Project Title: Predicting Effects of Climate Change on Riparian Obligate Species in the Southwestern United States

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1. Executive Summary

Riparian vegetation provides crucial habitat for wildlife and is a high conservation priority for land managers throughout the Southwest. Land-use practices have led to the widespread loss and degradation of riparian habitats, which are considered one of the most altered and vulnerable habitats in the world. Changes in the quality and distribution of riparian vegetation have resulted in the imperilment of dozens of riparian obligate species such as the endangered Southwestern Willow Flycatcher, and candidate species Yellow-billed Cuckoo and Northern Mexican Gartersnake. Riparian vegetation is heavily dependent on climatic conditions that affect ground and surface water derived from rainfall and snowpack. Climate change is predicted to have a severe effect on the Southwest by increasing the frequency and severity of drought, which will decrease water availability and negatively affect riparian health. A central scientific challenge is to generate quantitative predictions of how changes in water availability will affect the amount and quality of riparian wildlife habitat. The complex relationships linking riparian wildlife habitat to water are not completely understood and have not been synthesized into quantitative, predictive models. We recently developed models to predict and explain the future ranges of select upland bird and reptile species, with a focus on climate change as a driver of range change. This project was funded by the USGS National Climate Change and Wildlife Science Center (NCCWSC). Hydrologists have developed a variety of numerical models that characterize and predict hydrologic processes including flood recurrence intervals, surface-water flows, and ground-water levels and flows. Riparian ecologists understand many of the conditions and processes controlling the distribution and abundance of different types of riparian vegetation and have generated models relating different components of streamflow to response of individuals, populations, and communities. Remote sensing experts have developed GIS-based models that identify and quantify relations between wildlife and riparian habitat. These models allow for rapid and relatively inexpensive identification of potentially important habitat and could allow for linkage with hydrologic and geomorphic models. We propose to employ our methods developed during the NCCWSC project and use downscaled physical climate models to estimate the impacts of several climate change scenarios on surface and groundwater (Task A), riparian vegetation (Task B), and riparian dependent wildlife species (Task B). We will estimate linkages between physical and biological models to make predictions about how changes in climate and water management practices will affect riparian wildlife (Tasks B and C). Results of this work will be posted on a web-interface and will provide Reclamation and the partners involved in the Desert LCC with insights that will help them to better anticipate the nature and magnitude of climate-driven effects on riparian wildlife. Our results will also inform assessments of species resiliency and vulnerability, with implications for planning at the regional and continental scale (Task C). Of nearer term relevance, our results will enable managers to proactively manage riparian vegetation through restoration and enhancement activities and improved land-use planning (Task C).

2. Technical Project Description

GOALS:

- Efficiently realize additional gains from the major capital investment made in data, methods, skills, and other resources during our NCCWSC-supported efforts to develop models that predict the effects of climate change on upland wildlife, with application to riparian species
- Link hydrologic, geomorphic, and habitat models to better understand and predict how climate changes will affect critical riparian ecosystems in the region
- Provide management agencies with a decision support tool that provides scientific information required to restore, enhance, and mitigate effects of climate change on riparian vegetation and associated wildlife, as well as identify those areas that may be of greatest risk to predicted changes

MANAGEMENT NEEDS/ PROJECT CONTRIBUTIONS: Future climate variability and change is expected to reduce precipitation and water availability in the southwestern United States (Seager et al. 2007). Exacerbating this, human population growth in the Southwest is increasing at a rate faster than most other regions in the country (reviewed in Barnett et al. 2008). Surface-water supplies are fully allocated and a growing population is supported by increased groundwater use in much of the region. Riparian-obligate avian species are heavily dependent on the density and lushness of riparian vegetation (Greco et al. 2002), and ectotherms such as the Chiricahua Leopard Frog (*Lithobates chiricahuaensis*) depend on the availability of surface water (USFWS 2008, other species reviewed in Knopf et al. 1988). As the climate dries and droughts increase, riparian vegetation is likely to decrease in abundance and vigor, leading to decreased cover and humidity, and increased water temperatures. These changes are expected to cause a decline in riparian-obligate wildlife. A central scientific challenge is to generate quantitative predictions of how variability and changes in climate will affect the amount and quality of riparian wildlife habitat (Paxton et al. 2007), in terms that can be used by managers concerned with protecting riparian-obligate species in the future.

Riparian woodlands are crucial for wildlife throughout the Southwest (Johnson et al. 1985). There are hundreds of species that require riparian vegetation in this region, fulfilling a myriad of needs such as breeding, foraging, and shelter. Species of particular interest to wildlife managers in the Southwest are the endangered Southwestern Willow Flycatcher (Hatten and Paradzick 2003) and the candidate species Yellow-billed Cuckoo (Johnson et al. 2011) and Northern Mexican Gartersnake (*Thamnophis eques megalops*; USFWS 2008) and Chiricahua Leopard Frog. The flycatcher and cuckoo depend on healthy riparian woodlands and the snake and amphibian depend on healthy riparian and cienega habitat. The distribution and abundance of suitable riparian habitat depends on valley form (i.e., geomorphology), surface and groundwater availability, flow history (e.g., years since last scouring flood), and anthropogenic activities. These inherent and complex contingencies make predictions of future conditions difficult without proven modeling techniques.

Some linkages between climate and the condition of riparian vegetation have been made (e.g., Glenn et al. 2001), but not all pieces have been put together, particularly at the basin and regional scales. For example, hydrologists have developed a variety of tools, including numerical models, to characterize and predict hydrologic processes such as flood recurrence intervals,

surface-water flows, and groundwater levels and flows. Inputs to these models often include human-related factors such as groundwater withdrawals and land-use changes, and climate factors such as precipitation and groundwater recharge. The resulting simulations can be used to estimate the effects of various resource management actions (e.g., Leake et al. 2008) and climate patterns on availability of water to ecological systems. Geologists have developed conceptual and numerical models of sediment transport and sorting in valleys, and of channel morphologic adjustment--processes that determine the distribution of materials and landforms that comprise the substrate for riparian vegetation. Riparian ecologists understand many of the conditions and processes controlling the distribution and abundance of different types of riparian vegetation and have generated models relating different components of streamflow to response of individuals, populations, and communities (Merritt et al. 2009). Remote sensing experts have developed GIS-based models that help identify and quantify riparian habitat available to wildlife (Hatten and Paradzick 2003). These GIS-based models allow for rapid and relatively inexpensive identification of potentially important habitat that could allow for linkage with hydrologic and geomorphic models. However, integrating hydrologic, geomorphic, ecological, and remote sensing models is a challenging endeavor at the forefront of natural resource science, with important land and water management applications.

