.C. Ruegg, and T.B. Smith. 2005. Combining isotopic and genetic markers to identify breeding origins of migrant birds. Ecological Applications 15: 1487-1494.

Khatun, K., P. Imbach, and J.C. Zamora. 2013. An assessment of climate change impacts on the tropical forests of Central America using the Holdridge Life Zone (HLZ) land classification system. iForest 6: 183-189.

Klausmeyer, K.R., and M.R. Shaw. 2009. Climate Change, Habitat Loss, Protected Areas and the Climate Adaptation Potential of Species in Mediterranean Ecosystems Worldwide. PLoS ONE 4(7): e6392.

Korpela, K., M. Delgado, H. Henttonen, E. Korpimaki, E. Koskela, O. Ovaskainen, H. Pietiainen, J. Sundell, N.G. Yoccoz, and O. Huitu. 2013. Nonlinear effects of climate on boreal rodent dynamics: mild winters do not negate high-amplitude cycles. Global Change Biology 19: 697-710.

Lande, R., S. Engen, and B.E. Saether. 2003. Stochastic population dynamics in ecology and conservation. Oxford University Press.

Li, F., N. Chung, M.-J. Bae, Y.-S. Kwon, T.-S. Kwon, and Y.-S. Park. 2013. Temperature change and macroinvertebrate biodiversity: assessments of organism vulnerability and potential distribution. Climate Change 119: 421-434.

Lovette, I.B., S.M. Clegg, and T.B. Smith. 2004. Limited utility of mtDNA markers for determining connectivity among breeding and overwintering locations in three Neotropical migrant birds. Conservation Biology 18: 156-166.

Mace, G.M., and R. Lande. 1991. Assessing Extinction Threats: Toward a Reevaluation of IUCN Threatened Species Categories. Conservation Biology 5: 148-157.

Maclean, I.M.D., and R.J. Wilson, 2011. Recent ecological responses to climate change support predictions of high extinction risk. Proceedings of the National Academy of Sciences 108: 12337-12342.

Malhi, Y., J.T. Roberts, R.A. Betts, T.J. Killeen, W. Li, and C.A. Nobre. 2008. Climate Change, Deforestation, and the Fate of the Amazon. Science 319: 169-172.

Marra, P.P., C.M. Francis, R.S. Mulvihill, and F.R. Moore. 2005. The influence of climate on the timing and rate of spring bird migration. Oecoligia 142: 307-315.

Marra, P.P., D.R. Norris, S.M. Haig, M. Webster, and J.A. Royle. 2006. Migratory connectivity. CONSERVATION BIOLOGY SERIES-CAMBRIDGE-14. 157 p.

Marra, P.P., K.A. Hobson, and R.T. Holmes. 1998. Linking Winter and Summer Events in a Migratory Bird by Using Stable-carbon Isotopes. Science 282: 1884-1887.

McClure, M.M., E.E. Holmes, B.L. Sanderson, and C.E. Jordan. 2003. A large-scale, multispecies status assessment: anadromous salmonids in the Columbia River Basin. Ecological Applications 964.

Moller, A.P., D. Rubolini, and E. Lehikoinen. 2008. Populations of migratory bird species that did not show a phenological response to climate change are declining. Proceedings of the National Academy of Sciences 105: 16195-15200.

Moussus, J.-P., J. Clavel, F. Jiguet, and R. Julliard. 2011. Which are the phenologically flexible species? A case study with common passerine birds. Oikos 120: 991-998.

National Fish, Wildlife and Plants Climate Adaptation Partnership. 2012. National Fish, Wildlife and Plants Climate Adaptation Strategy. Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. Washington, D.C.

Nebel, S., A. Mills, J.D. McCracken, and P.D. Taylor. 2010. Declines of aerial insectivores in North America follow a geographic gradient. Avian Conservation and Ecology. 5(2): 1.

Neelin, J. David, M. Munnich, H. Su, J.E. Meyerson, and C.E. Holloway. 2006. Tropical Drying Trends in Global Warming Models and Observations. Proceedings of the National Academy of Sciences USA 103: 6110-6115.

Norris, D.R., P.P. Marra, G.J. Bowen, L.M. Ratcliffe, J.A. Royle, and T.K. Kyser. 2006. Migratory Connectivity of a Widely Distributed Songbird, the American Redstart (Setophaga ruticilla). Ornithological Monographs 61: 14-28.

North American Bird Conservation Initiative (NABCI). 2009. The State of the Birds: United States of America 2009.

North American Bird Conservation Initiative (NABCI). 2010. The State of the Birds: United States of America 2010.

Parmesan, C. 2006. Ecological and Evolutionary Responses to Recent Climate Change. Annual Review of Ecology, Evolution, and Systematics 37: 637-669.

