RIO GRANDE FISHES CONSERVATION ASSESSMENT AND MAPPING

Siglo Group, March 2018

Technical Project Team: Ben Labay, Ben Prince, Jonathan Ogren, and Kaitlin Tasker.

SOUTHERN ROCKIES
Landscape Conservation Cooperative

southernrockieslcc.org

The Southern Rockies Landscape Conservation Cooperative enhances collaborative management by addressing shared objectives, leveraging resources for scientific information and decision support tools, and informing on-the-ground conservation outcomes. Their vision is a Southern Rockies landscape that supports and sustains cultural resources, mule deer, elk, native fish and streamflows, and the sagebrush-steppe ecosystem.

DESERT FISH HABITAT
PARTNERSHIP

www.desertfhp.org

The Desert Fish Habitat Partnership (DFHP) seeks to address fish and habitat issues over a broad geographic area that encompasses the entirety of the Great Basin and Mohave deserts, and those portions of the Sonoran and Chihuahuan deserts that lie within the United States.

Western Native
Trout Initiative

westernnativetrout.org

WNTI serves as a catalyst for conservation or management actions through partnerships and co-operative efforts; resulting in improved species status, improved aquatic habitats, and improved recreational opportunities for native trout anglers across western states.

SIGLO
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Siglo Group uses the power of geographic information to help clients integreate land use with natural systems. Siglo specializes in conservation planning, regional analysis, site assessment, cartography, and spatial analysis. Their work has contributed to land being set aside in perpetuity for conservation, policies, and projects that work towards more sustainable land use, good development, and a greater understanding of the attributes and value of land.

The work was completed in collaboration with Texas Parks and Wildlife, University of Texas's Texas Natural History Collection, Desert Landscape Conservation Cooperative, Desert Fish Habitat Partnership, New Mexico Department of Game and Fish, and the U.S. Fish and Wildlife Service. Funding support was provided by the Southern Rockies Landscape Conservation Cooperative and the Western Native Trout Initiative, with whom much of this work was connected via previous and contemporary projects. For a complete list of organizations and contributors, see the table at the end of this report.

Cover Image. "Rio Grande Wild and Scenic River in New Mexico". Image courtesy of The Bureau of Land Management. www.flickr.com.

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PROJECT GOALS

1. Use the best data and analysis methods available to inform good, strategic conservation planning.
2. Conduct an overall characterization of the Rio Grande Watershed to identify areas appropriate for the efficient implementation of habitat-related projects and priority land and stream segments.
3. Create an informative, compelling tool that identifies areas of highest conservation value in the watersheds and supports and catalyzes action by stakeholders, decision makers, and conservation practitioners.

Image 2. "Corrales Sunset". Rio Grande River, Sandia Crest, Corrales, NM. Image courtesy of John Fowler. www.flickr.com.

SUMMARY

This conservation assessment of the U.S. Rio Grande Watershed identifies target areas for the implementation of habitat-related projects and priority areas, stream segments, and watersheds to improve ecological condition, restore natural processes, and prevent the decline of intact and healthy systems. Through systematic conservation planning, this assessment addresses multi-species and multi-jurisdictional concerns; work that complements and extends analogous conservation assessments completed for much of the Desert Landscape Conservation Cooperative's (DLCC) extent. In doing so, it provides a flexible working model into which priority taxa and habitats can be easily incorporated in the future.

The assessment combines practices used in Texas (Hendrickson et al. 2016) and for the Great Plains Landscape Conservation Cooperative (GPLCC) (Labay and Hendrickson 2014) with those from the Upper Snake River Basin and the Upper and Lower Colorado Basins (Dauwalter et al. 2011, Whittier and Sievert 2014, Williams and Dauwalter 2013). Specifically, this work utilizes the open source software Zonation (Moilanen 2007) to perform a spatial prioritization analysis that explicitly incorporates species-specific connectivity requirements and responses to fragmentation (Williams et al. 2011). Much of the species data and initial modeling needed for the assessment were drawn from the work of Cohen et al. (2013). Where priority taxa were not included in Cohen et al. 2013, species representation was incorporated via binary presence/absence data at a USGS hydrologic unit 8 or 12, based on data availability and the guidance of species experts (who were engaged as stakeholders in this project). The final products of the models are three different sets of stream prioritization coverages and landscape management areas, based on distinct units of unique priority species assemblages (Figures 5-10). These products are intended to facilitate communication and coordination, and ultimately conservation action (Fausch et al. 2002).

Implementation of this broad-scale multi-species approach complements traditional reactive management and restoration by encouraging cooperation and coordination among stakeholders and partners, and by increasing the efficiency of future monitoring and management efforts. The products of this assessment support managers, at different administrative levels, in the effective allocation of conservation resources through proactive, species-centric planning. Furthermore, results of the assessment lay the groundwork for the coordination and cooperation of multiple agencies and organizations as they identify areas for priority conservation, habitat improvement actions, and long-term monitoring and management.

INTRODUCTION

To achieve conservation for priority Rio Grande fishes, the diverse studies and rich information available on these taxa need to be integrated into an operational model of conservation planning and stakeholder collaboration (Knight et al., 2006). This requires a systematic assessment, whereby information on geographic scope and preliminary taxonomic priorities can be integrated with expert input and techniques to identify areas for conservation action (Knight et al., 2006). Figure 1 illustrates the major steps of the systematic conservation assessment process for the fishes of the Rio Grande watershed, and the key goals addressed by this project. This assessment complements existing research and strategic planning efforts to provide a scientific basis for decision making that incorporates stakeholder feedback.

To delineate landscape management areas, this assessment focuses on watersheds with distinct fish species of conservation concern. We distinguish these management areas as Native Fish Conservation Areas (NFCAs; Dauwalter et al. 2011, Williams et al. 2011). Native Fish Conservation Areas take a proactive conservation approach and innovate traditional, reactive approaches to management of aquatic resources. They also provide a geographic framework for conservation action as planning moves to implementation.

The NFCAs approach designates areas that adequately support: (1) the maintenance of processes that create habitat complexity, (2) the protection of all life stages, (3) the long-term persistence of priority species, and (4) a framework for sustainable management over time (Williams et al., 2011). It also considers taxonomic representation and persistence of biodiversity assets, riverscape connectivity, and spatial complementarity across the Rio Grande Basin. Through this systematic, multi-species method of assessment and prioritization, NFCAs provide strategy and decision support tools to more effectively prioritize on-the-ground conservation action. This approach is especially useful in the early stages of conservation planning, when stakeholders are best positioned to focus conservation resources on high value objectives and when the results of the assessment can inform coordination and implementation planning efforts.

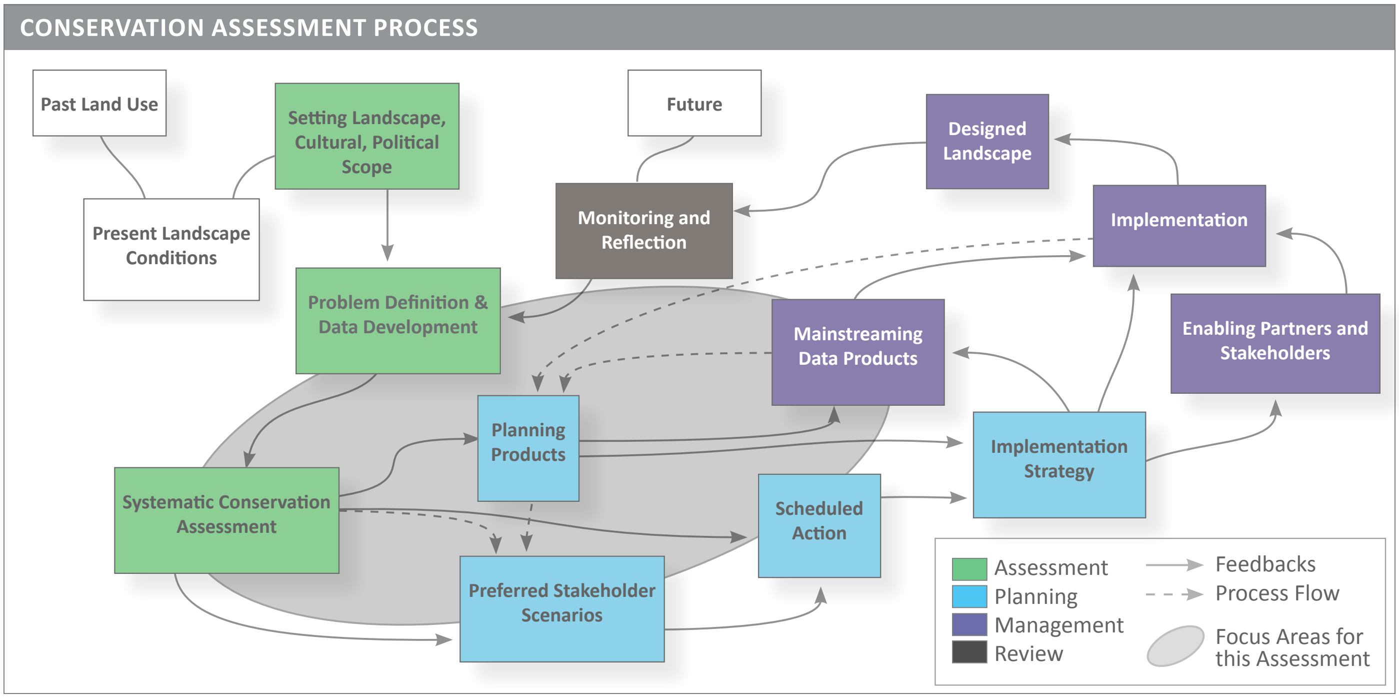


Figure 1. General steps associated with the conservation assessment process in the Rio Grande Watershed.

