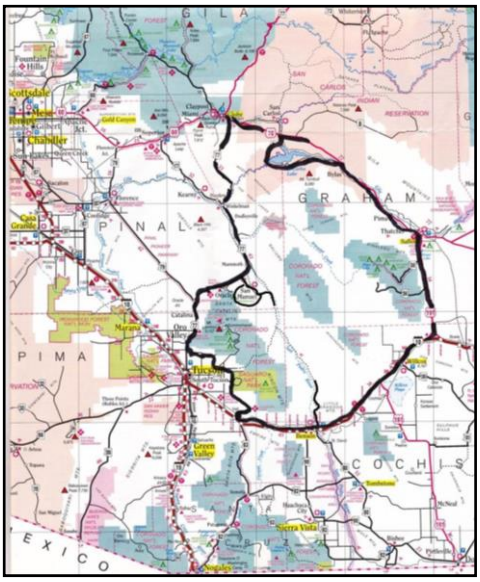
THE NORTHERN SKY ISLANDS:
LARGEST HIGH-BIODIVERSITY HABITAT BLOCK IN ARIZONA?



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ABSTRACT: This "citizen science" paper presents a biogeographical perspective on the Lower San Pedro River Valley as part of a larger Northern Madrean Archipelago wildlands. The paper focuses on connectivity as the critical issue uniting and nurturing the many environmental accolades attending the San Pedro River in the lower valley. After reviewing the theory of island biogeography and habitat loss through fragmentation, it reviews recent applications of "wilderness-compatible" and "wildlands" metrics to habitat blocks of connectivity in Arizona. Both of these metrics reveal the unfragmented areas in the Lower San Pedro River Valley to be the second largest in the state, but the latter, defined by no paved thruways or significantly impermeable linear infrastructure, expands the area to several million acres at the convergence of four ecoregions, six "Sky Islands," extensive "Desert Seas", and most of the lower San Pedro River. Studies indicate that this is the richest biodiversity area in the state, and thus is likely the largest high-biodiversity habitat block therein. While there are many threats to the ecological integrity of the area, this paper proposes that traditional western livelihoods and nature-based tourism can coexist in concert with a sustainable ecosystem, but that these fragmenting elements are deal-breakers to the maintenance of this widely recognized environmental and economic treasure.

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INTRODUCTION

The San Pedro River is widely regarded as the last major free-flowing "wild" river in the American Desert Southwest. National attention came to the river with the establishment of the San Pedro River National Conservation Area (SPRNCA) in 1988. In The Nature Conservancy (TNC)'s international campaign to save ecologically critical and largely intact areas, the San Pedro River became its first-named "Last Great Place."[1] Its significance grew when a 1998 study documented the San Pedro River Valley (SPRV) as the major avian Neotropical migratory route in the western U.S.[2] Its international economic significance was validated when NAFTA's Commission for Environmental Cooperation was assembled due to the SPRV avian corridor's critical importance for the U.S., Mexican and Canadian timber industries.[3] Tucson Audubon's county-level analysis further demonstrated the significant contribution to the local economy of wildlife viewing in the area.[4] And, a recent USGS, EPA and University of New Mexico study entitled "Biodiversity Metric" found that the San Pedro River Valley exceeds the Rio Grande and most other areas in the Southwest in ecosystem services.[5]

Until recently the Upper San Pedro River and SPRNCA have garnered the most public attention, but the Lower San Pedro River Valley (LSPRV) is now receiving greater scrutiny because of conflicts between the considerable conservation investments made along this portion of the LSPRV and the SunZia Transmission Project's proposed new utility corridor, as well as various other development interests. While these proposals may benefit investors and growth in the neighboring Sun Corridor, others see risk to conservation investments designed to mitigate prior impacts of development in Arizona and threats to a major river and habitat resource in an area of rich biodiversity, traditional rural livelihoods and values.

The Lower San Pedro River is also significantly biogeographically distinct from the Upper San Pedro. It begins at "the Narrows" a few miles north and downstream of Interstate 10. There the valley narrows and thereafter mountain front recharge provides the major portion of the river's surface and subflow.[6] Though surface flow of the San Pedro becomes more ephemeral in the LSPRV, it is no less ecologically significant than the Upper portion of the watershed. Its waters remain sufficient to feed the most extensive riparian area in the American desert southwest and it is a recognized Audubon Important Bird Area[7].

In the LSPRV the river is intimately tied to the enveloping mountain ranges and canyons, and the Neotropical avian migrants feed in the canyon and upland "oases" as much as the mainstem river.[8] The San Pedro River gradually descends into the Upper Sonoran bioregion, adding significantly to the valley's diversity. Chihuahuan scrub and grasslands continue in the piedmont while Madrean Woodland and AZ-NM Rockies flora and fauna inhabit the surrounding Rincon, Santa Catalina, Winchester and Galiuro Mountains' higher elevations. In addition to hosting this rare meeting of four major ecoregions, Brown and Lowe's iconic map of "The Biotic Communities of the Southwest" shows that within a 25-mile radius of the point where the Sonoran and Chihuahuan biotic communities meet in the LSPRV there are examples of nearly every major vegetation type in the desert southwest."[9]

Due to its rich biodiversity the list of environmental accolades in the LSPRV is long, but what ties those rarities together is perhaps the area's most critical attribute: its expansive intact habitat connectivity. Biogeographical studies of nature have revealed patterns that indicate the relative size of habitat patches, and the level of functional connectedness to nearby habitats and populations, influences wildlife population demographics, and in turn the number of species a given habitat patch can sustain through time. These relationships are instructive for understanding the nature of core habitats and wildlife movement corridors

which are critically important for the maintenance of ecosystem processes and valuable ecosystem services that sustain biodiversity and have sustained humanity in the region since Paleolithic times.

Since the publication of MacArthur and Wilson's landmark Theory of Island Biogeography, this issue of connectivity – or its antonym, fragmentation – has become one of the preeminent concerns in conservation planning. This paper seeks to discuss some of the implications of that concern for the importance and future of the LSPRV.

THE THEORY OF ISLAND BIOGEOGRAPHY

In 1967, two eminent ecologists, the late Robert MacArthur of Princeton University and E. 0. Wilson of Harvard published their "Theory of Island Biogeography", which explained how habitat area, and distance from nearest source populations combine to regulate the balance between immigration and extinction in island wildlife populations. The theory, which was supported by extensive data gathered by MacArthur and Wilson, predicts that islands with larger areas (and more, diverse habitats) can support a greater number of species through time, and islands closer to the mainland or other nearby islands have a greater rate of immigration because their closer proximity to source populations increases the probability of being colonized by organisms through time. And, according to this theory, the inverse is also true: islands with smaller areas can support relatively fewer species through time, and islands farther away from the mainland (or other islands with source populations) have lower rates of immigration because their further proximity to source populations decreases the probability of being colonized, and thus tend to acquire and sustain fewer species through time.