PROCEDURES/METHODS: We will employ methods developed during our NCCWSC project, "*Forecasting effects of climate change on federal and state managed wildlife within ecosystems of the arid Southwest"*, funded by USGS. The NCCWSC project is near completion, with an end-date of September14, 2012. Our NCCWSC project modeled upland bird and herpetofauna species. Here we propose to model riparian species, using many of the same methods. Unlike our NCCWSC project, this will involve acquiring hydrological data with which to build a GIS of geospatial variables to include in modeling each species (as described below). We propose to develop models that will address likely effects of climate change on riparian ecosystems. This approach will allow us to integrate empirical and theoretical models of hydrology, geomorphology, riparian vegetation, and wildlife habitat. These relationships can then be linked to regional-scale models of hydrology and geology to predict where high quality riparian habitat may occur, and where it may disappear under different climate change scenarios.

We will analyze relationships between hydrological and geomorphic variables and remotely sensed measures of vegetation vigor, such as the Normalized Difference Vegetation Index (NDVI), or other related vegetation indices (VIs), looking for consistent correlations that help explain the responses of these variables over the period of record; and relate VIs to select bird and herpetofauna species habitat and population data. Thus, our ultimate goal is to link the various models of water, geomorphology, and VIs in order to predict the effects of climate change and management decisions on wildlife habitat.

STUDY AREA: We propose to study two river reaches in the southwestern U.S. that have long-term datasets available (i.e., hydrological, geomorphological, biological), allowing analysis and modeling to proceed without significant data collection. These study reaches characterize a broad range of riparian conditions found in the Southwest, which is an important consideration for modeling. These sites are the Lower San Pedro River and the Verde River watershed, Arizona.

TASKS: Here we describe the projects tasks. The project schedule is shown in Table 1.

Task A - Select Focal Species: We will model the ranges of bird, reptile, and amphibian species for which we have sufficient data and ecological knowledge—enough data with enough coverage to support our quantitative work, and enough information on ecological relations to support the development of conceptual models. Candidate bird species include Southwestern Willow Flycatcher, Yellow-billed Cuckoo, Common Black-Hawk, and Gray Hawk. Candidate herpetofauna include Northern Mexican Gartersnake, Canyon Treefrog, Narrow-headed Gartersnake, and Lowland Leopard Frog, of which we will model 2 to 4 bird species, and 2 to 4 herpetofauna.

Task B - Develop Conceptual Models to Identify Candidate Explanatory Variables: We will develop conceptual models to synthesize, represent, and relate relevant life history information about focal species, as a basis for designing and interpreting our statistical habitat models. We will select focal species partly on the basis of whether existing information is sufficient to identify factors that conceivably determine its distribution. Conceptual models are not only a key means of disciplining our thinking, but also an efficient way to articulate hypotheses about how the world works in ways relevant to explaining why species occur where they do. In developing conceptual models, we carefully review the literature to identify a suite of factors likely to determine whether a species lived, died, or reproduced, along with any functional explanation. We then inter-relate these factors to form a logical picture of the determinants and contingencies of the species' distribution. We also identify the nature of prospective relations (positive or negative), and the likelihood of any interactions—requiring an interaction term in any statistical models. These conceptual maps will then be carefully followed in constructing candidate statistical models for explaining and predicting species ranges.

Task C - Build a GIS: For each species to be modeled we will build a GIS that contains spatially explicit data on species distributions, downscaled Global Circulation Model (GCM) data, hydrological data, and other candidate explanatory variables identified in our conceptual models.

Downscaled GCM data: We will apply a recently developed downscaled GCM modeling approach (Garfin et al. 2010, Cole et al. 2008) to simulate the effects of a changing climate (6 scenarios) on hydrology, riparian vegetation, and wildlife habitat over the next century. All of the GCM simulations (A1B carbon scenario) from the AR4 dataset (IPCC, 2007) have been evaluated on their ability to hindcast 20th century precipitation seasonality for the southwestern U. S. (Garfin et al. 2010). Five of the best performing simulations that predict a range of available future moisture **(**Hadgem1, Mpi_echam5, Csiro_mk3, Ncar_ccsm3, and Cnrm_cm3) and an ensemble of 44 runs of all 22 AR4 GCMs have been statistically down-scaled to a 4 km grid projecting month-by-month climates for every year from 1900 through 2099 AD for the United States west of 100 degrees longitude. This downscaling was accomplished through the comparison of 1950 through 1999 mean values for precipitation and maximum and minimum monthly temperatures as generated by the PRISM 4 km historical climate data set with estimates for that period generated by each GCM. This period incorporates a greater range of 20th century climate variability than more typically applied NOAA 30-year mean periods. All the GCM output was statistically downscaled to the 4 km grid using transfer functions estimated from comparisons of historical and simulated data.