STUDY AREA

The study area for this conservation assessment is the Rio Grande Basin, within the United States (Figure 2). The Rio Grande river flows 1,900 miles across three states—Colorado, New Mexico, and Texas—from its head waters in the Rocky Mountains to its confluence with the Gulf of Mexico (USGS 2016). The watershed, known as both the Rio Grande (U.S.) and the Rio Bravo (Mexico), covers more than 335,000 square miles; approximately half of which are within the United States. Due to limitations in study scope and data scarcity, the portion of the basin in Mexico was excluded from this study. However, future studies on these Mexican tributaries will be important, as research indicates that they contribute an average water flow three times the volume of major U.S. tributaries, with significant conservation value.

Major cities within the basin include Santa Fe, Albuquerque, and Las Cruces in New Mexico; El Paso, Del Rio, Laredo, and Brownsville in Texas; and Ciudad Juarez in Mexico. These urban centers and large-scale agricultural hubs create significant water demands and limit environmental flows. Despite allocations under many international treaties and interstate compacts, and impoundments in major reservoirs, the river annually runs dry in several reaches (Rister et al. 2011). This confluence of dynamic hydrology, complex political authority, population growth, water demand, and the presence of sensitive, endemic species make the watershed a conservation challenge—but also a prime candidate for systematic conservation assessment and planning.

Figure 2. Rio Grande Study Area, with focus on the U.S. portions of the watershed.

METHODS

This project uses species habitat distribution models (SDM) and professional knowledge of habitat ranges to prioritize areas for strategic fish species conservation throughout the basin. Professional knowledge was conveyed through virtual and in person meetings as well as the sharing of data. It resulted in the identification of priority taxa, risk factors, and opportunity costs, and how these factors complement to existing work in the basin. This process was formally initiated during the 2017 NFCA meeting for the Chihuahuan Desert region. At this meeting, existing species data and other assessments were reviewed, and an initial species-of-concern list was developed. Collaboration continued to inform the modeling process, which can be generalized into five successive steps:

Step One: Species Data Collection and Processing
Step Two: Environmental Condition Data Collection and Processing
Step Three: Species Weight and Environmental Response Determinations
Step Four: Model Testing and Iterations
Step Five: Generation of Landscape Prioritizations and Native Fish Conservation Areas

The following subsections provide a detailed description of the specific methodological and technical decisions made during the analysis.

Conservation Prioritization Model

This study used Zonation V4 software (www.helsinki.fi/en/researchgroups/metapopulation-research-centre) to generate a prioritization of selected fish species of the Rio Grande basin. The primary function of the software is to produce a landscape ranking based on conservation values, as defined by spatially identified species, habitat, or ecosystem occurrence. It does this by iteratively removing grid cells from the study area landscape that result in the smallest loss of conservation value as defined by an SDM. Though Zonation V4 starts with foundational species and environmental data, additional model tools can be added and adjusted later. In addition, the software also allows for alternative cell removal rules, meaning different types of conservation values can be prioritized simultaneously in the model. In this case, we selected the Core-Area Zonation cell removal rule (CAZ; Moilanen et al. 2005) to govern the process. This rule gives the highest rank to cells with the largest occurrence of the most valuable habitat, while balancing weights assigned to species-rich areas and areas representing rare species with restricted ranges.

Species Data

This study began with, and was reliant upon, spatially accurate species data. Because there were no universal databases for all 39 species of concern, presence/absence data were derived from multiple sources to create a common data input for the model. Data utilized came in multiple formats including raster grids, vector HUC 12s shape files, and coordinate point locations.

Most species information came from distribution models created by Cohen and colleagues in 2013 (Cohen, A.E., Labay, B.J., Hendrickson, D.A., Casarez, M., and Sarkar, S. 2013). These data were already in the 30-arc second ASCII raster grid format required for use in Zonation, and were used as a common template for all inputs. The data were then supplemented with information for non-modeled species, which were identified through literature review, interviews with knowledgeable professionals, past DLCC- and GPLCC-funded studies, and online databases (e.g., www.fishesoftexas.org). These sources provided presence/absence species information at the HUC 12 watershed scale or as point coordinates. Any data that were not at the HUC 12 level were extrapolated using ESRI ArcGIS® software (V10.5.1) and then converted to raster format with a consistent environmental extent and cell size (30-arc seconds).

Once all data were in a uniform raster grid format, the Cohen 2013 and supplementary species data were used to construct species distribution layers. Cells were reclassified as absent, present, or no data in an ASCII raster grid format (Sensu, Labay, and Hendrickson 2014). These species distribution layers were then used directly by Zonation

Table 1. Species of concern, their model weights, BQP curves, and distances.

Species Scientific Name	**Species Common Name**	**DFHP Species Weight**	**NatureServe Global Species Weight**	**NatureServe State Species Weight**	**BQP Curve Type**	**BQP Radius (Cells)**
Astyanax mexicanus	Mexican tetra	2	1	5	3	10
Catostomus plebeius	Río Grande sucker	4	2.5	6	4	50
Ctenogobius claytonii	**Mexican goby**	3*	1	6	1	10
Cycleptus elongatus	Rio Grande Blue sucker	6	2.5	6	4	50
Cyprinella proserpina	Proserpine shiner	5	3	5	3	10
Cyprinodon bovinus	**Leon Springs pupfish**	3	5	6	3	10
Cyprinodon elegans	**Comanche Springs pupfish**	3	5	6	3	10
Cyprinodon eximius	Conchos pupfish	6	2.5	6	3	10
Cyprinodon pecosensis	Pecos pupfish	6	5	6	3	10
Dionda argentosa	Manantial roundnose minnow	5	4	5	3	10
Dionda diaboli	Devils river minnow	2	5	6	3	10
Dionda episcopa	Roundnose minnow	2	1	4	3	10
Etheostoma grahami	Río Grande darter	5	3.5	5	3	10
Etheostoma lepidum	**Greenthroat darter**	4	2.5	5	3	10
Gambusia gaigei (clarkhubbsi)	**San Felipe gambusia**	6	5	6	1	1
Gambusia krumholzi (gaigei)	**Big Bend gambusia**	3	5	6	1	1
Gambusia nobilis	Pecos gambusia	3	4	6	1	1
Gambusia senilis	**Blotched gambusia**	6	2.5	3	1	1
Gambusia speciosa	Tex-Mex gambusia	4*	3	4	1	1
Gila pandora	Río Grande chub	6	3	6	3	10
Hybognathus amarus	Río Grande silvery minnow	4	5	5	7	100
Hybognathus placitus	Plains minnow	6*	2	2	7	100
Ictalurus furcatus	Blue catfish	1	1	5	4	50
Ictalurus lupus	Headwater catfish	5	3	6	3	10
Ictalurus sp	**Chihuahua catfish**	6	4.5	1	3	10
Ictiobus bubalus	Smallmouth buffalo	4	1	4	4	50
Macrhybopsis aestivalis	Speckled chub	2	2.5	5	4	50
Moxostoma albidum	Longlip jumprock	6*	2	1	4	50
Moxostoma austrinum	Mexican redhorse	6*	3	6	4	50
Moxostoma congestum	Gray redhorse	4	2	6	4	50
Notropis amabilis	Texas shiner	6*	2	2	3	10
Notropis braytoni	Tamaulipas shiner	5	2	3	3	10
Notropis chihuahua	Chihuahua shiner	6	3	5	3	10
Notropis jemezanus	Río Grande shiner	4	3	5	4	50
Notropis simus pecosensis	**Pecos bluntnose shiner**	2	4	5	3	10
Oncorhynchus clarki virginalis	**Río Grande cutthroat trout**	4*	2	5	3	10
Percina macrolepida	**Bigscale logperch**	1	1	5	3	1
Platygobio gracilis	Flathead chub	5*	1	3	4	50
Rhinichthys cataractae	Longnose dace	1	1	5	4	50

** Species not ranked by DFHP. Ranks based on Natureserve state and global status, and expert input reconciliation.*
***Bolded** names indicate species data complied from non-modeled sources.*

software for the analysis. Table 1 provides a full list of species used in the assessment. Data that were utilized in the model and were not obtained from Cohen et al. 2013 are included as a geodatabase supplement to this report.

Species Weights

To further distinguish priorities, species weights were incorporated into the model. These weights influenced the order in which the landscape was removed, as well as what fraction of a species distribution was retained at any point. With all else being equal, cells that contain a highly ranked species are retained longer. However, the Zonation software also balances high cell ranks between those cells of high species richness and those of rare species in restricted ranges (Lehtomäki and Moilanen, 2013).

Table 2. Species model weight conversion table, from Nature Serve state and global status.

Weight	Status code	Status
0	SX	presumed extirpated
0	SH	possibly extirpated
6	S1	critically imperiled
5	S2	imperiled
4	S3	vulnerable
3	S4	Apparently secure
2	S5	secure
1	SNR	species not recorded (but present)
0	OR	out of range
5	G1	critically imperiled
4	G2	imperiled
3	G3	vulnerable
2	G4	Apparently secure
1	G5	secure

Table 3. Species model weight conversion table, from Desert Fish Habitat Partnership 2015 status.