This theory has since been successfully applied to mainland terrestrial ecosystems as well. In place of the open ocean as the barrier to dispersal and colonization of organisms, the relative permeability of natural barriers like deep canyons, expansive deserts, and anthropogenic barriers like agricultural fields, clear-cuts, highways and developments influence the balance between immigration and extinction in land-locked habitat patches. In combination with the size and diversity of habitats within a given habitat patch, the level of functional connectivity to adjacent habitat patches in part determines an area's species richness and its ability to maintain native biological diversity through time. The current understanding of metapopulation dynamics, including "source" and "sink" populations of plants and animals, population genetics, and the forces that cause species extinction are all informed by the Theory of Island Biogeography and emerging fields of Wildlife Biology, Population Biology, Conservation Biology, Conservation Genetics, Landscape Ecology and Road Ecology. Human-caused habitat destruction, and the fragmentation of habitats into ever smaller and more isolated fragments are the leading cause of species extinction in the nation and world-wide[10, 11, 12].

Informed by these scientific disciplines and observational data, the overwhelming conclusion is that maintaining and restoring habitat quality and connectivity is vital for the maintenance of ecosystem processes, metapopulations, genetic interchange, dispersal, migration and range shifts that allow species survival and successful adaptation during changing environmental conditions.

The importance of connectivity and the ecological coherence of the LSPRV have been widely recognized. It's *"largely unfragmented landscape"* was, for example, a major rationale in Pima County's acquisition of the A-7 Ranch which extends from the Rincon and Santa Catalina mountains to the valley floor and San Pedro River.[13] It was also articulated as one of their conservation strategies to *"Maintain relatively unfragmented landscape connections between the Rincon, Santa Catalina, Galiuro and Winchester mountain ranges and through the San Pedro River valley that facilitate movement of wide-ranging wildlife species to meet seasonal and annual life requirements and for genetic interchange."*[14]

There are also a number of proposals that promote the need for maintenance of these connections. Pinal County has recognized the unfragmented nature of the area by adopting a County Open Space and Trails Master Plan that identifies much of the Lower San Pedro Valley as open space.[15] The Sonoran Institute has proposed a Galiuro-Rincon Corridor in cooperation with the Arizona State Land Department.[16] The U.S. Forest Service's support of the Forest Legacy Project in the SPRV was largely determined by its lack of fragmentation.[17] TNC's Apache Highlands[18] and Sonoran Desert[19] conservation portfolios describe much of the area as largely intact and unfragmented, and in response to the SunZia proposal TNC stated that, "There are few places remaining in the southwestern U.S. that are as intact and have the quality and extent of aquatic and riparian habitat as that found on the San Pedro River."[20]

In recognition of the LSPRV's largely intact and unfragmented character, 192,000 acres of mitigation and conservation lands have already been set aside, representing an estimated $42 million in investments. These figures do not include acreage under direct management by the BLM, USFS, and the National Park Service, so the total acreage for the LSPRV watershed in conservation status is closer to half of the lower valley's some 1.3 million acres. Investors include: The Nature Conservancy, Archaeology Southwest, Arizona Land and Water Trust, Arizona Game & Fish Department, Arizona State Parks, Bureau of Land Management, Bureau of Reclamation, Pima County, Salt River Project, U.S. Fish & Wildlife Service, Resolution Copper Company, Cascabel Conservation Association and Saguaro-Juniper Corporation. [21]

Ironically, this key resource of "connectivity" is also challenging to define. The LSPRV is extolled for its "largely unfragmented and intact" condition, but exactly what area are we talking about as "largely unfragmented and intact?" What makes it so, and why is that so significant?

FRAGMENTING BARRIERS

> *By far, the largest single threat to biological diversity worldwide is the outright destruction of habitat, along with habitat alteration and fragmentation of large habitats into smaller patches (Meffe et al. 1997). The two components of habitat fragmentation are 1) the reduction of the total amount of a habitat type in a landscape; and 2) the reapportionment of the remaining habitat into smaller, more isolated patches of habitat (Harris 1984; Wilcove et al. 1986; Saunders et al. 1991 in Meffe et al. 1997).*[22]

"Habitat patches", "habitat blocks" or "unfragmented areas" are usually identified without regard to political boundaries or management regimes. Rather they are defined by land cover in concert with the human built environment, including road networks, energy infrastructure, canals, railroads, etc. These long, linear, artificial barriers to wildlife movement are generally agreed to be the main causes of landscape fragmentation. Localized fragmentation may require as little as a plowed field or a barking dog, but landscape-scale fragmentation typically occurs when long linear structures or major developments form significant barriers to animal movement and create isolated habitat islands.

Habitat fragmentation creates landscapes made of altered habitats or developed areas fundamentally different from those shaped by natural disturbances that species have adapted to over evolutionary time (Noss and Cooperrider 1994 in Meffe et al. 1997).[23] Adverse effects of habitat fragmentation to both wildlife populations and species include:

- Increased isolation of populations or species, which leads to adverse genetic effects… and increased potential for extirpation of localized populations….
- Changes habitat vegetative composition, often to weedy and invasive species….
- Changes the type and quality of the food base….
- Changes microclimates by altering temperature and moisture regimes….

- Changes flows of energy and nutrients…
- Changes availability of cover and increases edge effect….
- Increases opportunities for exploitation by humans, such as poaching or illegal collection for the pet trade…[24]

The adverse impacts of fragmentation are clear, but the difficulty in defining unfragmented areas is that "fragmentation" is itself a relative term. There is considerable scientific literature on various methods for quantifying landscape fragmentation because "…habitat fragmentation is scale-dependent with different processes predominating at different scales for a given species."[25]