Hydrological data: Our GIS will include hydrological geospatial datasets. Specific variables that will be included in the GIS will be based on our wildlife species conceptual models. Surface water and groundwater regimes have profound effects on the vegetation along a river (e.g., Shafroth et al. 2002, Webb et. al. 2007). Key metrics include soil moisture and its temporal variability, stream base flow, and the frequency, magnitude, timing, and duration of floods and droughts. Predicting how future climate will affect riparian habitat requires an understanding of how water becomes available to riparian plants and streams. For simulation of hydrological variables in the historical period and projection of these variables into the future we will use downscaled climate data and the variable infiltration capacity (VIC) model (Liang et al., 1994, 1996). The atmospheric forcing for the VIC model will come from the statistically downscaled data described above, using all available scenrios. As a semi-distributed macroscale hydrological model, VIC balances both the water and surface energy budgets within the grid cell; and its sub-grid variations are captured statistically. Distinguishing characteristics of the VIC model include: subgrid variability in land surface vegetation classes; subgrid variability in the soil moisture storage capacity; drainage from the lower soil moisture zone (base flow) as a nonlinear recession; inclusion of topography that allows for orographic precipitation and temperature lapse rates resulting in more realistic hydrology in mountainous regions. As rain is input into the model domain, the soil progressively fills and excess water becomes fast runoff. There is also a slow baseflow component from the sub-surface, and both fast and slow responses are transported to the outlet of the cell by a unit hydrograph and then subsequently routed to the outlet of the basin using a Saint-Venant type scheme. Total evapotranspiration (ET) is computed for each grid cell as a combination of 1) evaporation from the canopy layer of each vegetation tile, 2) transpiration from each vegetation tile and 3) evaporation from bare soil (Liang et al., 1994) weighted by the respective surface fractional cover. In addition, VIC includes a snow model that is a collection of sub-functions that compute snow accumulation and ablation, atmospheric stability, snow interception and canopy effects, and blowing snow – this characteristic is particularly important in the Verde Basin. VIC has been adapted to allow representation of water management effects including reservoir operation and irrigation diversions and return flows (Gao et al. 2009).

Riparian vegetation*:* NDVI values obtained from Landsat Thematic Mapper and Moderate Resolution Imaging Spectrometer (MODIS) imagery provide a measure of vegetation density and vigor at 30-m resolution. NDVI has the benefits of being a well archived data set dating back to 1984, providing ~25 years of information on riparian vegetation that spans the entire Southwest, at no cost. For each site we will obtain 20 years of Landsat imagery, acquired during midsummer, for modeling the extent and dynamics of riparian vegetation. We will calculate the mean, range, and standard deviation in NDVI values to characterize the stability and dynamics of riparian vegetation (Paxton et al. 2007).

Task D - Model Wildlife Habitat: Existing models use measures of NDVI and some simple floodplain features to predict the habitat of the endangered Southwestern Willow Flycatcher (Hatten and Paradzick 2003; Paxton et al. 2007) and Yellow-billed Cuckoo (Johnson et al. 2011). Our objective here is to take the linkages built between hydrology, geomorphology, and NDVI to assess how changes in water availability will affect riparian vegetation and riparian-obligate species. The Flycatcher and Cuckoo models require vegetation characteristics obtained from satellite imagery and a digital elevation model (DEM). Preliminary results from the Cuckoo

model include an overall classification accuracy of ~73%. The Flycatcher model, which has been tested over a broad region, has achieved classification accuracies between 75-85% (Paxton et al. 2007; Hatten and Sogge 2007). These models employ logistic regression equations that predict the likelihood of occurrence based upon site and neighborhood characteristics extracted from satellite and DEM data. Specifically, the flycatcher model characterizes vegetation features (obtained from NDVI) within a 120-m radius (4.5 ha), whereas the cuckoo model characterizes vegetation (also obtained from NDVI) within a 480-m radius (72 ha). These models characterize current habitat conditions for these species, and are not linked to hydrological processes.

Our objective is to link hydrologic, geomorphic, and wildlife models. This necessitates that we establish a statistical relationship between physical models and VIs, such as NDVI (Fig. 2). We are confident that this is possible since a previous modeling effort explained 51% of the variability in NDVI fluctuations, and 37% of the variability in predicted flycatcher habitat, with non-summer rainfall data over a 20-yr period along the Gila and San Pedro rivers (Paxton et al. 2007). We expect that analyzing VIs, or predicted flycatcher habitat as a function of measures of hydrology (e.g., various surface flow variables, groundwater depth, or ET) and geomorphology (e.g., particle size, deposit age, channel vertical stability), will significantly improve these relationships, leading to a robust multivariable wildlife model.

The next step is to populate the multivariate model with downscaled GCM data to estimate effects on wildlife habitat directly. By running multiple GCM scenarios, we hope to produce the first estimates of how climate change will directly impact the habitat of obligate riparian birds and indirectly, the overall health of the riparian ecosystem.

Task E - Project Ensembles of future distributions expected with climate change: Output from our riparian response model will be used to simulate the effects of different climate-change scenarios on select riparian bird and herpetofauna species habitats. A set of maps and GIS layers will be produced to show in a spatially explicit manner how and where riparian vegetation is expected to change and the resulting impacts to riparian obligate species. These analyses will form the foundation for a decision support system whereby managers can simulate different climate-change scenarios and view the expected results.

Task F - Provide Decision Support Tool: A set of maps and GIS layers will be produced for each bird and herpetofauna species we model that show in a spatially explicit manner how and where riparian vegetation is expected to change and the resulting impacts to riparian obligate species. These analyses will form the foundation for a decision support system whereby managers can simulate different climate-change scenarios and view the expected results. This interactive website is a product of our NCCWSC project, and is managed at Northern Arizona University.

Tasks G, H, I – Write Project Report: We will complete a draft of the final report in time to have it reviewed by Reclamation and LCC partners. We will then address all reviewer's edits and comments and produce a final report at the end of the project.

Table 1. Project tasks and estimated timeline for completing the tasks.