Weight	DFHP Rank
1	1.22 to 1.48
2	1.48 to 1.74
3	1.74 to 2.00
4	2 to 2.26
5	2.26 to 2.52
6	2.52 to 2.78

While the software's default is an equal weighting of all species, it is important to understand that this is itself a form of weighting, as all species do not have equal conservation value nor are they equally in need of conservation. In addition, the geographic extent of species varies substantially. To account for these considerations, our weighting is based on expert input and the iterative evaluation of results. Ultimately this resulted in three final prioritizations being run, using the following three weighting systems:

1. Natureserve lowest state status (based on highest level of threat; Faber-Langendoen et al. 2009)
2. Natureserve global status (Faber-Langendoen et al. 2009)
3. The Desert Fish Habitat Partnership 2015 rank (DFHAP 2015)

Each ranking system used a different set of parameters to determine priority areas with global or local conservation potential. NatureServe state status denotes localized conditions within portions of the basin and accounts for sub-basin jurisdictions within which decisions are made. In contrast, NatureServe global status reflects both intra- and extra-basin status as well as the role of interstate and international conservation potential. These rankings were complemented by conservation rankings from the Desert

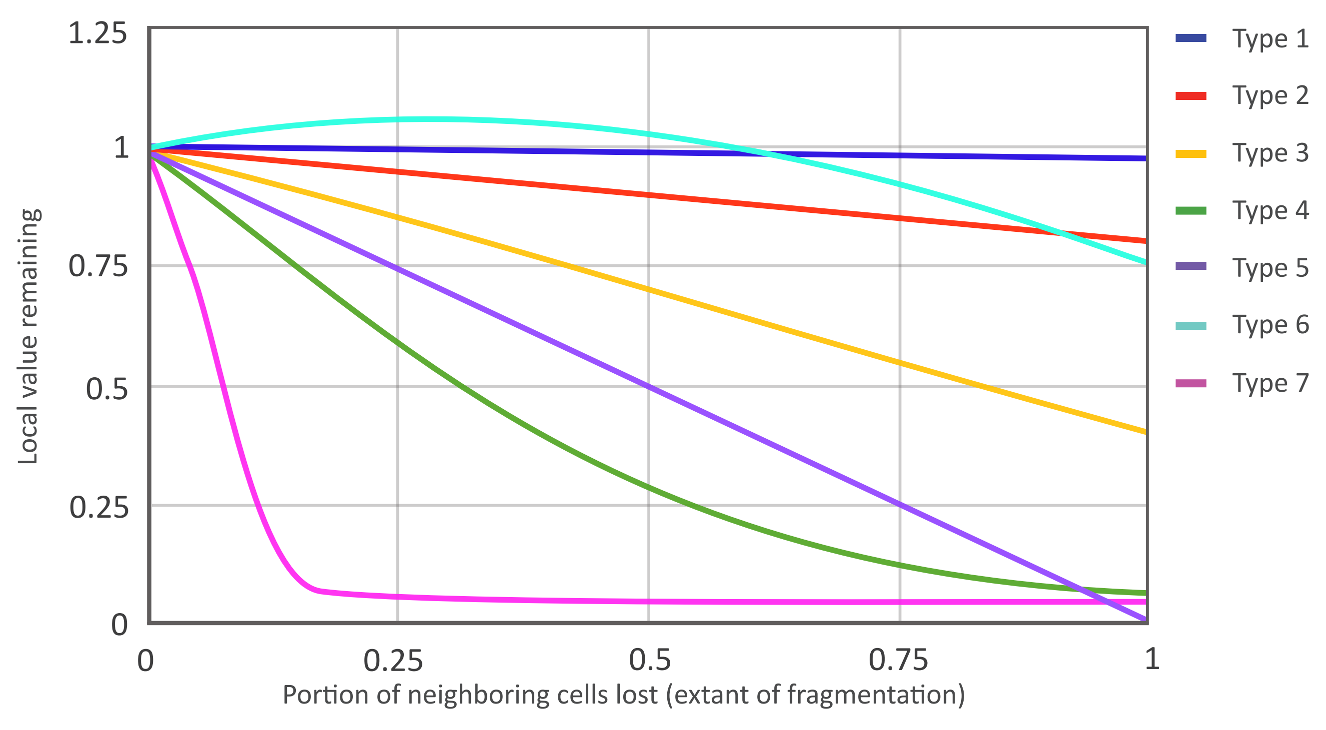


Figure 3. Boundary Quality Penalties (BQP) response curves.

Fish Habitat Partnership (DFHP) because the DFHP's data is reliable, contemporary to this study, and has significant spatial overlap with the study area (DFHP 2015). In all three cases, system ranks had to be converted into Zonation compatible ranks (1-6), where higher numbers denote a higher value in the prioritization model (Lehtomäki and Moilanen, 2013). Where split ranks (e.g. G3/G4) existed, a median value (e.g. 3.5) was assigned. State ranks were similarly translated. For example, TX-S1, NM-S1 and CO-S1 were weighed as 1. In instances where NatureServe State ranks differed for a given species, the lowest of all ranks (the most threatened status) was used for the overall state rank. The weight translations are shown in Tables 2 and 3.

Species BQP Curves and Radius

Each species' sensitivity to environmental conditions (e.g. stream segment length, fragmentation) was integrated into the model via a Boundary-Quality Penalty (BQPs; Table 1). BQPs are a quantitative method of evaluating species-specific responses to environmental degradation. This can include riverine fragmentation (Moilanen & Wintle 2007), edge effects, metapopulation size, or connectivity. With BCPs, areas are given a high ranking if they are surrounded by and connected to other high ranking areas for species distributions or habitat.

For the assessment, each species was assigned one of seven pre-determined BQPs, as based on two key species characteristics: (1) the species' response curve, indicating how it reacts to fragmentation and habitat loss and (2) the species' response radius, indicating at what distance (in raster cells) increasing fragmentation or decreasing fragment size affect the species. BQP curves and radii were assigned to each species and reflect their reaction to variations in stream segment length (curves) and at what length these effects are triggered (radius). As cells in the model are iteratively removed below the radii threshold, the stream segment value for a species is lowered, and thus removed preferentially. This results in the relative magnitude of the effect of fragmentation—indicating how critical the loss of a particular stream is for a species—to be a function of the trigger BQP response curve.

Within the coding of the model, species were grouped into one of seven BQP response curves shown in Figure 3. Species in group one are least impacted by changes in stream length, while species in group seven are the most impacted. Species are also assigned a BQP radius group, which identifies the distance from the focal cell (e.g. 1, 10, 50, or 100 raster cells) at which stream length will affect a species. The greater the number of cells, the more sensitive they are to stream size. For example, a pelagic, broadcast-spawning fish with drifting eggs needs long stretches of river, and would have a large radius of effect relative to a speleophilic nester, which uses crevices and has adhesive eggs. Expert opinion regarding fish reproductive guild ecology (Simon 1999; Frimpong and Angermeier 2009) was used to determine radii for each species. Where relevant life history characteristics were unavailable a 10-km radius was used, as suggested by Hitt and Angermeier's (2008; 2011).

Connectivity Constraints and Habitat Condition

In addition to BQP and species data, an enriched National Anthropogenic Barrier Dataset (NABD) provided by Arthur Cooper at Michigan State University (Cooper 2013) was used to capture connectivity constraints as a critical function of environmental quality (Moilanen 2017, 2008). This dataset contains information on stream segment length between anthropogenic obstructions (e.g. dams and weirs), which is closely associated with habitat viability. We used this stream segment data in two key ways. First, stream line locations were converted into 30-arc second ASCII raster grids and used to generate a mask file for hierarchical cell removal. Within the model, this was used to create a rule to retain stream line cells until all other cells had been eliminated. This effectively prioritized the actual waterway above other adjacent cells in the basin. Second, an enriched National Anthropogenic Barrier Dataset (Cooper, 2013) was used to incorporate qualitative information about the environment into the model. This dataset included segment-level metrics including distance-based measures to dams and metrics integrating cumulative dam effects.

The enriched NABD was incorporated in the form of a Condition File, which represents stream fragment length between impoundments represented in the NABD. The Condition File is a 30-arc second ASCII raster grid. Each cell contains a value between 0 and 1, representing a normalization of the stream length between dams (Figure 4) that has been aggregated to corresponding 12-digit HUCS. This measure was generated by overlaying point locations of large dams on the NHDplus v1 stream network and calculating total mainstem availability (river km). Mainstem availability is defined as the distance to any mainstem dams (if present) above and below each stream reach (Cooper, 2013). Upstream mainstem pathways represent the longest upstream route, whereas downstream mainstem pathways were defined as the shortest route to a stream network outlet (e.g., ocean). The Condition File only affected species with a BQP of 10 cells or greater, as species with less than 10 km dispersal needs are not as responsive to stream fragmentation (Simon 1999; Frimpong and Angermeier 2009). Though National Fish Habitat Partnership data (NFHP 2015) provided another potential indicator of the environmental quality, it was not used in the analysis due to concerns about the consistency and accuracy of data over the extent of the study area.

Administrative units

The Rio Grande Basin crosses several political jurisdictions, most notably between The United States and Mexico, and the states of Colorado, New Mexico, and Texas. These borders are consequential both in terms of unique regulatory and cultural composition, and in the real impacts they generate on hydrology and biology.

To balance the global and local species conservation priorities that arise from these jurisdictions, we created two weighting schemes: NatureServe lowest State status and NatureServe Global status, as detailed in the Species Weighting section above. To further account for this dichotomy of scale, we used Zonation's administrative units function for the state-based rankings and combined it with NatureServe's lowest species status, drawn from Colorado, New Mexico, and Texas. For the global ranking model, the administrative units function was turned off and NatureServe Global species threat statuses were translated to species weights.