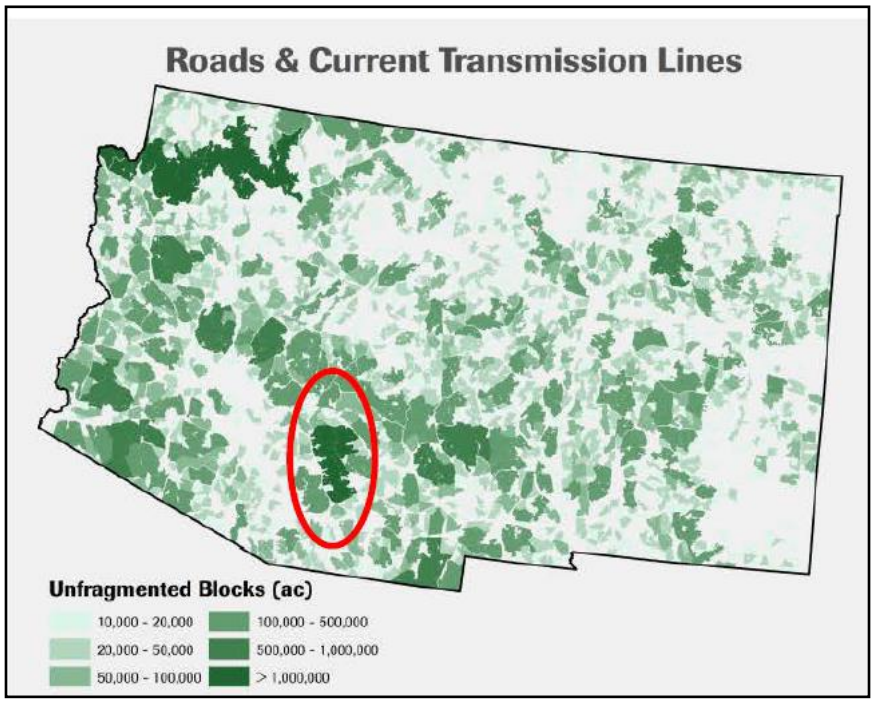
> *A crucial question in the development of indicators of landscape fragmentation is which landscape elements should be considered as fragmenting elements. Some landscape elements may be complete barriers to animal movement, whereas others are filters of varying effectiveness.*[26]

These nuances raise the topic of "permeability," which *"…refers to the degree to which regional landscapes, encompassing a variety of natural, semi-natural and developed land cover types, are conducive to wildlife movement and may sustain ecological processes*."[27] The lack of fragmentation is often associated with "intact" habitats, which is also a relative term: "Intact habitat represents *relatively* undisturbed areas that are characterized by the maintenance of *most* original ecological processes and by communities with *most* of their original suite of native species [*author's emphases*]."[28]

Despite this difficulty in defining the permeability of barriers for respective species, for landscape scale assessments and planning there are some established thresholds.

A WILDERNESS-COMPATIBLE STANDARD FOR FRAGMENTATION

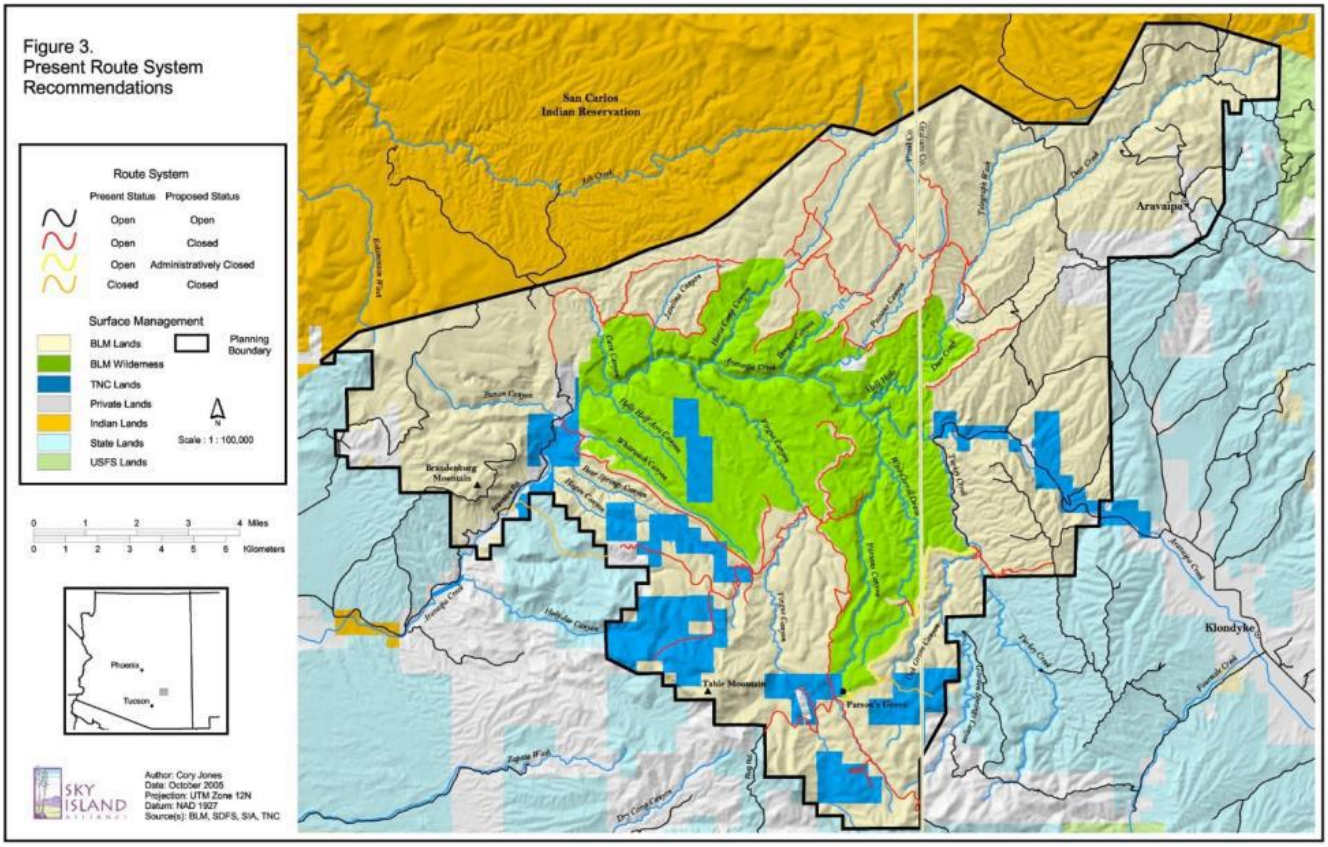
The Center for Science & Public Policy of the Arizona Chapter of The Nature Conservancy made a significant contribution to the issue of connectivity in the LSPRV by proposing a metric for fragmentation. In their paper, "Cumulative Effects Analysis for Proposed SunZia Transmission Line," they found that an area from the Galiuro Mountains in the San Pedro River Valley to the Santa Teresa Mountains in the Gila River Valley is *"the second largest unfragmented landscape remaining in the southwestern U.S…."*[29] This area "*encompasses over [1,000,000]*[30] *acres of intact, high value wildlife habitat*," and "*outside of the Grand Canyon, there is no habitat block larger than the Galiuro-Aravaipa-Santa Teresa area*." The paper concludes that "*it raises the question of whether mitigation measures are even possible for disturbances to the region's second largest intact landscape*."[31]



This conclusion is highly significant ecologically, especially in this southeastern Arizona noted "hotspot" of biodiversity, for the larger the intact connected area remaining, the better this critical landscape can support the health and survival of more species into the future. Further, invoking fragmentation in support of an argument against the SunZia transmission line project's Aravaipa Canyon proposed route, which was since abandoned, demonstrates the importance that the issue of connectivity can lend to policy debates.