TASK	TASK DESCRIPTION	Estimated Timeline
A	Select Focal Species	Jan. – Feb. 2012
B	Develop Species Conceptual Models	Feb. – April 2012
C	Build GIS	Jan. – Sept. 2012
C	▪ Format GCM data for hydrological modeling	Jan. – March 2012
C	▪ Perform Hydrologicmodeling using VIC	April – Sept. 2012
	▪ Acquire and process riparian vegetation data (NDVI)	Jan. – Sept. 2012
C	▪ Acquire and process Species distribution data	Jan. – Sept. 2012
D	Model bird and herp habitat	Sept. 2012 – Feb. 2013
E	Project future distributions of bird and herp species	March – Aug. 2013
F	Populate decision support tool with results	Aug. – Oct. 2013
G	Write draft project report	April – Oct. 2013
H	Submit draft project report for review	Nov. 2013
I	Revise draft and submit final report	Dec. 2013

PROJECT DELIVERABLES

- Downscaled GCM database, hydrologic data and procedures made available in ArcGIS layers
- Set of maps and GIS layers for each bird and herpetofauna species modeled that show in a spatially explicit manner how and where riparian vegetation is expected to change and the resulting impacts to riparian obligate species.
- Decision support system whereby managers can simulate different climate-change scenarios and view the expected results.
- Publication comparing downscaled dynamic models
- Conceptual models of ecological effects on species populations for each species
- Compilation of future forecasts for select riparian-obligate birds and herpetofauna
- Spatial models and maps for projected changes in species distribution for suite of select riparian-obligate species
- Journal article on “proof of concept” approach focused on its application to other species

ANTICIPATED PROBLEMS/DIFFICULTIES: Modeling hydrological effects on riparian vegetation and wildlife habitat, and forecasting the effects of climate change on wildlife, are complex. However, we have spent considerable time and effort during our NCCWSC project to develop proven methods for modeling wildlife habitat using downscaled climate data and for forecasting the effects of climate change on upland wildlife. We will apply these proven methods and expand their applicability by including projections of climate-driven hydrological changes in modeling riparian species. We have a new team member, Francina Dominguez, with considerable experience in downscaling climate data for hydrological applications, which will allow us to expand our analyses to riparian species.

RELATED/INFORMATIVE STUDIES:

USGS NCWSC project (2009-2012): “Forecasting climate impacts on wildlife of the arid southwest at regional and local scales using downscaled climate models”

Arizona Game and Fish Department, Heritage Grant Program (2010-2011): “Arizona’s Riparian Raptors: distribution, abundance, habitat requirements, and breeding ecology along the San Pedro River and Aravaipa Canyon”

Bureau of Land Management (2010): “Arizona’s Riparian Raptors: distribution, abundance, habitat requirements, and breeding ecology along the San Pedro River Conservation Area”

U.S. Forest Service (2011): “Common Black-hawk and Southwestern Willow Flycatcher Distribution and Abundance and Breeding Ecology in Fossil Creek, AZ”

National Park Service (2010): “Surveys for Northern Mexican Gartersnakes in Tavasci Marsh (Tuzigoot National Monument)”

Arizona Game and Fish Department Wildlife Conservation Fund (WCF) Grant (2008-2010): “Riparian Raptors: distribution, abundance, habitat requirements, and breeding ecology within the Verde River Watershed, Arizona”

Arizona Game and Fish Department (2009-2011): Inventory and Monitoring of the Common Black Hawk and other riparian bird species.

USDA Prescott National Forest (2009-2012): “Prescott National Forest Riparian Herpetofauna Surveys”

Arizona Power Service (APS; 2005-2010): “Common Black-hawk and Yellow-billed Cuckoo Distribution and Abundance and Breeding Ecology in Fossil Creek, AZ”

Bureau of Reclamation (2008-2011): “Development of a GIS-based model of yellow-billed cuckoo breeding habitat within the Lower Colorado River Multi-Species Conservation area, San Pedro River and Verde River, AZ”

Department of Energy, National Institute for Climate Change Research (NICCR) project (2007-2009): “Dominant Plant Species Response to Climate Change Project Summary: Regional Dynamic Vegetation Model for the Colorado Plateau: A Species-Specific Approach”

Arizona Game and Fish Department, Heritage IIAPM Grant Program (2007-2008): “Population Impacts on the Narrow-headed Gartersnake”

USGS (2007): “Using a remote sensing/GIS model to predict southwestern willow flycatcher breeding habitat along the Rio Grande, New Mexico.

Arizona Game and Fish Department, Heritage Program II Funding (2005-2006): "Narrow-headed Gartersnake Monitoring in Oak Creek Canyon, Arizona"

USFWS and AZGFD (1999-2003) "A multiscaled model of southwestern willow flycatcher breeding habitat"

NON-FEDERAL SOURCES/SUPPORT: Sources for non-federal funding are Arizona Game and Fish Department, through a Wildlife Conservation Fund grant, and a Heritage Fund grant. In addition, Northern Arizona University contributes by foregoing IDC. See the budget for funding amounts from non-federal sources.

3. Project Evaluation Criteria

TECHNICAL MERIT

Project Scope:

Primary Objectives:

- Link various hydrologic, geomorphic, and habitat models to better understand and predict how climate changes will affect critical riparian ecosystems and wildlife in the region. We will produce a set of maps and GIS layers for each bird and herpetofauna species we model that show in a spatially explicit manner how and where riparian vegetation is expected to change and the resulting impacts to riparian obligate species.
- Provide management agencies with a decision support tool, so that we can provide scientific information required to restore, enhance, and mitigate effects of climate change on riparian vegetation and associated wildlife, as well as identify those areas that may be of greatest risk to predicted changes.

This project will demonstrate methods for developing finer-resolution probabilistic or presence/absence-based estimates of riparian species distributions, linked to climate and hydrological variables, and thus suited for probabilistic predictions of future distributions **(Task Area B(a)-Projecting changes in the distribution of riparian plant communities; Task Area B(b)- Projecting changes in the distribution and populations of wildlife that are dependent on large rivers or permanent streams)**. A sub-product of the forecasts of the effects of climate change on specific bird and herpetofauna species will be projections of hydrological indices based on downscaled GCMs for the San Pedro and Verde River basins **(Task Area A(a)-Obtaining climate information relevant to the Desert LCC; Task A(e)-Projecting natural system responses to changes in climate, hydrology, etc.)**. Results for riparian bird and herp species will provide data-informed assessments of future prospects and vulnerabilities for a set of species of interest to managers of riparian plant communities and would serve as "proof of concept" to be applied to additional species **(Task Area B(a)-Projecting changes in the distribution of riparian plant communities; Task Area B(b)- Projecting changes in the distribution and populations of wildlife that are dependent on large rivers or permanent**

streams; Task Area C(b)-Developing methodologies or decision support tools). First, we will develop focal species habitat/distribution models, based on predictive, explanatory variables that are comprehensively mapped for our region; e.g., indices of vegetation (NDVI and EVI) providing density and extent information, indices of geomorphology derived from DEMs, DLG-derived linear features, and hydrological indices. Focal species include the endangered Southwestern Willow Flycatcher, and candidate species Yellow-billed Cuckoo and Northern Mexican Gartersnake **(Task Area B(f)- Projecting changes to endangered species habitat distribution that may affect water releases and habitat improvement projects).**