Iterations

The conservation prioritization model requires input in the form of quantitative spatial data and informed expert opinions to steer and refine the output. To investigate the impacts of adjusting different variables—including weighting schemes, administrative units, environmental conditions, groups, and BQP curves—over 25 initial iterations of the model were run. Based on a review and discussion of the initial runs, the model was then refined to create multiple final draft iterations. These were in turn reviewed by stakeholders and further adjusted to produce the final model, Landscape Rankings, and NFCAs.

Post Processing & NFCAs

Each model variation generates a prioritization raster grid. The values of these grids are then classified and mapped to make them more intelligible. Zonation's post-processing utility takes this one step further by providing for the identification of distinct management units. These distinct units are based on distance and feature (in our case, taxonomic composition similarity) (Moilanen et al. 2005). This process is defined by four user-specified parameters (bold), which were achieved as described below:

1. **Percentage of the landscape to consider for inclusion in the management units**: Only cells in the top 10 percent of the landscape ranking were retained.
2. **Minimum inclusion fraction for each unit** (the top fraction that must be present to distinguish it as a separate unit): Cells were grouped into units based on whether at least one cell in the unit was in the top 2 percent of the landscape rankings.
3. **Maximum distance between units**: Cells within the unit were no more than 25 grid cells from their nearest neighboring cell.
4. **Maximum difference in composition between units**: Units were split into two units if more than 20 percent of species had a 1-log difference in their probability density.

The results of this postprocessing, detailed below, are a set of NFCA maps for each of the three weighting schemes. These maps are composed of priority cells aggregated to the closest aligning HUC 12 basin. The HUC 12 composition of each NFCA have been reviewed by locally knowledgeable professionals and amended where necessary. Specifically, Kirt Patten of the New Mexico Department of Fish and Game identified ephemeral HUCs, which were removed because they no longer provide viable habitat.

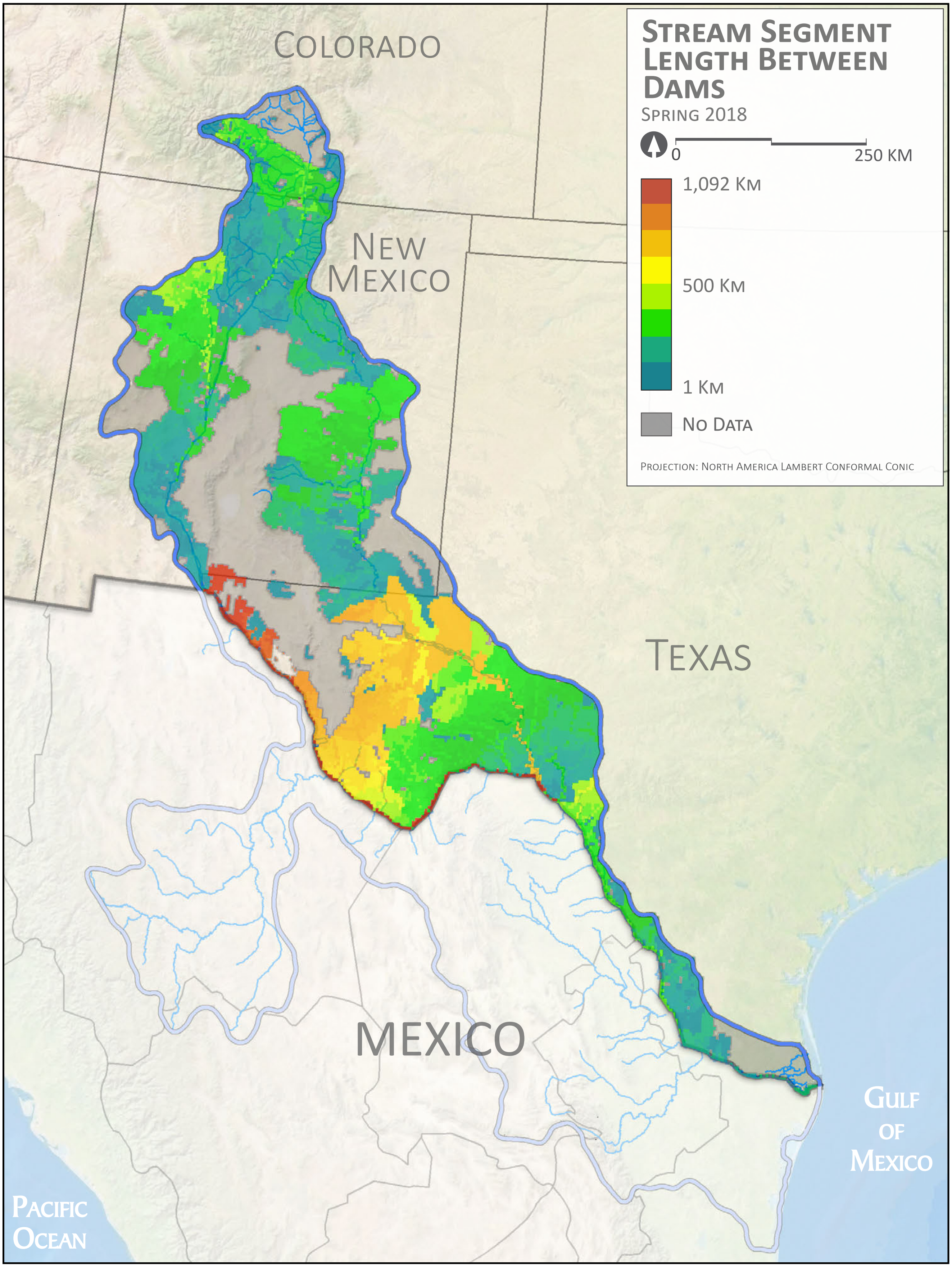


Figure 4. BQP stream segment lengths between dams, aggregated to HUC 12s. Data developed from National Anthropogenic Barrier Dataset (Cooper 2013).

RESULTS

The results of this study are presented in the six maps below (Figures 5-11). All six maps are organized based on which of the three weighting schemes (NatureServe State, NatureServe Global, Desert Fish Habitat Partnership) they used. The first three landscape ranking maps (Figures 5-7) depict the highest priority (top 10%) 30-arc second raster grid cells in the study area. The subsequent three maps (Figures 8-10) show Native Fish Conservation Areas (NFCAs) based on the prioritization results, Zonation post-processing, and expert assessment. These second maps identify NFCAs that are composed of priority HUC 12 units, which serve as the most important sub-watersheds for efficient multispecies conservation. The three ranking maps (Figures 5-7) have notable differences in prioritization coverage; a result of the differences in species ranking schemas. The three weighting schemas were performed for the explicit purposes of illustrating these effects and the impact of the weighting metric in the Zonation modeling algorithm. Resource managers should consider this when interpreting any one particular map or leveraging its conclusions for management or communication purposes.

Figures 5-7 depict the NatureServe State, NatureServe Global, and DFHP weighting systems, respectively. Figure 5 depicts a prioritization with state-specific weighting and thus Mexico is excluded from the results. This weighting schema results in a lower prioritization of streams and landscapes with the top 2% of the area. In contrast, Figure 6 depicts results from the NatureServe Global weighting schema. This schema captures the main stem of the Rio Grande along Big Bend National Park, the stretch of the Rio Grande downstream of El Paso, and tributaries of the Rio Grande just downstream of Lake Amistad and Del Rio, Texas. In doing so, it manages to include a higher amount of stream habitat within the top 2% of the landscape. Finally, Figure 7 depicts the results of the DFHP species weighting system. This system resulted in similar prioritization coverage to the NatureServe Global weightings, with a couple of key notable differences. Primarily, the DFHP-based model resulted in a higher amount of the top 2% of the landscape being ranked within the main stem of the Rio Grande within New Mexico. Both the NatureServe Global and DFHP weightings resulted in less top tier prioritization ranking within Colorado streams. Figure 11 represents areas of NFCA concurrence between the three weighting schemes.

Figures 8 through 10 show the aggregation of priority HUC 12s into NFCAs. Total area in NFCAs for each of the three scenarios is as follows:

1. State NFCA: area 64,335 sqr Km, 634 HUC 12s
2. Global NFCAs: area: 72,929 sqr Km, 739 HUC 12s
3. DFHP NFCAs: area 59,690 sqr Km, 606 HUC 12s

There is considerable overlap across these three weighting scenarios. State, Global, and DFHP NFCAs overlap in 452 HUC 12s, with a combined area of 45,429 sq. Km (Figure 11). The HUCs comprise 40 percent of total NFCA HUCs, and 15 percent of the total study area by both number of HUC 12s and area. This includes an overlap of 53,705 sq. Km (543 HUC 12s) between the State status and Global status models, an overlap of 46,160 sq. Km (460 HUC 12s) between the State Status and DFHP model, and an overlap of 57,044 sq. Km (578 HUC 12s) between the Global and DFHP models.

As with model prioritization, the NatureServe State weighting system normalizes priorities across all three states, resulting in additional watersheds in the northern portions of the analysis area. Figures 9 and 10 both include a greater number of priority watersheds within New Mexico and Texas, with additional watersheds off the main stem prioritized. All scenarios include the main stem of the Rio Grande in northern New Mexico though the area is expanded in the Global and DFHP scenarios. In the DFHP scenario, similarities in the species assemblages result in expansive contiguous priority areas in the Rio Grande and upper Pecos Basin. All three scenarios result in priorities throughout most of the lower Pecos basin. In the state scenario, the variation in state ranking results in five NFCAs within the Lower Pecos compared to one NFCA in the global scenario and three in the DFHP scenario.