In TNC's analysis the fragmenting elements assessed include: 1. All paved roads 2. All unpaved roads that cross over the mountain ridge axis 3. All transmission lines.[32] These were all critical elements of the SunZia proposal, though other barriers were not excluded as possibilities. Transmission lines were an obvious fragmenting concern, but the access roads required to install and maintain this major new energy corridor – which were well-documented through the line siting process – would be at least as impactful.

The number two fragmenting element assessed, "unpaved roads that cross over the mountain ridge axis," may sound locally particular, but the point is to distinguish unpaved roads that connect with other unpaved roadways creating a large encircling barrier across mountain ranges. For ease of discussion these will be referenced as unpaved *thruways*. By virtue of connecting with other road systems, thruways not only create habitat islands, but they also increase traffic. Increased traffic further exacerbates fragmentation through greater disturbance, roadkill, and edge effects. Unpaved road spurs and loop roads may exist within the proscribed area as they are not isolating on a landscape scale. This is in fact the case here, for while there are no unpaved thruways within the proscribed unfragmented area, an October, 2005 Sky Island Alliance map (below) depicts the road network in the Lower San Pedro River Watershed, including routes to consider for closure in the Coronado National Forest's travel management planning process.[33]



This metric, which identifies nearly any landscape-scale barrier as fragmenting regardless of permeability, is a strict one that defines an ecological area of high connectivity. That defined area is not the same as legally designated wilderness, but it is consistent with areas largely exclusive of human habitation and more commonly found in designated and de-facto wilderness areas. Indeed, the area described is inclusive of the Aravaipa Canyon Wilderness, the North Santa Teresa Wilderness, the Galiuro Wilderness and Redfield Canyon Wilderness areas.

A WILDLAND STANDARD FOR FRAGMENTATION

Another model for "unfragmented areas" in the LSPRV was employed by the Arizona Game and Fish Department (AGFD) in its spatial analysis as part of its Statewide Wildlife Action Plan.[34] Similar to the TNC analysis, the AGFD model identifies this study area as one of the largest, most intact habitat blocks in Arizona, second only to the Grand Canyon. Following is a description of the methodology used to develop the model:

> *Unfragmented Areas: This category analyzes large swaths of contiguous, unfragmented blocks of habitat. The Department has identified the importance of maintaining unfragmented habitats as a critical component in the conservation of wildlife and wildlife habitat as well as addressing existing and predicted global climate change (i.e., protecting blocks of habitat across an elevational and vegetation gradient). Determining contiguous habitat was based on GIS analyses using all major barriers (i.e., roads, railways, canals, etc.) to delineate areas. Methodology – Unfragmented blocks of habitats were defined by first mapping barriers to wildlife movement including: 1.) Major roads: The source was the Trans123 dataset, derived from the U.S. Census Bureau TIGER/Line® files, downloaded from the AGIC GeoData portal. Roads regional staff had previously identified as incorrectly categorized as a major road were erased. 2.) Arizona railroads: The source was the railroads dataset from the National Atlas (http://www.nationalatlas.gov/). These railroads were revised to match the current railroads as shown on the BqAZ framework map. Figure 14. Sport fish model Arizona Game and Fish Department May 16, 2012 Arizona's State Wildlife Action Plan 2012 – 2022 Page 47 3.) Colorado River: The Colorado River and the Grand Canyon have long been recognized as a geographic barrier to some species (Grinnell 1914, Goldman 1937) and has been hypothesized to be the cause of genetic drift in tree squirrels (Lamb et al. 1997) and mule deer (Travis and Keim 1995). The river was traced from Lake Mead to the Utah border including the outlines of Lake Mead and Lake Powell. 4.) Canals: Regions 4, 5, and 6 provided input into which canals are barriers to wildlife movement. These datasets were combined into one layer. 5.) Developed areas: Codes 111 and 112 were extracted from the SWReGAP landcover dataset.*[35]

In summary, the main fragmenting elements delineated by the AGFD spatial study in Arizona are 1. Major roads 2. Railroads 3. Colorado River 4. Canals 5. Developed Areas. The geologic barrier of the Colorado River as a fragmenting element does not enter into the LSPRV. Neither are railroads or canals presently at issue, and continuous developed areas exist only on the northern periphery of the lower valley. In the LSPRV, "Major roads" appear to be the main fragmenting concern according to this metric.

Comparing the fragmentation metrics employed by TNC and AGFD in the LSPRV, the relevant differences are: (1) AGFD's employment of *paved thruways* rather than TNC's use of *unpaved thruways* as fragmenting elements (2) AGFD does not isolate powerlines as fragmenting barriers. These differences in approach to roads and power lines as fragmenting elements will be reviewed separately.

ROADS

Roads are the most ubiquitous of the fragmenting barriers, but not all roads are created equal.

> *As a measuring unit, effective mesh size assigns equal weight to all barriers. In real life, however, it makes a big difference whether an animal is confronted with a small country road or a highway. While it is possible that for some species, all listed infrastructure elements might constitute insurmountable obstacles, for most species, it will be the nature of the barrier placed in their path (volume of traffic, wideness, animal-tight fences, etc.) that carries the most weight.*[36]

In the TNC study *all paved roads* and *all unpaved thruways* are the defining fragmenting elements. Scientists seem to agree that these long, continuous structures create the most severe landscape-scale fragmentation, but the relative permeability of the barrier is equally important. In that regard, the best available science supports the intuitive notion that paved thruways are more harmful and less permeable to wildlife and ecosystem processes than are unpaved ones.