A set of maps and GIS layers will be produced for each bird and herpetofauna species we model that show in a spatially explicit manner how and where riparian vegetation is expected to change and the resulting impacts to riparian obligate species. These analyses will form the foundation for a decision support system whereby managers can simulate different climate-change scenarios and view the expected results **(Task Area C(b)-Developing methodologies or decision support tools)**. This interactive website is a product of our NCCWSC project, and is managed at Northern Arizona University.

The specific tasks that will be undertaken to reach the proposed objectives are described Technical Project Description. The expected timeline for completing the tasks is given in Table 1.

Ability to Accomplish Project Scope:

MANAGEMENT PLAN: Matthew J. Johnson will provide overall project management and coordination among personnel and partners. The task work schedule depicted in Table 1 would be evaluated quarterly. The project team will communicate at least quarterly with a project conference call. Reporting, technical and journal papers, and presentations responsibilities will be shared among the project team.

TEAM MEMBERS and ABILITIES: Project team members and their responsibilities are listed below. For budget allocations per team member, please refer to the Budget Narrative. All members of the project team are capable of proceeding with the tasks within the proposed project immediately upon entering into a financial assistance agreement.

Matthew J Johnson – Northern Arizona University – Lead PI, Matthew J. Johnson will provide overall project management and coordination among team members and partners. He will evaluate the task work schedule depicted in Table 1 on a quarterly basis, assist in data acquisition and modeling. He will work on task A-I. He has extensive experience in project management, including managing our multi-faceted USGS NCCWSC project.

James Hatten - USGS Western Fisheries Research Center, Columbia River Research Laboratory – Co-PI, will lead the development and testing of GIS-based habitat models for birds and herpetofauna, project ensemble future distributions, production of maps and GIS layers, and development of final report. He will work primarily on Tasks C, D, E, and G. He is the lead modeler on the USGS NCCWSC project and is largely responsible for the development of the methods we propose to employ.

Francina Dominguez – Department of Hydrology and Water Resources and Department of Atmospheric Sciences University of Arizona Co-PI, will lead the development and testing of forecasting hydrological models using downscaled GCMs for the study areas, assist in projecting ensemble future distributions of wildlife, and development of final report. She will work primarily on Tasks C, and assist with tasks D, E, and G. She has extensive experience in applying downscaled climate data to hydrological modeling, including within are proposed study areas.

Erika Nowak – Northern Arizona University – Co-PI, will conduct herpetofauna data acquisition and conceptual modeling, report writing. She will work primarily on Tasks A, B, C, G, H, and I. She has performed these same tasks on the USGS NCCWSC project and assisted in the development of the methods we propose to employ.

Jennifer Holmes – Northern Arizona University – Co-PI, will conduct bird data acquisition and conceptual modeling, report writing. She will work primarily on Tasks A, B, C, G, H, and I. She has performed these same tasks on the USGS NCCWSC project and assisted in the development of the methods we propose to employ.

Michael Peterson – Northern Arizona University – Data Manager and Web Guru, will lead data management and processing, and updating and management of the interactive website/decision support tool. He has been an invaluable contributor to the USGS NCCWSC project and assisted in the development of the methods we propose to employ. He will work primarily on Tasks C and F. He is currently developing a cutting-edge interactive website that will serve as a decision support tool for the USGS NCCWSC project, and we propose to use this same website for the Desert LCC project.

PROJECT RELEVANCE TO THE LCC: We propose to study two river reaches in the southwestern U.S. These study reaches typify a broad range of riparian conditions found in the Southwest, which is an important consideration for modeling. The recommended sites are the Lower San Pedro River and the Verde River, Arizona. This work is a direct compliment to our NCCWSC project

The NCCWSC project utilizes down-scaled modeling to link impacts of climate change with potential changes in upland wildlife that are being managed on state and federal lands within the Desert LCC. Through climate-based predictive modeling, results will show the losses and gains of wildlife species that land managers will be expected to experience. A unique aspect of this project is the development of a cutting-edge interactive website where managers and the public will be able to view results, including zooming in to their location of interest. We propose to use this same website to post this project's results.

The NCCWSC project focused on upland species, given the complexities of projecting stream and riverine hydrology. Major capital investments have been made in data, methods, skills, and other resources in forecasting the effects of climate change on upland species. The Desert LCC could capitalize on these existing resources by providing funding to tackle the task of forecasting the effects of climate change on riparian species such as the Southwestern willow flycatcher and Northern Mexican Gartersnake. This work, if funded by the Applied Science

Grants for the Desert LCC, will enable forecasting of the effects of climate change on water resources and riparian vegetation, which are crucial for wildlife throughout the Southwest.

A set of maps and GIS layers will be produced for each bird and herpetofauna species we model that show in a spatially explicit manner how and where riparian vegetation is expected to change and the resulting impacts to riparian obligate species. These analyses will form the foundation for a decision support system whereby managers can simulate different climate-change scenarios and view the expected results. This interactive website is a product of our NCCWSC project, and is managed at Northern Arizona University.

The Advisory Team (AT) for the NCCWSC project is comprised of several LCC partners, and the AT requested we apply our methods to riparian species. We could accomplish this with funding from the Applied Science Grants for the Desert LCC.

Please see the attached letters of support.

DISSEMINATION OF RESULTS: Spatially explicit data will be produced for each bird and herpetofauna species we model that show in a spatially explicit manner how and where riparian vegetation is expected to change and the resulting impacts to riparian obligate species. These analyses will form the foundation for a decision support system whereby managers can simulate different climate-change scenarios and view the expected results. This interactive website is a product of our NCCWSC project, and is managed at Northern Arizona University.