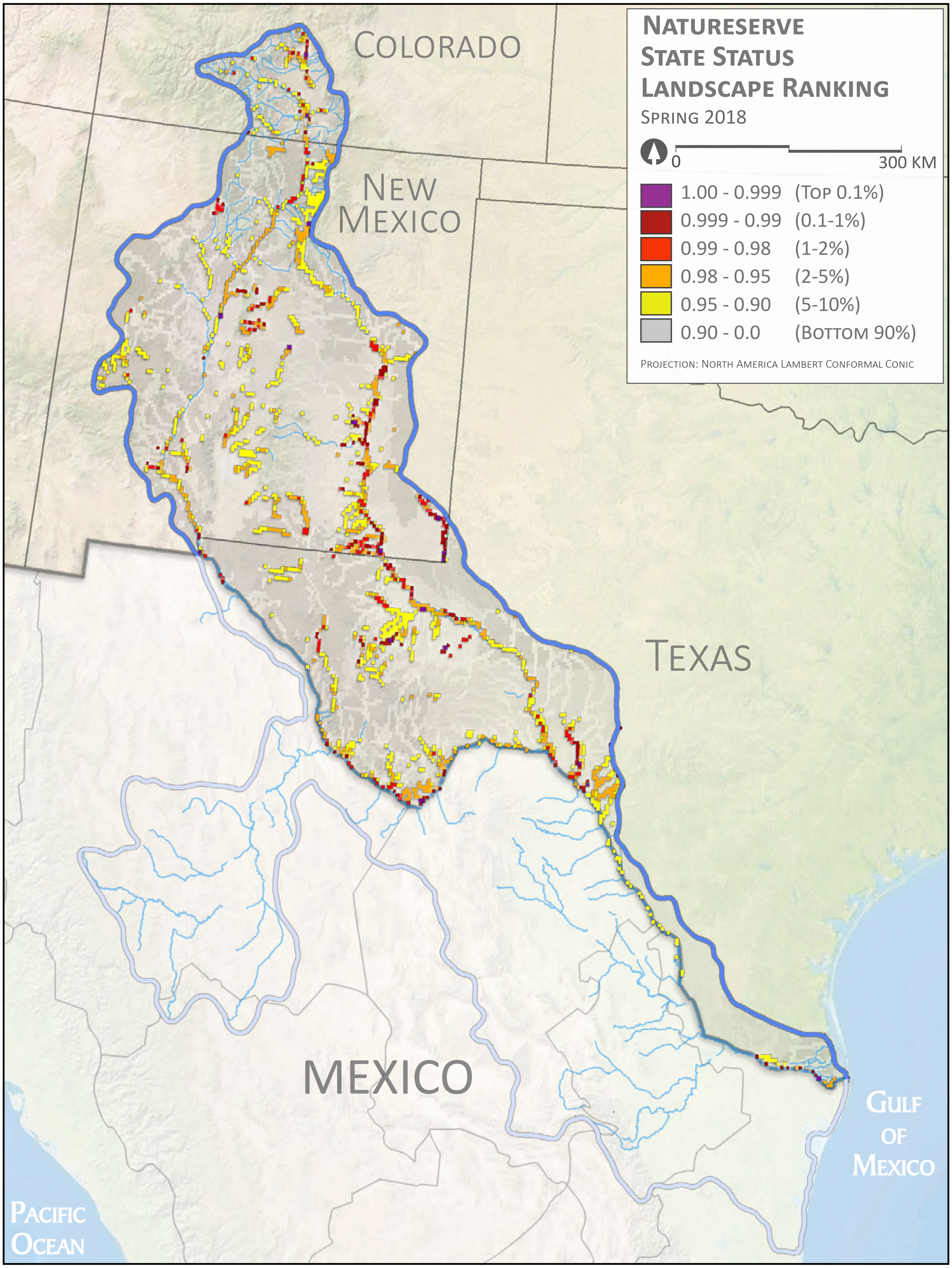


Figure 5. Natureserve State status model prioritization, showing top 10 percent cell rankings.

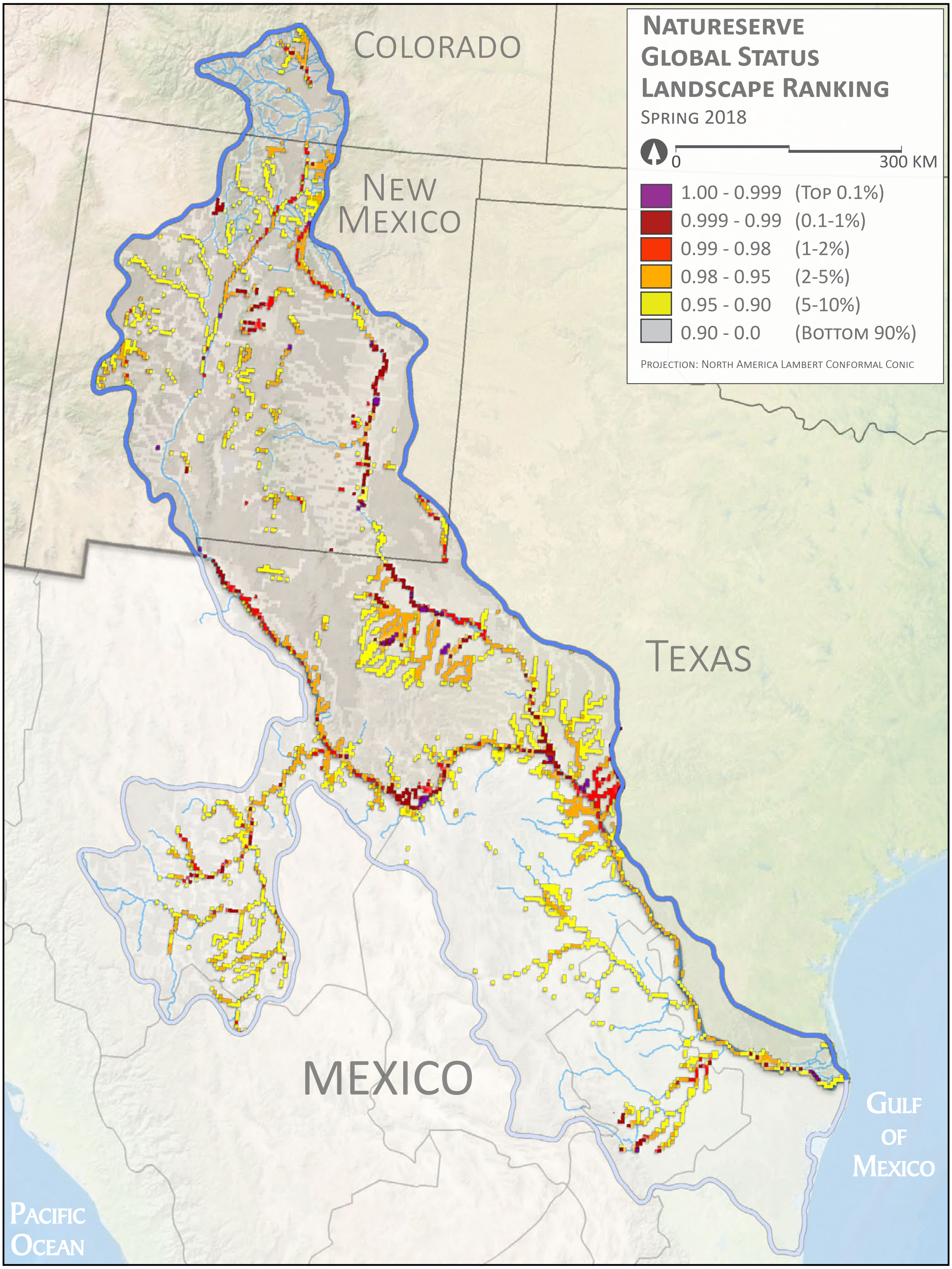


Figure 6. Natureserve Global status model prioritization, showing top 10 percent cell rankings.