Paxton, K.L., E.B. Cohen, E.H. Paxton, Z. Németh, and F.R. Moore. 2014. Climatic variability at over-winter sites in Caribbean-Central and South America differentially affects intercontinental migrants during spring migration. PLoS One 9: e95383.

Percy, K.E., C.S. Awmack, R.L. Lindroth, M.E. Kubiske, B.J. Kopper, J.G. Isebrands, K.S. Pregitzer, G.R. Hendrey, R.E. Dickson, D.R. Zak, E. Oksanen, J. Sober, R. Harrington, and D.F Karnosky. 2002. Altered performance of forest pests under atmospheres enriched by CO2 and O3. Nature 420: 403-407. [online] URL: www.nature.com/nature/journal/v420/n6914/abs/nature01028.html.

Perry, L.G., P.B. Shafroth, D.M. Blumenthal, J.A. Morgan, and D.R. LeCain. 2012. Elevated CO2 does not offset greater water stress predicted under climate change for native and exotic riparian plants. New Phytologist 197: 532-543.

Poole, A. 2005. The birds of North America online. Cornell Laboratory of Ornithology, Ithaca, NY.

Potter, B.A., R.J Gates, G.J. Soulliere, R.P. Russell, D.A. Granfors, and D.N. Ewert. 2007. Upper Mississippi River and Great Lakes Region Joint Venture Shorebird Habitat Conservation Strategy. U.S. Fish and Wildlife Service, Fort Snelling, MN. 101 p.

Pryor, S.C., D. Scavia, C. Downer, M. Gaden, L. Iverson, R. Nordstrom, J. Patz, and G.P. Robertson. 2014. Climate Change Impacts in the United States: The Third National Climate Assessment, Ch. 18: Mid¬west. J.M. Melillo, Terese (T.C.) Richmond, and G.W. Yohe (eds.). U.S. Global Change Research Program, 418-440 p.

Punjabi, A.O., P.J. Blancher, R. Dettmers, and K.V. Rosenberg. 2012. Partners in Flight Technical Series No. 3, Version 2012. Rocky Mountain Bird Observatory [online] URL: www.rmbo.org/pubs/downloads/Handbook2012.pdf.

Rockwell, S.M., C.I. Bocetti, and P.P. Marra. 2012. Carry-over effects of winter climate on spring arrival data and reproductive success in an endangered migratory bird, Kirtland's Warbler (Setophaga kirtlandii). The Auk 129: 744-752.

Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig, and J. A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. Nature 421: 57-60.

Root, T.L., and S.H. Schneider. 2006. Conservation and Climate Change: The Challenges Ahead. Conservation Biology 20: 706-708.

Royle, J.A., and D.R. Ruberstein. 2004. The role of species abundance in determining breeding origins of migratory birds with stable isotopes. Ecological Applications 14: 1780-1788.

Rubenstein, D.R., C.P. Chamberlain, R.T. Holmes, M.P. Ayres, J.R. Waldbauer, G.R. Graves, and N.C. Tuross. 2002. Linking Breeding and Wintering Ranges of a Migratory Songbird Using Stable Isotopes. Science 295: 1062-1066.

Rushing, C.S., T.B. Ryder, J.F. Saracco, and P.P. Marra. 2014. Assessing migratory connectivity for a long-distance migratory bird using multiple intrinsic markers. Ecological Applications 445.

Ryder, T.B., J.W. Fox, and P.P. Marra. 2011. Estimating Migratory Connectivity of Gray Catbirds (Dumetella carolinensis) using Geolocator and Mark–recapture Data. The Auk 1228: 448-453.

Saino, N., D. Rubolini, N. Jonzen, T. Ergon, A. Montemaggiori, N. Chr. Stenseth, and F. Spina. 2007. Temperature and rainfall anomalies in Africa predicting timing of spring migration in trans-Saharan migratory birds. Clim. Res. 35: 123-134.

Salido, L., B.V. Purse, R. Marrs, D.E. Chamberlain, and S. Schultz. 2011. Flexibility in phenology and habitat use act as buffers to long-term population declines in UK passerines. Ecography 34: 001-010.

Sillett, T.S., and R.T. Holmes. 2002. Variation in Survivorship of a Migratory Songbird Throughout Its Annual Cycle. Journal of Animal Ecology 71: 296-308.

Small-Lorenz, S.L., L.A. Culp, T.B. Ryder, T.C. Will, and P.P. Marra. 2013. A blind spot in climate change vulnerability assessments. Nature Climate Change 3: 91-93.

Stakhiv, E.Z. 2011. Pragmatic Approaches for Water Management Under Climate Change Uncertainty. Journal of the American Water Resources Association 47: 1183-1196.