Additional products will include 1-3 journal articles on results and the "proof of concept" approach focused on application to others species, and presentation of findings at 2-3 scientific conferences and 1-5 resource manager's meetings within the LCC.

CONNECTION TO RECLAMATION PROJECT ACTIVITIES:

This project will develop knowledge, information, and tools that can lead to enhanced management of natural resources that are affected by Reclamation and others water resources managers in a changing climate within the Desert LCC. Within the Desert LCC, future climate variability and change is expected to reduce precipitation and water availability. Exacerbating this, population growth in the Southwest is higher than in any other region in the country. Surface-water supplies are fully allocated and a growing population is supported by increased groundwater use in much of the region. Riparian obligate species such as the Southwestern Willow Flycatcher are heavily dependent on the density and lushness of riparian vegetation. As the climate dries and droughts increase, riparian vegetation is likely to decrease in abundance and vigor, leading to a decline in riparian obligate wildlife. Given the heavy dependence of dozens of species on surface water and/or riparian vegetation in the Southwest, a central scientific challenge is to generate quantitative predictions of how variability and changes in climate will affect the amount and quality of riparian wildlife habitat. This project will estimate linkages among physical and biological models so that we can make predictions about how changes in climate and water management practices will affect wildlife. Results of this project will be posted on a web-interface and will provide Reclamation and the partners involved in the Desert LCC with insights that will help them to better anticipate the nature and magnitude of climate-driven changes on riparian wildlife. This will provide a basis for assessing species resiliency and vulnerability, with implications for planning at the regional and continental scale. Results will enable managers to act proactively to preserve riparian vegetation through restoration and enhancement activities, and improved land-use planning.

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POST-PROJECT BENEFITS

Upon completion of the project, we will submit a final report describing the completed project and quantify the actual project benefits.

POTENTIAL ENVIRONMENTAL IMPACTS

There will be no environmental compliance associated with the proposed project.

REQUIRED PERMITS OR APPROVALS

No permits or approvals are required for the proposed project.

FUNDING PLAN and LETTERS of COMMITMENT

Attached are the letters of commitment from Arizona Game and Fish Department, Wildlife Conservation Fund and Heritage Fund. Each letter states; 1) The amount of funding committed to this project, 2) The date the funds will be available to the applicant, 3) Any time constraints on the availability of fund, and 4) Any other contingencies associated with the funding commitment. See attached budget for dollar amounts committed in Tables 2 and 3.

THE STATE OF ARIZONA
GAME AND FISH DEPARTMENT
5000 W. CAREFREE HIGHWAY
PHOENIX, AZ 85086-5000
(602) 942-3000 • WWW.AZGFD.GOV

July 25, 2011

Matthew Johnson, Research Associate
Northern Arizona University
Box 5614
Flagstaff, AZ 86011

Re: Grant Award WCF09027, "*Riparian Raptors.*"

Dear Mr. Johnson:

We approve your request to use $68,045.00 in Wildlife Conservation Grant dollars from the above referenced Wildlife Conservation Fund Grant award as matching funds. Our records indicate the 90% payment of the total grant award was paid September 09, 2009 to Northern Arizona University in the amount of $61,240.50. This project was awarded April 08, 2009 and has been extended until September 30, 2011. Once these dollars have been committed to a specific project as matching they are not available to match any other project. Please notify us as to the final status of these matching funds.

If you have any questions, please call me at (623) 236-7530.

Sincerely,

Robyn Beck
Heritage Grant Coordinator

rb

THE STATE OF ARIZONA
GAME AND FISH DEPARTMENT
5000 W. CAREFREE HIGHWAY
PHOENIX, AZ 85086-5000
(602) 942-3000 • WWW.AZGFD.GOV

July 25, 2011

Matthew Johnson, Research Associate
Northern Arizona University
Box 5614
Flagstaff, AZ 86011

Re: Grant Award I10006, "*Inventory and Development of a long term monitoring program for Arizona Riparian Raptors.*"

Dear Mr. Johnson:

We approve your request to use $63,141.00 in Heritage Grant dollars from the above referenced Heritage Fund Grant award as matching funds. Our records indicate the 90% payment of the total grant award was paid April 7, 2010 to Northern Arizona University in the amount of $63,141.00. This project was awarded on September 22, 2009 and will expire September 22, 2012. Once these dollars have been committed to a specific project as matching they are not available to match any other project. Please notify us as to the final status of these matching funds.

If you have any questions, please call me at (623) 236-7530.

Sincerely,

Robyn Beck
Heritage Grant Coordinator

rb

LETTERS of PROJECT SUPPORT

See attached letters of support.

NORTHERN ARIZONA UNIVERSITY

Office of the Vice President for Research

Northern Arizona University
PO Box 4087
Flagstaff, AZ 86011-4087

928-523-4340
928-523-1075 fax
www.research.nau.edu

24 March 2011

Dr. Matthew Johnson
Northern Arizona University
Colorado Plateau Research Station

Dear Dr. Johnson (Matt):

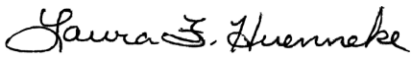
I am writing to express the strong support of Northern Arizona University for your proposal to the WaterSMART Applied Science Grants program of the Desert Landscape Conservation Cooperative (LCC) through the US Bureau of Reclamation and US Fish and Wildlife Service. Your project, "Predicting Effects of Climate Change on Water Resources, Riparian Vegetation, and Riparian Obligate Species in the Southwestern United States," outlines an ambitious plan for exploring potential impacts of climate change on important (and vulnerable) riparian species and systems.