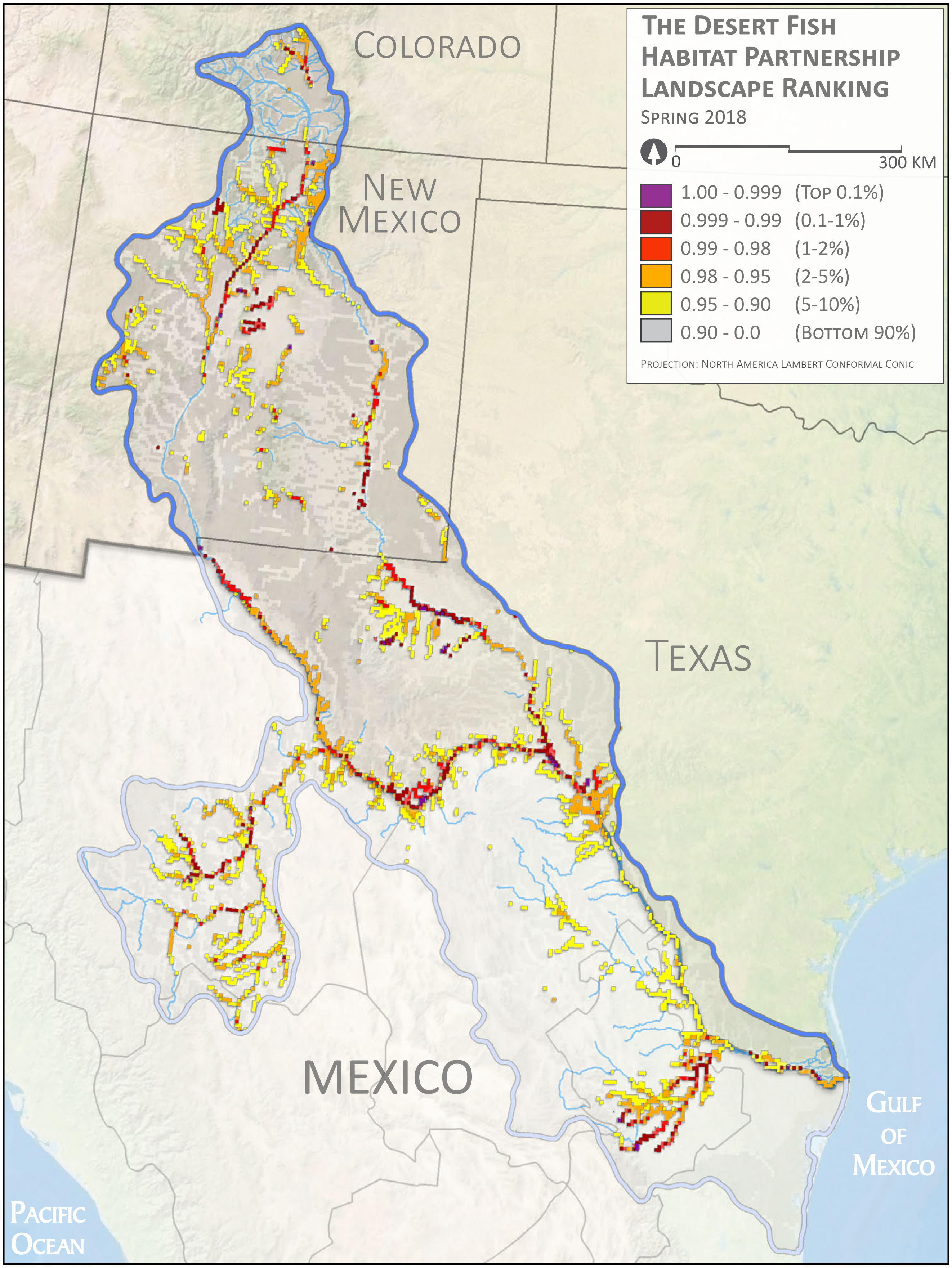


Figure 7. The Desert Fish Habitat Partnership model prioritization, showing top 10 percent cell rankings.

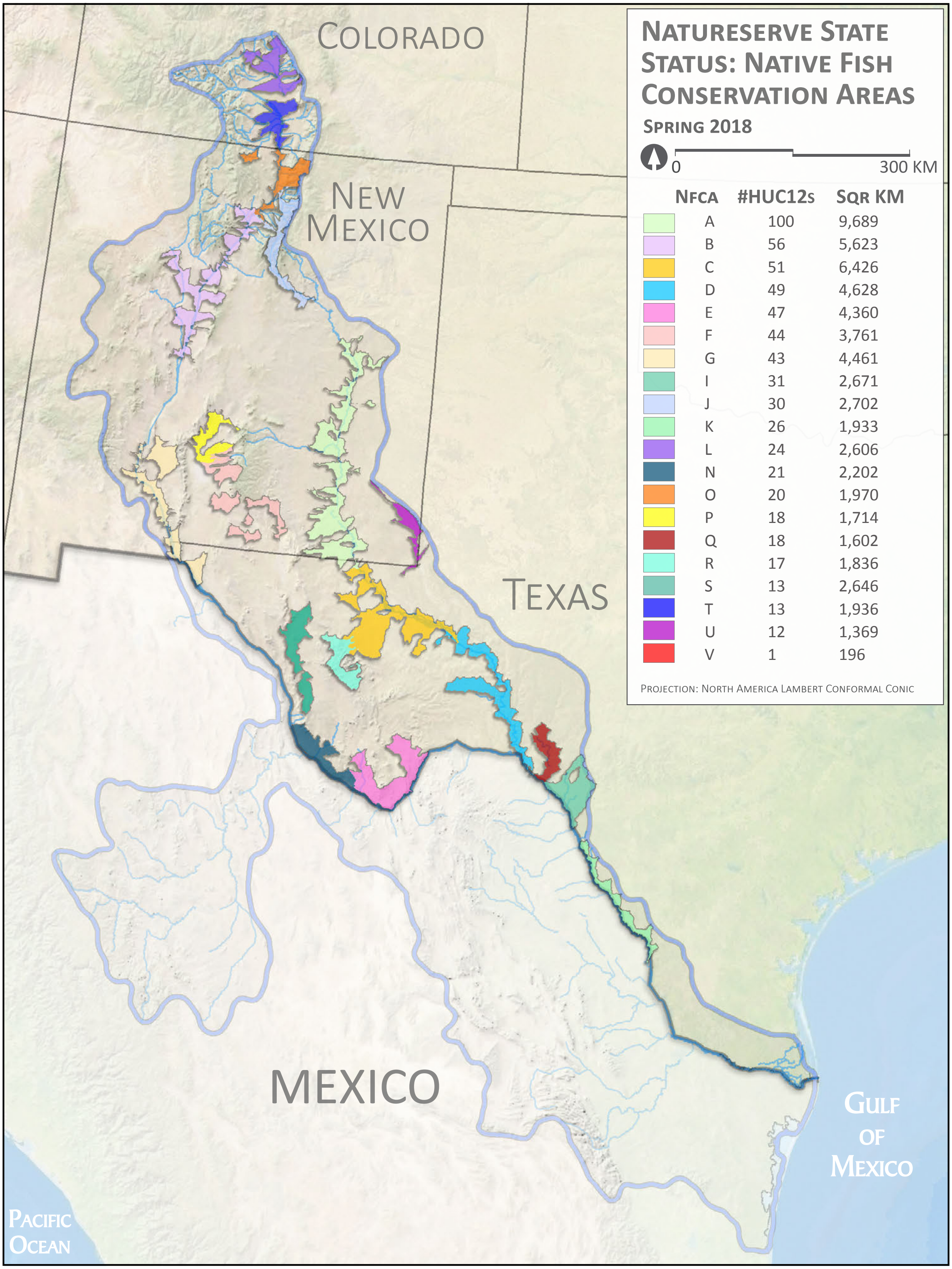
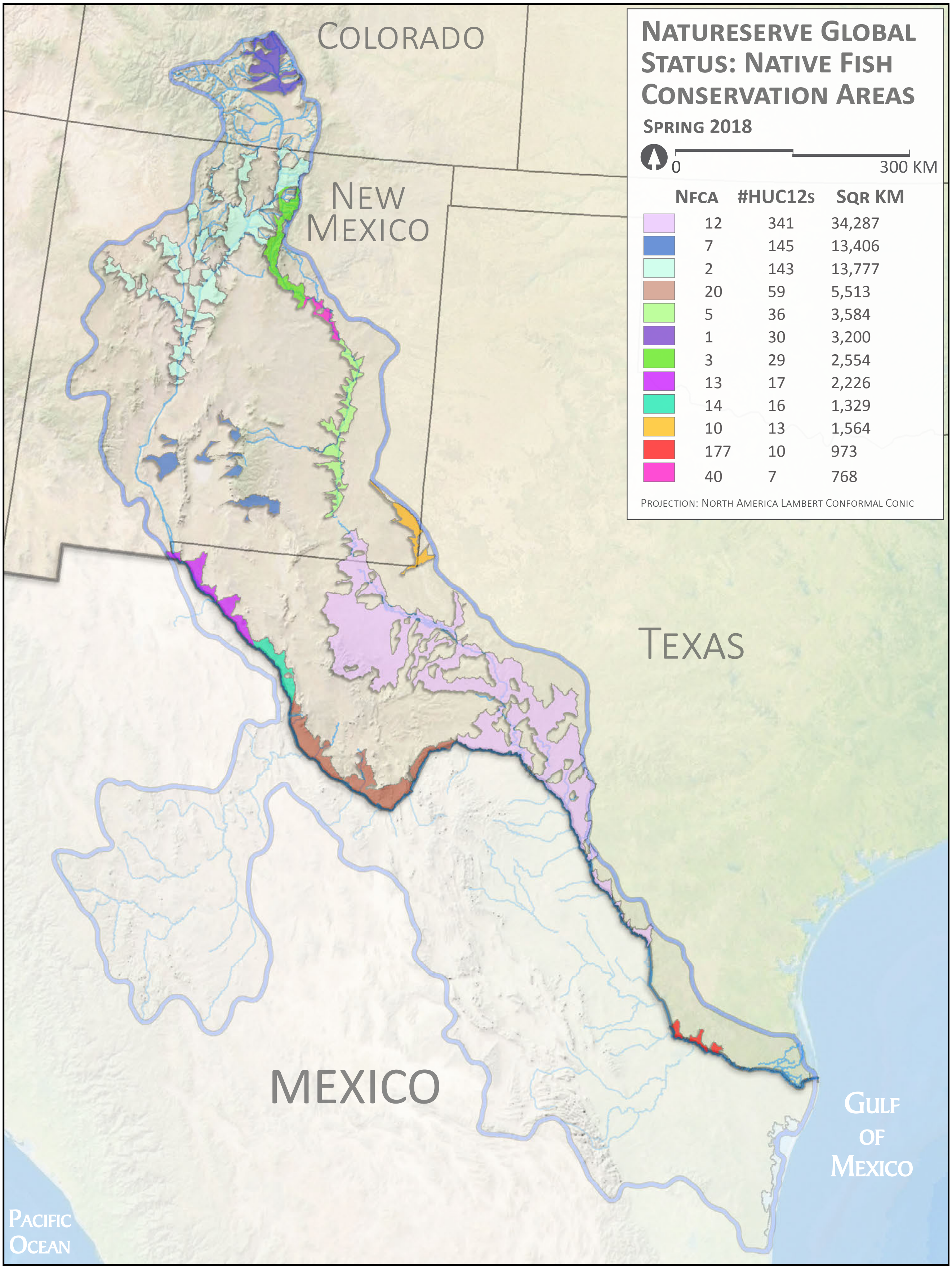


Figure 8. Native Fish Conservation Areas based upon Natureserve State status model prioritization.