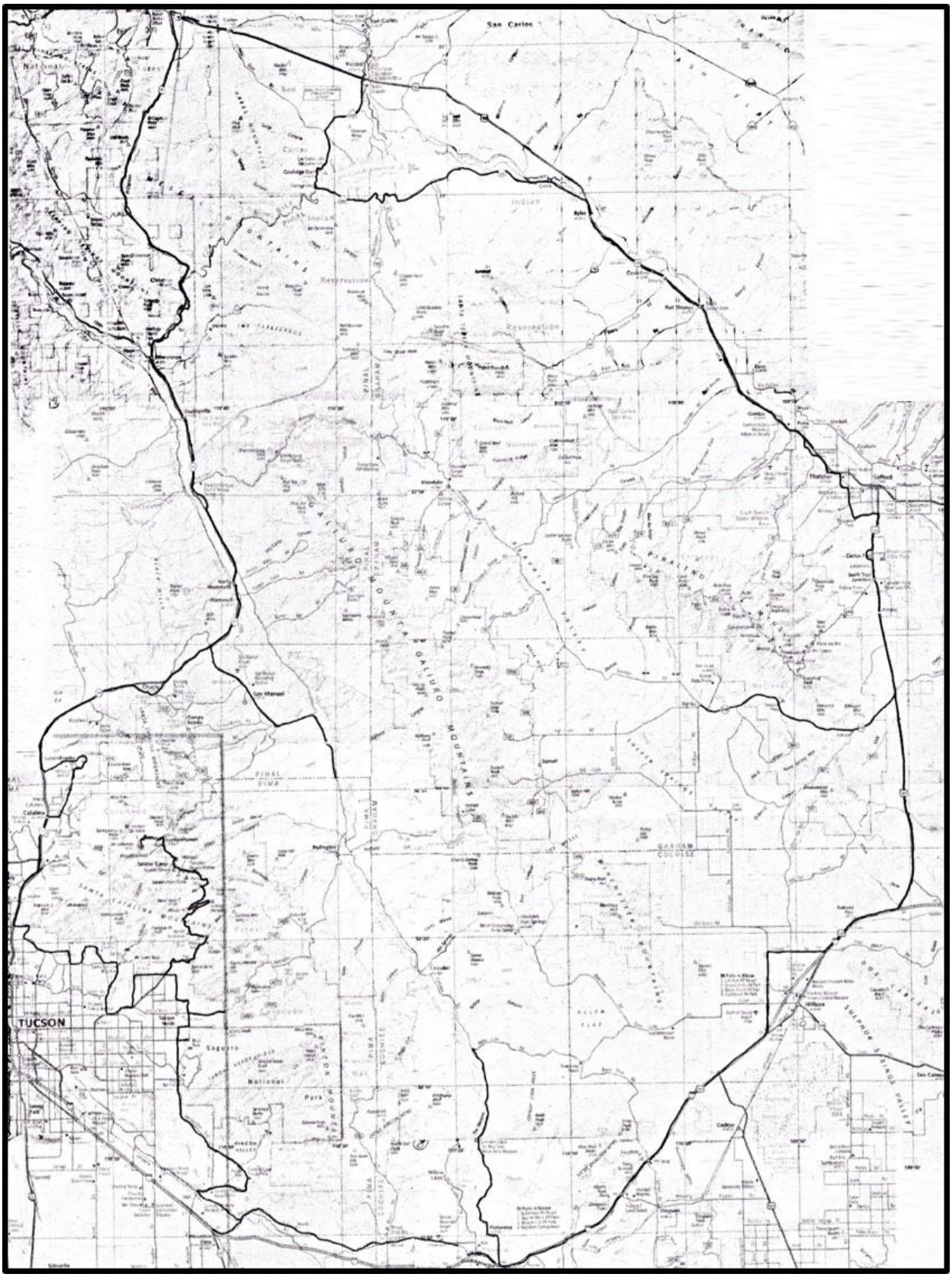
> *Vehicles on high-speed highways pose the greatest threat to wildlife. Unpaved roads, particularly when "unimproved," are less dangerous. Roadkill usually increases with volume of traffic. …Increases in traffic volume do result in more collisions on any given road…*[37]

> *Forman and Alexander (1998) report that road width and traffic density determine the intensity of the "barrier effect" that results in avoidance of roads by wildlife, leading to habitat fragmentation and dividing existing populations into smaller, isolated metapopulations*.[38]

All roads are fragmenting to some degree, but studies demonstrate that impacts vary based upon physical structure and the volume and velocity of vehicular travel. The Arizona Game and Fish Department's 2012 *Arizona Wildlife Linkages Assessment*, focusing on the Santa Catalina/Rincon-Galiuro Linkage in the Lower San Pedro River Valley, noted that scale is a critical concept to consider when analyzing impacts to ecological pathways. Their assessment specifically addressed the Cascabel-Redington Road, noting that while their linkage design contains about 130 miles of roads, "most of these roads are currently gravel and easily passable by wildlife."[39]

"Unimproved" and "primitive" unpaved roads, as the Cascabel-Redington Road is classified, support less volume and velocity of vehicles than a paved road, highway, or interstate, and have helped maintain the LSPRV's agreed-upon largely unfragmented and intact status. Thruways invite more traffic volume since they allow connectivity to other road systems, but unpaved thruways invite much less volume and velocity of traffic than do paved ones. The Cascabel-Redington Road is a textbook example. Though the northern and southern ends of the road are now paved, its transition into an unpaved road inhibits thru-traffic such that only light local traffic traverses these paved spurs with significantly less fragmenting impact. Near the road's midpoint there are rarely more than a couple dozen vehicles per day, mostly made up of locals and various service vehicles.[40]

Researching the paved thruways in the LSPRV area, the connecting paved roads (including a small stretch of the BNSF railway just north of Interstate-10) were traced on a composite of the latest available Arizona road maps.[41] (See map following page.)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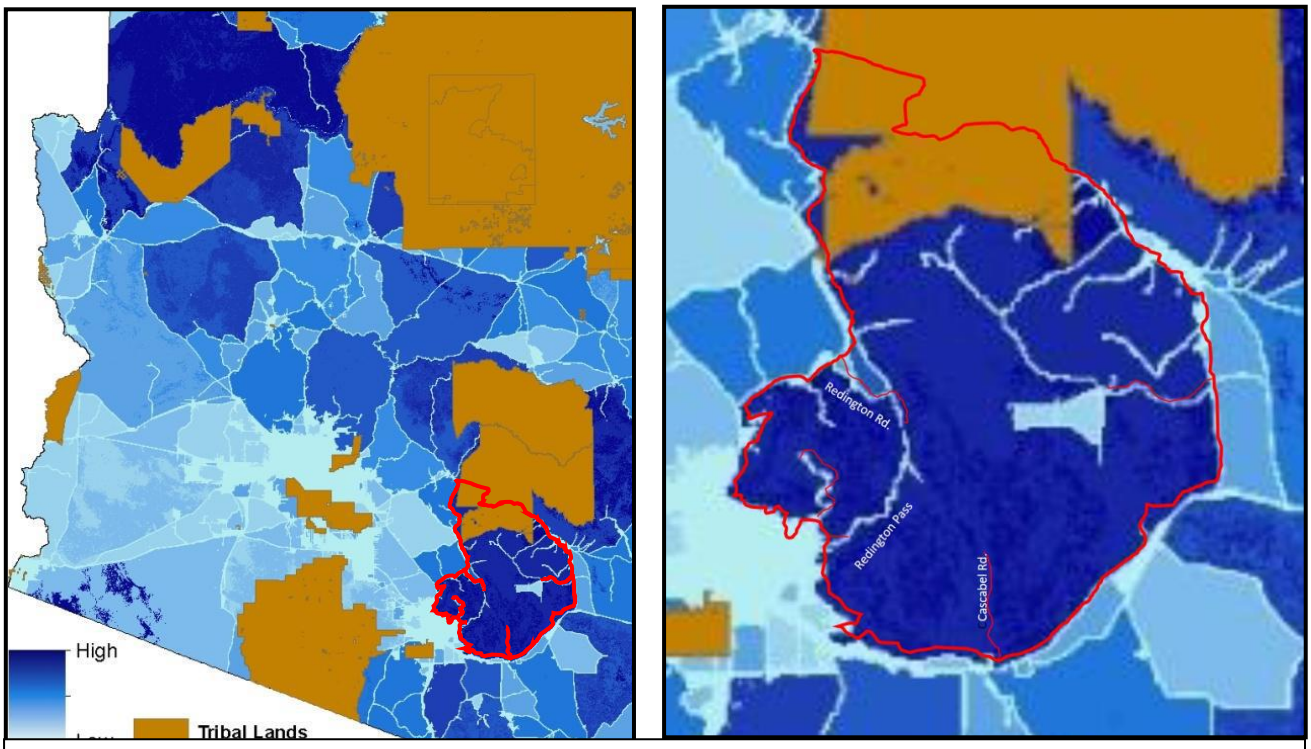
In turn, overlaying that outline of paved thruways on the AGFD spatial analysis shows exact correspondence with their "Major roads" barrier (including the small BNSF railway portion). This demonstrates that, much as the TNC metric relied on *unpaved* thruways as fragmenting elements, in the AGFD analysis, "major roads" equals "paved thruways," at least in this area.