The proposed work is a natural complement and successor to your work with another project, one that you and I have both been associated with over the past year-plus. That project, "Forecasting effects of climate change on federal and state managed wildlife within ecosystems of the arid Southwest," has developed and validated a rigorous approach to assessing climate change impacts on unique species. Each analysis requires very intensive and extensive work, from documenting and summarizing what is known of the species' biology, ecology, and demography to building models of species response to climate changes as predicted by various global circulation models. Given the depth and detail of each modeling effort, the previous project has necessarily focused on a small number of upland (arid and semiarid ecosystem) wildlife species. The investigators and the Advisory Committee (of which I am a member) all recognize, though, that some of the most vulnerable systems and species in the western United States are those associated with streams, rivers, and springs – riparian systems.

Your new proposal would leverage the approaches and resources that have been developed through the earlier project. This would be a significant contribution for early accomplishments through the Desert Landscape Conservation Collaborative. An attractive aspect is the development of tools for translating the results of the analyses and predictions into a form that can be accessed and used directly by land and resource managers.

Northern Arizona University has an exceptional track record in environmental science and in the application of science to significant regional problems. This project is closely aligned with those core strengths and commitments of the institution. The university is committed to furthering your efforts and supporting the important work you have outlined in this project.

Sincerely,



Laura Foster Huenneke, Ph.D.
Vice President for Research

To: Matthew Johnson, Northern Arizona University, Colorado Plateau Research Station

From: Marcos Robles, The Nature Conservancy

Subject: Letter of support for proposal

This letter is to express The Nature Conservancy of Arizona's support for the following proposal under the Funding Opportunity Announcement R11FS81307, WaterSMART Applied Science Grants for the Desert Landscape Conservation Cooperative (LCC) through the Bureau of Reclamation and USFWS.

Title: Predicting Effects of Climate Change on Water Resources, Riparian Vegetation, and Riparian Obligate Species in the Southwestern United States

Lead PI: *Matthew J. Johnson*

This letter expresses my support for funding the project "*Predicting Effects of Climate Change on Water Resources, Riparian Vegetation, and Riparian Obligate Species in the Southwestern United States*". I am currently on the Advisory Team for another of their projects, "*Forecasting effects of climate change on federal and state managed wildlife within ecosystems of the arid Southwest*", funded by the USGS National Climate Change and Wildlife Science Center (NCCWSC). As part of the Advisory Team, I have participated in providing advice and guidance to the project's science teams on prioritization of species, refinement of methods, and means of information transfer to land managers such as the LCC partners.

The NCCWSC project utilizes down-scaled modeling to link impacts of climate change with potential changes in upland wildlife that are being managed on state and federal lands. Through predictive modeling of the effects of climate change, results show the losses and gains of wildlife species that land managers will be expected to experience. A unique aspect of this project is the development of a cutting-edge interactive website where managers and the public will be able to view results, including zooming in to their location of interest.

The NCCWSC project focused on upland species, given the complexities of projecting stream and riverine hydrology. In forecasting the effects of climate change on upland species, major capital investments have been made in data, methods, skills, and other resources. The Desert LCC could capitalize on these existing resources by providing funding to tackle the task of forecasting the effects of climate change on riparian species such as the Southwestern willow flycatcher and leopard frogs. The proposed study through the Applied Science Grants for the Desert LCC will enable forecasting of the effects of climate change on water resources and riparian vegetation which are crucial for wildlife throughout the Southwest.

Should this project be selected for funding, we look forward to working with the scientists to express our specific management and research needs and to provide data that could assist with this research. We hope that this project provides another opportunity to further strengthen our collaborative partnerships to address our common interest in climate change and wildlife within riparian ecosystems.

Sincerely,

To: Matthew Johnson, Northern Arizona University, Colorado Plateau Research Station

From: Lisa Thomas, National Park Service, Southern Colorado Plateau Network

Subject: Letter of support for proposal

This letter is to express my support for the following proposal under the Funding Opportunity Announcement R11FS81307, WaterSMART Applied Science Grants for the Desert Landscape Conservation Cooperative (LCC) through the Bureau of Reclamation and USFWS.

Title: Predicting Effects of Climate Change on Water Resources, Riparian Vegetation, and Riparian Obligate Species in the Southwestern United States

Lead PI: *Matthew J. Johnson*

This letter expresses my support for funding the project "*Predicting Effects of Climate Change on Water Resources, Riparian Vegetation, and Riparian Obligate Species in the Southwestern United States"*. I am currently on the Advisory Team for another of their projects, "*Forecasting effects of climate change on federal and state managed wildlife within ecosystems of the arid Southwest"*, funded by the USGS National Climate Change and Wildlife Science Center (NCCWSC). As part of the Advisory Team, I have participated in providing advice and guidance to the project's science teams on prioritization of species, refinement of methods, and means of information transfer to land managers such as the LCC partners.

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Should this project be selected for funding, we look forward to working with the scientists to express our specific management and research needs and to provide data that could assist with this research. We hope that this project provides another opportunity to further strengthen our collaborative partnerships to address our common interest in climate change and wildlife within riparian ecosystems.

Sincerely,

Lisa Thomas
Southern Colorado Plateau Network, NPS

OFFICIAL RESOLUTION

According to the Funding Opportunity Announcement No. R11SF81307 on page 28, university applicants are not required to submit an Official Resolution.

BUDGET PROPOSAL

Included in the budget proposal are the summary of non-federal and federal funding sources (Table 2), estimated project costs for years 1 and 2 (Table 3), and a budget narrative. The budget submitted clearly delineates Bureau of Reclamation and our contributions.

Table 2. Summary of non-federal and federal funding sources for LCC proposal; "Predicting Effects of Climate Change on Riparian Obligate Species in the Southwestern United States".

Table 3. Summary of budget for LCC proposal; "Predicting Effects of Climate Change on Riparian Obligate Species in the Southwestern United States".

Budget Narrative: The budget narrative describes the project team member's responsibilities per budget allocation.

Matthew J Johnson – Northern Arizona University – Lead PI, will be allocating 24 weeks toward this project. Matthew's salary is $29.55 per hour, his fringe benefit rate is 49%. Matthew's time will be directed toward overall project management and coordination among team members and partners. He will evaluate the task work schedule depicted in Table 1 on a quarterly basis, assist in data acquisition and modeling. He will work on tasks A-I.