	NFCA	#HUC12S	SQR KM
🟪	12	341	34,287
🟦	7	145	13,406
⬜	2	143	13,777
🟫	20	59	5,513
🟩	5	36	3,584
🟪	1	30	3,200
🟩	3	29	2,554
🟪	13	17	2,226
🟦	14	16	1,329
🟨	10	13	1,564
🟥	177	10	973
🟪	40	7	768

Figure 9. Native Fish Conservation Areas based upon Natureserve Global status model prioritization.

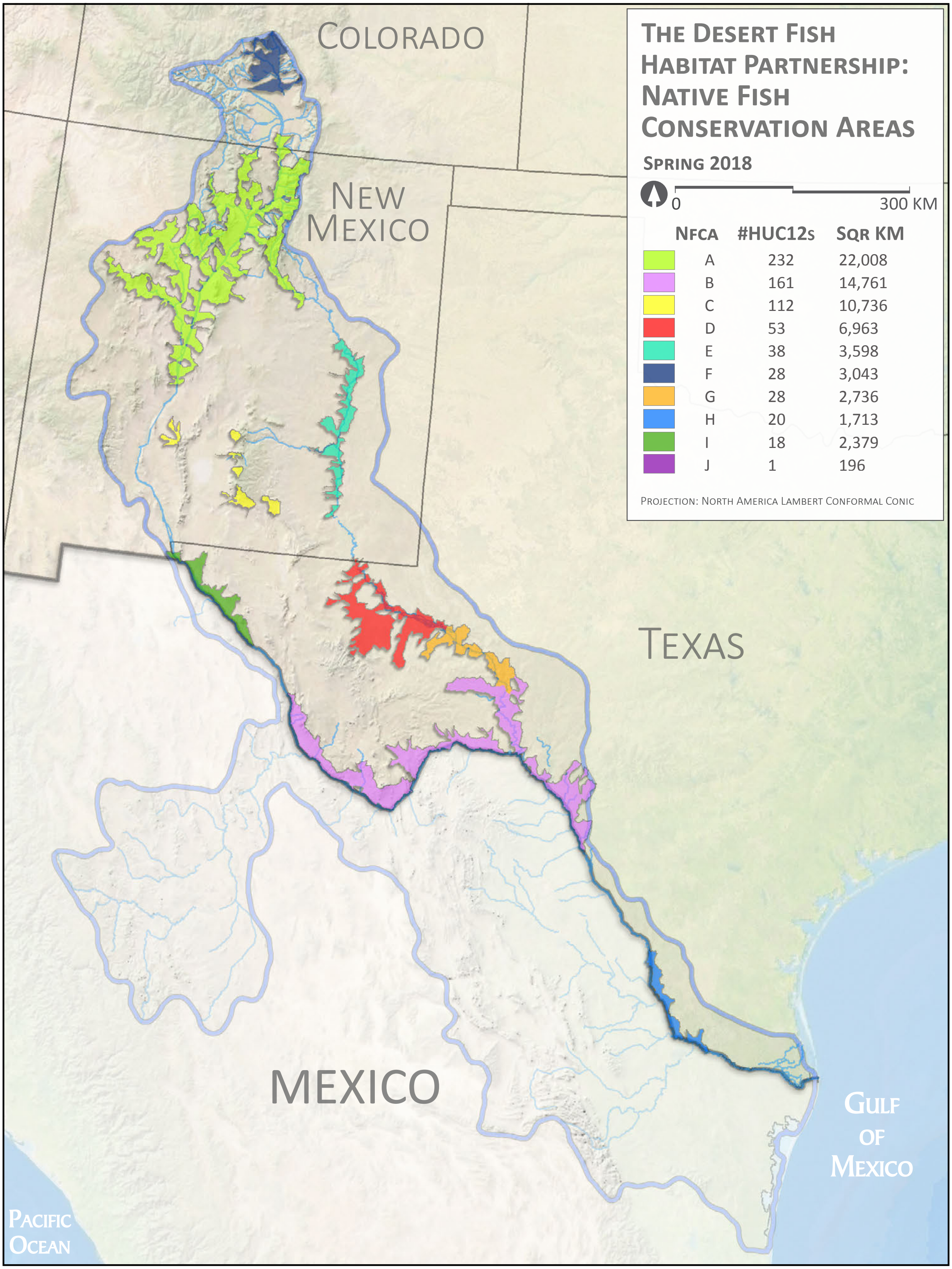


Figure 10. Native Fish Conservation Areas based upon The Desert Fish Habitat Partnership model prioritization.

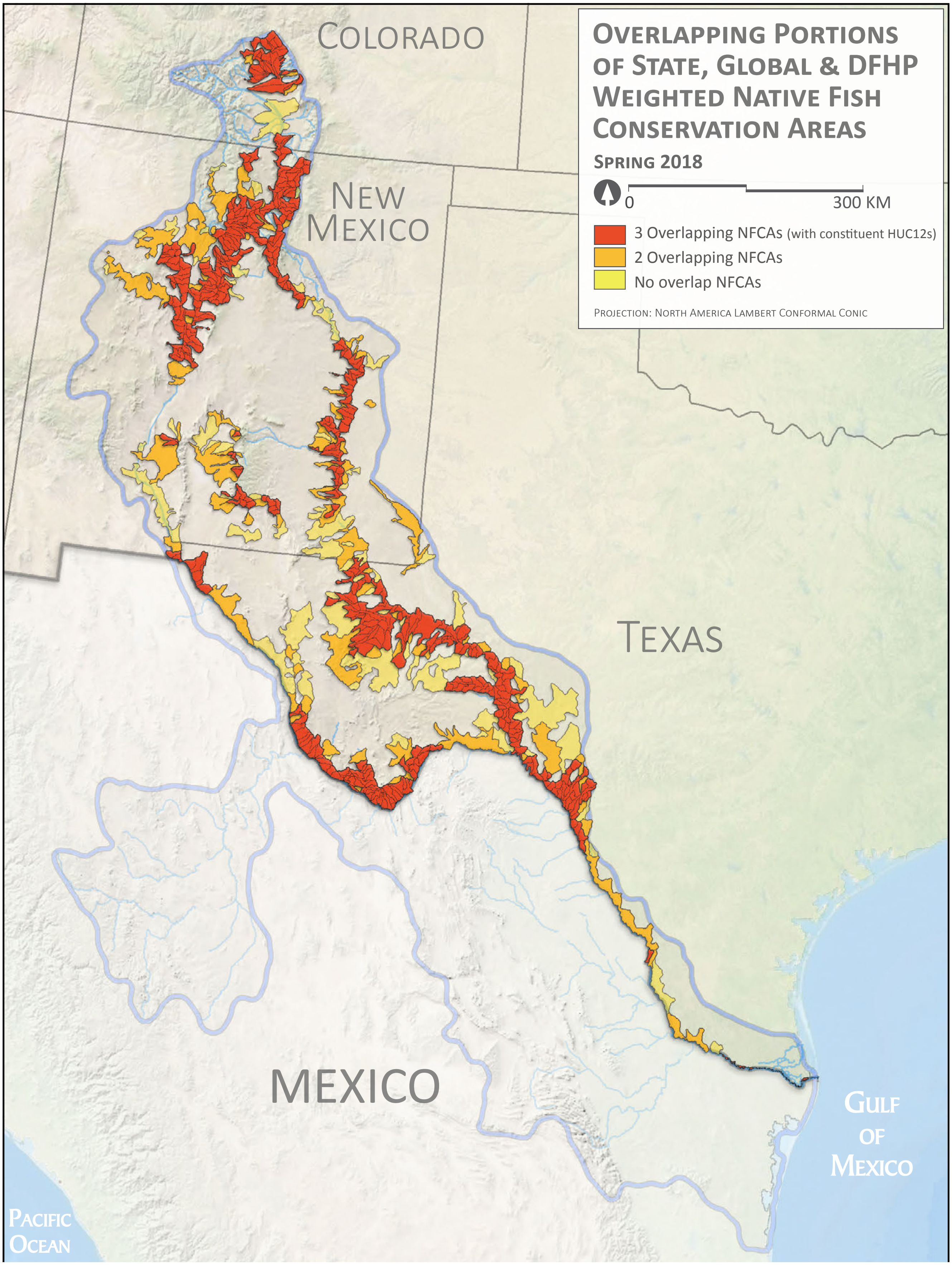


Figure 11. Overlapping sections of State, Global, and DFHP based NFCA, Highlighting HUC 12s of triple concurrence areas.

DISCUSSION

This assessment examined 39 fish species and associated environmental conditions within the Rio Grande River Basin. Through stakeholder collaboration and a quantitative modeling methodology commonly used in multi-species, aquatic landscapes (Moilanen et al. 2005), the assessment delivers a landscape ranking of stream segments that reflect both the presence of species-specific habitat and riverine connectivity. These results lend themselves to the development of Native Fish Conservation Areas, which form a matrix of the most important HUC 12 sub-watersheds for conservation of key species. Individual NFCA units are composed of high value stream segments that have similar species composition. These NFCA stronghold units can serve as the building blocks of a cohesive conservation action program for sets of native fish species 'strongholds'. Together, they facilitate proactive conservation action by providing a spatial- and assemblage-based framework for communication and coordination.