LSPRV paved thruways overlaid on the AGFD unfragmented spatial analysis

It is worth noting that the white lines within the dark blue AGFD area analysis apparently represent disturbed areas and potential fracture zones, but are not defined fragmenting barriers. For example, one of the white lines corresponds to the northern portion of the Redington Road, which is now a paved spur but segues into an unpaved road carrying minimal thru traffic. Also, rather than following the Cascabel Road, the line follows the Redington Pass road which is all dirt and very lightly traveled. Though these are potential fracture zones, there are neither paved thruways nor continuous development in this area. The metric of unfragmented area also extends into tribal lands not considered in the state's analysis, but habitat blocks exist across political boundaries and management regimes.

As the AGFD report states, a preponderance of species can cross an unpaved road if it is not overly wide and has the typical reduced volume and velocity of vehicles. Though the impacts of unpaved thruways can be significant, as they often enable a range of impacts to occur in what would be otherwise inaccessible terrain, the science of Road Ecology has demonstrated that gross environmental impacts increase enormously with paving, the scale of road improvement and concomitant traffic volumes and development.

TRANSMISSION LINES

Beyond roads, *all transmission lines* are the other fragmenting element in TNC's metric. Avian mortality, as well as the aerial and terrestrial fragmentation caused by transmission lines, is well documented. [42,43,44]

> *Powerlines fragment bird flight paths, leading to collisions of birds with the lines, resulting in injury and death. …In the USA collisions with automobiles and powerlines were the most frequent cause of bird mortality (Stout and Cornell 1976).*[45]

Their impact is of obvious concern in the LSPRV as a main western migratory corridor for neotropical birds. Though all transmission lines are fragmenting to some degree, their impacts and capacity for mitigation are often difficult to assess. There are differences in scale of impact between major and minor installations, just as there are between dirt roads and paved highways. The middle SPRV has a long linear 115Kv transmission line and unpaved service roads that run intermittently along its length. Again, the AGFD report finds:

> *The current utility infrastructure that exists within the linkage design may have little effect on the wildlife species that occur here. However, future large-scale utility infrastructure projects, like the proposed SunZia Southwest Transmission Project, may have numerous negative impacts on wildlife in the San Pedro Valley. Large-scale utility infrastructure projects would threaten wildlife connectivity in this linkage, specifically for the numerous rare bird species that use the area for reproduction*.[46]

The relative permeability of the structure is an issue with transmission lines as it is with roads. The AGFD assessment, much like the TNC analysis of the Galiuro-Aravaipa-Santa Teresa area, concludes that "the construction of large-scale utility infrastructure, like that proposed by the SunZia Southwest Transmission Project, may be devastating to the area's wildlife, regardless of the mitigation measures implemented."[47]

Reaffirming the criticality of connectivity, the assessment concludes that, "The San Pedro River Valley, in which this linkage passes through, is a relatively pristine place. …This area remains permeable to a wide variety of wildlife species, and that permeability should be maintained into the future."[48] In other words, this lightly populated wildland area with unpaved roads and minimal infrastructure is judged by these biological teams to share the same critical importance for wildlife as even more remote upland wilderness areas.

Approval of SunZia's Transmission Line Proposal by the Arizona Corporation Commission, despite strenuous dissent, may make fragmentation of the area by a major infrastructure corridor appear a *fait accompli*. However, the project's actual installation, and the degree thereof, remains uncertain at this writing. Even if built out in its entirety, the Environmental Planning Group's finding that impacts could be mitigated remains to be seen. Nonetheless, there will be no question about the fragmenting impact of the attendant service roads, especially if contributing to paved thruways as discussed above.[49] These questions surrounding mitigation and variability of impact may be why the AGFD does not consider transmission lines in its assessment of major fragmenting barriers.

WILDLANDS

The divergent standards employed in the TNC study and the AGFD analysis reflect varying thresholds of connectivity. Though they are generalizations of a difficult subject, they establish scientifically supported parameters in policy discussions. The metric employed in TNC's study is meaningful for defining unfragmented wilderness-compatible areas with very limited human impact. The metric employed in AGFD's spatial study helps define areas that are *largely* unfragmented and intact ecosystems, which are here being referenced as "wildlands." Such variability of the fragmentation mesh reflects the issue of permeability and allows applicability to watered valleys where human development is common.

The main difference between these standards is with regard to roads where the fragmentation criteria is revised from *unpaved* thruways to *paved* thruways, the latter being significantly more impermeable than dirt and gravel roads to most vertebrate species. Again, paved road spurs and loops may exist within the

proscribed area as they are not isolating on a landscape scale, and are comparable to the many unpaved road spurs and loops in TNC's study.