Jennifer Holmes – Northern Arizona University – Co-PI, will be allocating 27 weeks of her time toward this project. Jennifer's salary is $28.78 per hour, her fringe benefit rate is 19%. Jennifer's time will be directed toward bird data acquisition, conceptual modeling and report writing. She will work primarily on Tasks A, B, C, G, H, and I.

Erika Nowak – Northern Arizona University – Co-PI, will be allocating 45 weeks of her time toward this project, Erika's salary is $33.00 per hour, her fringe benefit rate is 41%. Erika's time will be directed toward herpetofauna data acquisition, conceptual modeling and report writing. She will work primarily on Tasks A, B, C, G, H, and I.

Michael Peterson – Northern Arizona University – Data Manager, will be allocating 26 weeks toward this project. Michael's salary is $17.83 per hour, his fringe benefits are 31%. Michael time will be directed toward data management and processing, updating and management of the interactive website/decision support tool. He will work primarily on Tasks C and F.

Contractors

James Hatten - USGS Western Fisheries Research Center, Columbia River Research Laboratory – Co-PI. Jim will be a sub-contractor on this project. Jim will be allocating 30 weeks toward this project. Jim's salary is $59.00 per hour which includes in fringe benefits. Jim's time will be directed toward the development and testing of GIS-based habitat models for birds and herpetofauna, project ensemble future distributions, production of maps and GIS layers, and development of final report. He will work primarily on Tasks C, D, E, and G.

Francina Dominguez – Department of Hydrology and Water Resources and Department of Atmospheric Sciences, University of Arizona Co-PI, will be allocating 34 weeks toward this project. Francina's salary is $46.80 per hour, her fringe benefit is 28%. Francina's time will be directed toward the development and testing of forecasting hydrological models using downscaled GCMs for the study areas, assist in projecting ensemble future distributions of wildlife, and development of final report. She will work primarily on Tasks C, and assist with tasks D, E, and G.

Indirect Costs

Northern Arizona University's requested indirect cost rate is calculated at the approved Colorado Plateau Cooperative Ecosystem Study Unit (CPCESU) rate of 17.5% of total direct costs. Northern Arizona University's contributed foregone indirect cost is calculated at our approved DHHS federally approved rate of 49% modified total direct cost minus the allowed rate of 17.5%. See budget proposal in Table 3 for details.

Matching Funding

Attached are the letters of commitment from Arizona Game and Fish Department, Wildlife Conservation Fund ($68,045) and Heritage Fund ($63,141). Each letter states; 1) The amount of funding committed to this project, 2) The date the funds will be available to the applicant, 3) Any time constraints on the availability of fund, and 4) Any other contingencies associated with the funding commitment. See attached budgets for dollar amounts committed in Tables 2 and 3.

Funding Sources	**Funding Amount**
Non-Federal Entities	
Arizona Game and Fish Department Wildlife Conservation Fund Grant	$68,045
Arizona Game and Fish Heritage Fund	$63,141
NAU foregone IDC	$48,049
Non-Federal Subtotal	**$179,235**
Other Federal Entities (not allowed under this RFP)	$0
Requested Reclamation Funding	**$179,236**
Total Project Funding	**$358,471**

Year 1 Climate Change affects on Southwestern Riparian Wildlife 2011-12					
	$/Unit and Unit	**Quantity**	**Recipient Funding**	**Matching Funds From Other Partners**	**Requested BOR Funding**
Program Manager	29.55	1/2 time 9 weeks	Matthew Johnson		3,536
ERE (NAU-49%)					1,733
					5,269
Biologist PI	28.78	1/2 time 8 weeks	Jennifer Holmes		3,454
ERE (NAU-19%)					656
					4,110
Biologist PI	33.00	1/2 time 26 weeks	Erika Nowak		13,200
ERE (NAU-41%)					5,412
					18,612
GIS Programer	17.83	1/2 time 18 weeks	Michael Peters		7,132
ERE (NAU-31%)					2,211
					9,343
OutsideSubcontractors;					
USGS	59.00	1/2 time 18 weeks	Jim Hatten		21,240
Univ of Arizona	46.80	1/2 time 25 weeks	Francina Dominguez		23,400
subtotal					**44,640**
Arizona Game and Fish Department Wildlife Conservation Fund Grant				$43,000	
Arizona Game and Fish Heritage Fund				$33,000	
Total Direct Costs				**$76,000**	**$81,974**
Indirect Costs (CPCESU Rate)	17.50%	TDC			**$14,345**
NAU foregone IDC	31.50%	MTDC		**$25,822**	
Total Project Costs				**$101,822**	**$96,319**

Year 2 Climate Change affects on Southwestern Riparian Wildlife 2012-13					
	$/Unit and Unit	**Quantity**	**Recipient Funding**	**Matching Funds**	**Requested BOR Funding**
Program Manager	29.55	1/2 time 15 weeks	Matthew Johnson		$8,865
ERE (NAU-49%)					$4,344
					$13,209
Biologist PI	28.78	1/2 time 19 weeks	Jennifer Holmes		$10,936
ERE (NAU-19%)					$2,078
					$13,014
Biologist PI	33.00	1/2 time 19 weeks	Erika Nowak		$12,540
ERE (NAU-41%)					$5,141
					$17,681
GIS Programer	17.83	1/2 time 8 weeks	Michael Peters		$1,498
ERE (NAU-31%)					$464
					$1,962
OutsideSubcontractors;					
USGS	59.00	1/2 time 12 weeks	Jim Hatten		15,340
Univ of Arizona	46.80	1/2 time 9 weeks	Francina Dominguez		9,360
subtotal					**24,700**
Arizona Game and Fish Department Wildlife Conservation Fund Grant				$25,045	
Arizona Game and Fish Heritage Fund				$30,141	
Total Direct Costs				**$55,186**	**$70,567**
Indirect Costs (CPCESU Rate)	17.50%	TDC			**$12,349**
NAU foregone IDC	31.50%	MTDC		**$22,228**	
Total Project Costs				**$77,414**	**$82,916**