This assessment supplements existing fine-scale assessments of priority sub-regions (e.g., identified species management units) and jurisdictional units (e.g., states) as well as results of stakeholder workshops and planning processes (e.g., Great Plains NFCA workshop project - http://nativefishconservation.org/initiatives/great-plains-nfcn/), to form a critical component of the broader process of conservation planning (Figure 1). The Native Fish Conservation Area approach applied here is grounded in principles of sustainability, whereby the protection of aquatic communities is united with the management and provision of resources for compatible human uses (Williams et al. 2011). This philosophy emphasizes the maintenance of habitat complexity, the protection of all life stages, and the sustainable management of systems over time. This represents a conceptual shift in conservation design and recognizes that conservation can often be best assured through actions in areas remote from the conservation features of concern (Nel et al. 2009).

To bridge the assessment-implementation gap in conservation planning, conservation assessment products, such as those produced here, must be paired with an implementation strategy (Figure 1). This can be achieved by 'mainstreaming' the planning products, and coupling their recommendations into policies and communication tools for coordination between stakeholders (Figures 8-10). In practice, this may mean interpreting and redesigning these tools to facilitate a decision framework for a diversity of stakeholders whose work influences natural resource management (e.g., Pierce 2003). For example, the federally-required state wildlife action plans include guidance for interpretive land and stream habitat management. Placing these guidelines into a strategic planning framework facilitates efficiency for land-use planners and conservation organizations. Web-based spatial planning tools (e.g. Habimap, Southern Great Plains Crucial Habitat Assessment Tool, the Wyoming Interagency Spatial Database and Online Management tools) and the various habitat assessment tools for western states (often funded by the Southern Rockies Landscape Conservation Cooperative) are examples of how states and regions can encourage others to utilize and contextualize spatial assessment products.

CALL TO ACTION

To facilitate establishment of this proposed NFCA network, the conservation partnerships involved and influenced by this work need to initiate a series of watershed-based conservation planning workshops using the provided NFCA maps. Due to the nature of the Desert Fish Habitat Partnership's stakeholder- and partner-driven species rankings, we recommend focusing on the DFHP NFCA map (Figure 10) for planning purposes and using the other two maps as a point of context for managers. As this framework and its recommendations are incorporated into a planning process, practitioners would do well to remember that the framework is sensitive to changes in status determinations, and is thus well suited to augmentation and supplementation as data becomes available.

Planning workshops should be used to identify potential conservation actions (e.g., improved land management practices, barrier removal or redesign, water rights acquisition) and related science needs, to help prioritize, guide, and evaluate these conservation actions (e.g., determine flow-ecology relationships of focal species, identify and prioritize intact watersheds for zoning restrictions or easements). The workshops could also be used to facilitate dialogue among local stakeholders, especially regarding the development of local alliances and coordinated watershed-scale conservation actions. Examples of workshops based on this approach, and their respective conservation action plans and science agendas, can be seen on nativefishconservation.org.

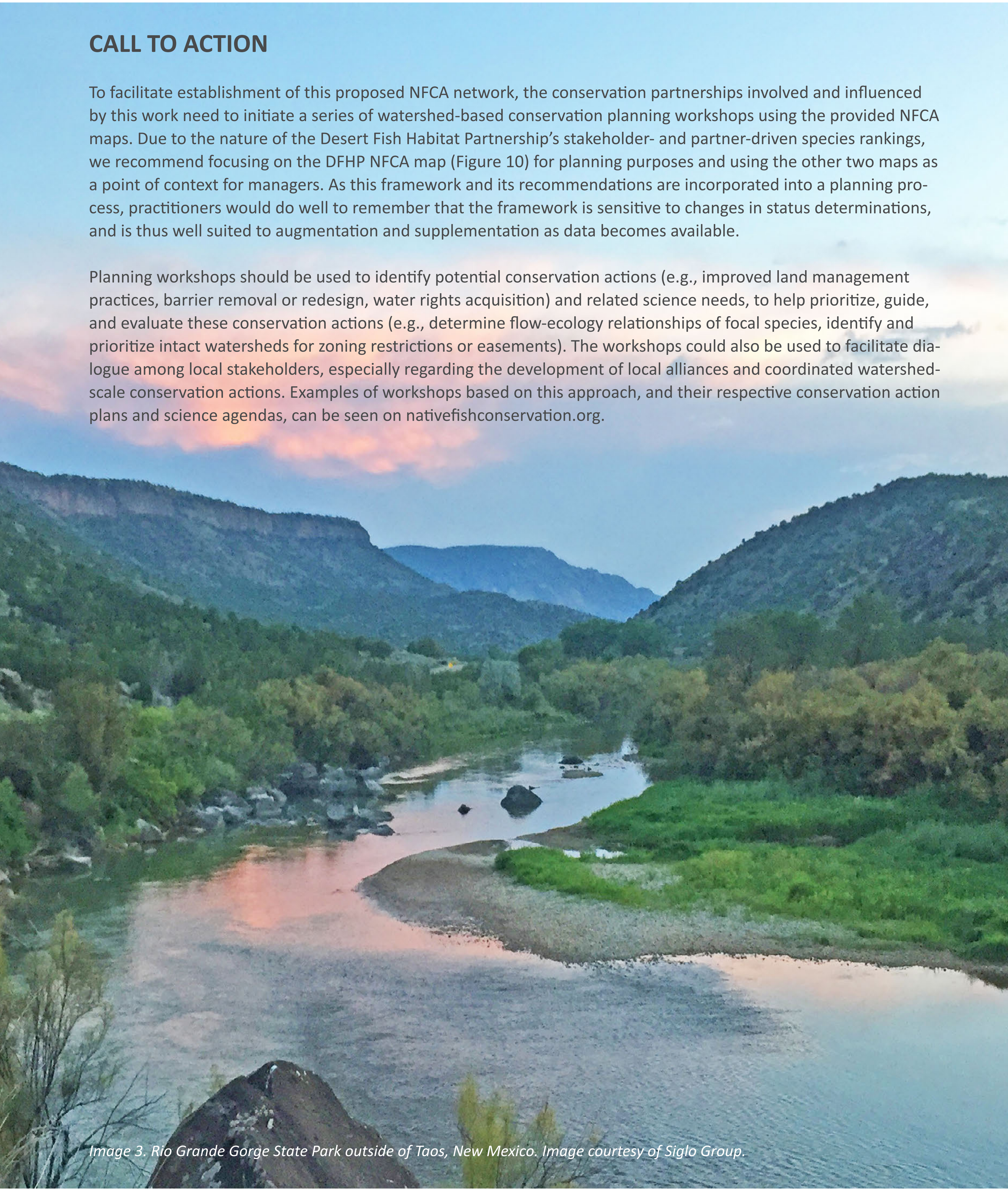


Image 3. Rio Grande Gorge State Park outside of Taos, New Mexico. Image courtesy of Siglo Group.

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IMAGE CREDITS

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Image 2. Courtesy of John Fowler. “Corrales Sunset” Rio Grande River, Sandia Crest, Corrales, NM. Attribution 2.0 Generic. www.flickr.com/photos/snowpeak

Image 3. Courtesy of Siglo Group. Rio Grande Gorge State Park outside of Taos, New Mexico.

CONTRIBUTING ORGINIZATIONS AND INDIVIDUALS

Table 4. Individuals who participated in any capacity during project initiation, webinars, calls, email exchanges, or in rounds of feedback on the process and methods.

Organization	Contributor
Colorado Parks and Wildlife	Harry Crockett
Michigan State University	Arthur Cooper
National Fish Habitat Partnership	Gary Whelan
Nevada Department of Wildlife	Brandon Senger
New Mexico Department of Fish and Game	Kirk Patten
New Mexico Department of Fish and Game	Michael Ruhl
New Mexico Department of Fish and Game	Joanna Hatt
New Mexico Department of Fish and Game	Bryan Bakevich
New Mexico Department of Fish and Game	Eric Frey
Retired - New Mexico Department of Game & Fish	Dave Propst
Retired - U.S. Fish and Wildlife Service	Jim Brooks
Siglo Group	Ben Labay
Siglo Group	Jonathan Ogren
Siglo Group	Ben Prince
Siglo Group	Kaitlin Tasker
Southern Rockies Landscape Conservation Cooperative	Kevin Johnson
Southern Rockies Landscape Conservation Cooperative	John Rice
Texas Parks and Wildlife Department	Megan Bean
Trout Unlimited	Dan Dauwalter
U.S. Fish and Wildlife Service	Bill Rice
U.S. Fish and Wildlife Service	Karin Eldridge
U.S. Fish and Wildlife Service	Jess Newston
U.S. Fish and Wildlife Service	Zachary Jackson
U.S. Fish and Wildlife Service	Thomas Sinclair
U.S. Fish and Wildlife Service	Stephanie Vail-Muse
U.S. Forest Service	Yvette Paroz
U.S. Geological Survey	Daniel Wieferich
University of Texas at Austin	Gary Garrett
Utah Department of Wildlife	Krissy Wilson
Western Native Trout Initiative	Therese Thompson

SOUTHERN ROCKIES
Landscape Conservation Cooperative

DESERT FISH HABITAT
PARTNERSHIP

Western Native
Trout Initiative

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GROUP