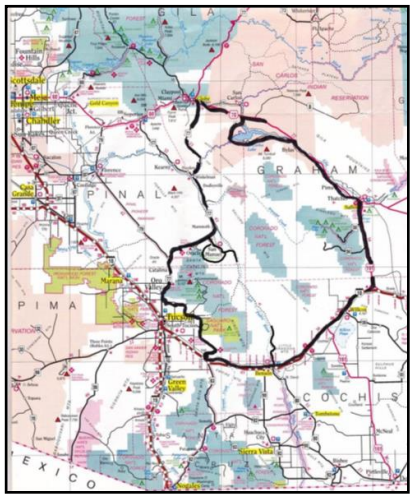
With regard to other infrastructure barriers, any *transmission line* is counted a fragmenting element in the TNC study, and not considered a major fragmenting element at all in the AGFD analysis. Though not specified, the strict nature of the TNC metric would doubtless agree that *railroads, canals,* the *Colorado River,* and *extensive developments* are significant infrastructural barriers to the movement of most wildlife.

The benefit of these varying standards is to note that the terms "unfragmented" and "intact" are equally useful when associated with the concept of "wildlands" as with "wilderness-compatible" areas. Conservationists today are often more comfortable replacing *"…the ideal of a wilderness untouched by man with the new ideal of 'wildness,'" which is "measured not by isolation from disturbance but by the diversity of organisms that can complete their life cycles."*[50] The term "wildlands" is becoming commonly associated with "…lands and waters where natural processes dominate and human impact is minimized. This assumes a gradient of 'wildness' or lack of human impact and thus most forests, grasslands, rangelands, streams, and natural lakes would fit this definition of wildlands."[51]

A downside of limiting unfragmented areas to a strict wilderness-like definition has been that mountainous areas become the primary unfragmented core areas, whereas it is the well-watered valley bottoms where humans live that connectivity is often important for more species, and indeed for maintaining connectivity with and between these higher elevations. Much of the LSPRV is described as "largely unfragmented and intact." This has been the rationale for the protection of many mitigation lands and connectivity proposals in the valley, and yet these areas are not captured by the wilderness-compatible definition of "unfragmented."

When viewing fragmentation as a gradient rather than an absolute, the AGFD's metric helps define a "largely unfragmented and intact" wildland area. The standard used by TNC has the advantage of defining an unfragmented "wilderness-compatible" area succinctly for the purpose of public policy debates. Defining this "wildland" area helps to crystalize the importance of this largely unfragmented and intact area into an easily graspable concept as well.

THE NORTHERN MADREAN ARCHIPELAGO



When the map is redrawn using these parameters for large landscape connectivity – i.e., no paved thruway or other gross barrier to general wildlife movement – the unfragmented wildland area expands considerably to some three million acres.[52] Perhaps most notably, this largely unfragmented area includes the Santa Catalina, Rincon, Winchester, and Pinaleño Mountains as well as all of the Galiuro and Santa Teresa Mountains of TNC's original study. These half dozen "Sky Islands" constitute the northernmost extent of the Madrean Archipelago, "a region boasting the highest biodiversity in inland North America."[53]

This Northern Madrean Archipelago (NMA) wildland area also includes a confluence of four major ecoregions: Sonoran Desert, Chihuahuan Desert, Madrean Woodland and AZ-NM Rocky Mountains. It includes the greater part of the lower San Pedro River, at least five major Conservation Sites in TNC's ecoregional assessment of the Apache Highlands[54] and Sonoran Desert[55], and has representatives of nearly every major biotic formation in the Desert Southwest.[56] The NMA fits within the scope of the AGFD's concern for areas that are "home to a disproportionately large number of species (see Species of Greatest Conservation Need (SGCN), p. 43); have

an intrinsic economic importance to the Department and/or the people of Arizona; provide unique hunting, fishing, and other recreational opportunities (see Species of Economic and Recreational Importance (SERI), p. 44 and Sport Fish, p. 46); are exceptionally important habitat (see Riparian, p. 48); and, a few areas, remain relatively unfragmented providing unique management opportunities for wildlife (see Unfragmented Areas, p. 46).[57]

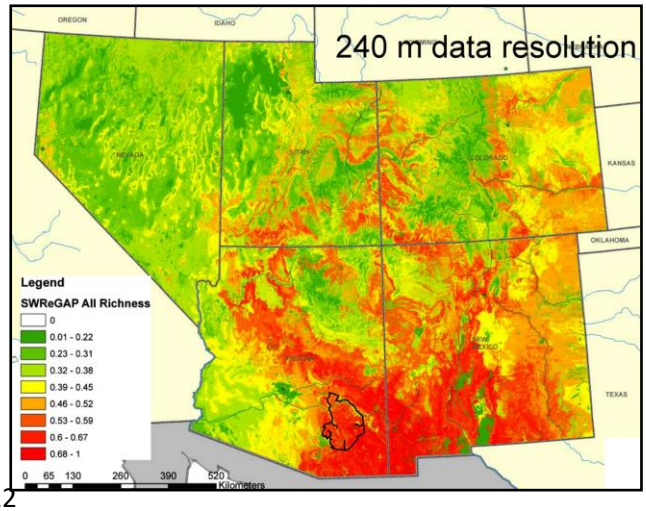
The inclusion of "Sky Islands" in this largely unfragmented area is particularly salient, since the most critical finding from the science of island biogeography is that islands are negative indicators for long-term species survival. A major significance of this larger unfragmented area is that it includes the valley basins or "Desert Seas" of semi-desert grassland and Sonoran and Chihuahuan desert-scrub that surround and connect these "Sky Islands," allowing the evolutionary processes and rich species diversity of these islands to continue. Both the TNC analysis and the AGFD assessment, in their respective regions of study in the LSPRV, concluded that a major infrastructure project would be devastating for wildlife and questioned whether mitigation measures are even possible for the major fragmentation of such a large intact landscape.

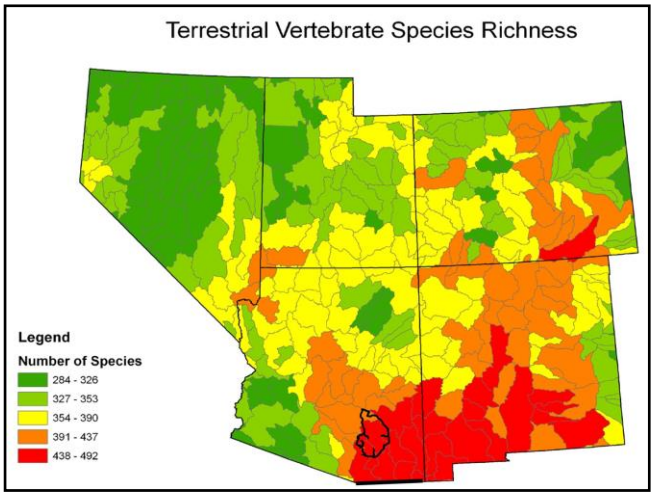
Connectivity is particularly important in the Desert Southwest since, though these desert ecosystems have high biodiversity, the abundance of each species is often low or patchy due to the scarcity of water.[58] Climate change models forecast the impacts to be severe in the Desert Southwest, i.e. increased temperatures and aridity,[59] and the opportunity for wildlife movement and dispersal will become even more crucial for these small and increasingly stressed populations. In particular, the dramatic elevational and vegetation gradient of the Sky Island ecotones increases the need to protect blocks of habitat across elevations and between mountain ranges.