Stanley, C.Q., M. MacPherson, K.C. Fraser, E.A. McKinnon, and B.J.M. Stutchbury. 2012. Repeat Tracking of Individual Songbirds Reveals Consistent Migration Timing but Flexibility in Route. PLoS ONE 7(7): e40688.

Studds, C.E., and P.P. Marra. 2007. Linking fluctuations in rainfall to nonbreeding season performance in a long-distance migratory bird, Setophaga ruticilla. Clim. Res. 35: 115-122.

Studds, C.E., and P.P. Marra. 2011. Rainfall-induced changes in food availability modify the spring departure programme of a migratory bird. Proc. R. Soc. B 278: 3437-3443.

Stutchbury, B.J.M., E.A. Gow, T. Done, M. MacPherson, J.W. Fox, and V. Afanasyev. 2011. Effects of post-breeding moult and energetic condition on timing of songbird migration into the tropics. Proc. R. Soc. B 278: 131-137.

Thogmartin, W.E., M.G Knutson, and J.R. Sauer. 2006. Predicting Regional Abundance of Rare Grassland Birds with a Hierarchical Spatial Count Model. The Condor 108: 25-46.

Thorup, K., F. Korner-Nievergelt, E.B. Cohen, and S.R. Baillie. 2014. Large-scale spatial analysis of ringing and re-encounter data to infer movement patterns: A review including methodological perspectives. Methods in Ecology and Evolution.

Tovar, C., C.A. Arnillas, F. Cuesta, and W. Buytaert. 2013. Diverging Responses of Tropical Andean Biomes under Future Climate Conditions. PLoS ONE 8(5): e63634.

U.S. Environmental Protection Agency (EPA). 2009. A framework for categorizing the relative vulnerability of threatened and endangered species to climate change. National Center for Environmental Assessment, Washington, DC; EPA/600/R-09/011. Available from the National Technical Information Service, Springfield, VA [online] URL: www.epa.gov/ncea.

U.S. Fish and Wildlife Service (USFWS). 2009. Strategic Plan for Responding to Accelerating Climate Change.

Vegvari, Z., V. Bokony, Z. Barta, and G. Kovacs. 2010. Life history predicts advancement of avian spring migration in response to climate change. Global Change Biology 16: 1-11.

Vose, J.M., D.L. Peterson, and T. Patel-Weynand (eds.). 2013. Effects of Climatic Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector. Gen. Tech. Rep. PNW-GTR-870. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 282 p.

Webster, M.S., and P.P. Marra. 2005. The importance of understanding migratory connectivity and seasonal interactions. in: R. Greenberg and P.P. Marra (eds.). Birds of two worlds: the ecology and evolution of migration. Johns Hopkins University Press, Baltimore, MD. 199-209 p.

Webster, M.S., P.P. Marra, S.M. Haig, S. Bensch, and R.T. Holmes. 2002. Links between worlds: unraveling migratory connectivity. TRENDS in Ecology and Evolution 17: 76-83.

Williams, S.E., L.P. Shoo, J.L. Isaac, A.A. Hoffmann, and G. Langham. 2008. Towards an Integrated Framework for Assessing the Vulnerability of Species to Climate Change. PLOS Biol. 6(12): e325.

Wilson, S., S.L. LaDeau, A.P. Tottrup, and P.P. Marra. 2011. Range-wide effects of breeding- and nonbreeding-season climate on the abundance of a Neotropical migrant songbird. Ecology 92: 1789-1798.

Wires, L.R., S.J. Lewis, G.J. Soulliere, S.W. Matteson, D.V. Weseloh, R.P. Russell, and F.J. Cuthbert. 2010. Upper Mississippi Valley/Great Lakes Waterbird Conservation Plan. A plan associated with the Waterbird Conservation for the Americas Initiative. Final Report submitted to the U.S. Fish and Wildlife Service, Fort Snelling, MN.

Wolf, B. 2000. Global warming and avian occupancy of hot deserts; a physiological and behavioral perspective. Revista Chilena de Historia Natural 73: 395-400.

Young, B., E. Byers, K. Gravuer, K. Hall, G. Hammerson, and A. Redder. 2011. Guidelines for using the NatureServe climate change vulnerability index. NatureServe 2011, Arlington, VA.

Young, B.E., K.R. Hall, E. Byers, K. Gravuer, G. Hammerson, A. Redder, and K. and Szabo. 2012. Rapid assessment of plant and animal vulnerability to climate change. in: J. Brodie, E. Post, and D. Doak (eds.). Wildlife Conservation in a Changing Climate. University of Chicago Press, Chicago, IL. 129-152 p.

7. Index