BIODIVERSITY

It is rare to find such a large area in the Desert Southwest not transected by a paved thruway or major fragmenting barrier. What magnifies that significance is its congruence with the area of the richest species diversity in the region. The extent of intact habitat connectivity and the richness of species diversity are the hallmarks of wildlands.

A recent USGS, EPA and University of New Mexico study entitled "Biodiversity Metric" found that the San Pedro River Valley exceeded the Rio Grande and most other areas in the Southwest in ecosystem services.[60] Their maps, as well as numerous studies, show the Madrean archipelago to be a "hotspot" containing some of the greatest species diversity in the Desert Southwest. The biodiversity metric maps pictured below, one shown by grid analysis and the other by sub-basin units, reveal the areas of highest species richness in the Southwest. When the outlined NMA unfragmented area is overlaid on this map, it is clearly within an area of the highest richness.[61]





When rich diversity of species overlaps with large landscape connectivity, the two brightest stars in conservation priorities are in alignment. The World Wildlife Fund assessment of terrestrial ecoregions gives the highest priority to *"Globally or regionally outstanding ecoregions that present rare opportunities to conserve large blocks of intact habitat,"* which not incidentally includes the Chihuahuan Desert, Sonoran Desert, Arizona Mountain, and Madrean Woodland ecoregions, all of which converge in the LSPRV.[62] The environmental significance of this area can hardly be overstated, with its some three million largely unfragmented and intact acres, six "Sky Island" mountain ranges at the convergence of four major ecoregions, and with one of the last major wild river systems in the Desert Southwest coursing through it. The congruence of such a large unfragmented area with such biological richness suggests that this may well be the largest unfragmented area containing the greatest species diversity in the entire American Desert Southwest.

CONCLUSION

> *Conservationists are far from able to assist all species under threat, if only for lack of funding. This places a premium on priorities: how can we support the most species at the least cost? One way is to identify 'biodiversity hotspots' where exceptional concentrations of endemic species are undergoing exceptional loss of habitat.*[63]

The Northern Madrean Archipelago is a basin-range transition zone between the northern temperate and southern semi-tropical latitudes, and the eastern cold-winter Chihuahuan desert and the western mild-winter Sonoran Desert. As such, it contains enormously rich and unique biodiversity of flora and fauna, which at the same time is exceptionally vulnerable to fragmentation that breaks connections between the mountain range "Sky Islands" and the valley basin "Desert Seas." The point of this paper is to propose a conceptual framework that helps define this critically important transition area and advocate for its wise stewardship into the future.

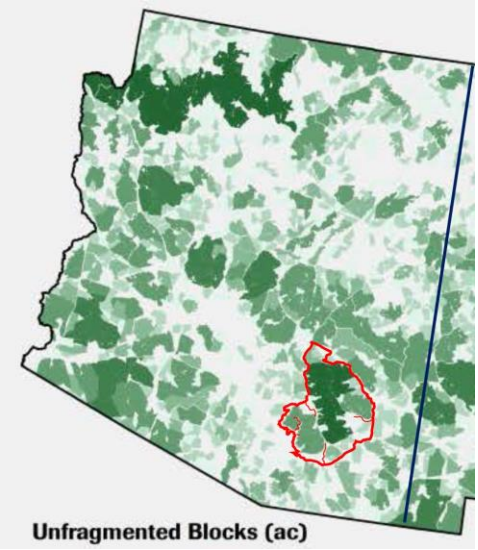
Connectivity, as has been confirmed by the Theory of Island Biogeography and related scientific disciplines, is the *sin qua non* of sustainable habitats. Fragmentation, despite being a relative measure, has agreed upon thresholds for both "wilderness-compatible" and "wildland" barriers whereby the threat of habitat loss and species extirpation become critical. A wildland fragmentation metric, such as described by the AGFD, is inclusive of areas where a limited amount of human interaction and livelihood can coexist with relatively intact ecosystems that maintain most of their original ecological processes and their original suite of native species.

The major fragmenting elements of wildland areas, as defined in the AGFD GIS spatial analyses, are paved thruways and significantly impermeable linear infrastructure such as railways, canals and extended development, including geological barriers such as the Colorado River. As so defined, the Northern Madrean Archipelago wildland area is inclusive of the Santa Catalina, Rincon, Galiuro, Winchester, Santa Teresa, and Pinaleño "Sky Islands" and most of the Lower San Pedro River Valley.

An advantage of this "wildlands" perspective is that it does not seek to isolate human impacts and activities from an idealized wild nature, while valuing the enormous biodiversity that can and does coexist with well managed working landscapes.[64] It thereby removes the discussion from the either/or camps of "protectionism" or "exploitation" allowing for a more nuanced approach. Nature is homeland to humans and is flexible. Some livelihoods following good practices can integrate within critical wildland areas and have done so for generations.

Nonetheless, there are breaking points in nature where connectivity is severed. The Northern Madrean Archipelago ecosystem is doubtless subject to death by a thousand cuts from numerous and various anthropogenic impacts. But as in human relations, nature too has its deal-breakers. The introduction of any

of these major fragmenting elements severing the connection between river and mountain ranges would effectively seal the fate of the ecosystem's health and the sustainability of the native denizens of quite possibly the largest high-biodiversity habitat block in the Desert Southwest.



The science of island biogeography not only helps define the NMA habitat block, but also what will irremediably fracture it. That returns the discussion to where it began, for the LSPRV is clearly the most threatened *potential fracture zone* of the NMA. The LSPRV hosts the San Pedro River, the last major wild river in the Desert Southwest and a major flyway in the west for neotropical migrants. While maintaining the upper river's hemispheric north-south avian connectivity, the LSPRV has the added quality of an east-west connectivity across large landscapes – a demonstrable necessity for wildlife and sustainability in this critical area. As discussed, TNC's study showed that connectivity across mountain ranges to be the second largest in the state. AGFD's spatial fragmentation study expands that area dramatically, and within the area of richest biodiversity, it appears to be the largest habitat block in the state if not the Desert Southwest.

TNC's study helped define the fragmenting elements for areas of wilderness quality in the LSPRV, arguing that unpaved thruways and transmission lines would be sufficiently impactful as to make successful mitigation questionable in the Galiuro-Aravaipa-Santa Teresa area. If the SunZia project is built along planned routes in the LSPRV, it remains a question whether the AGFD assessment that it may be "devastating to the area's wildlife, regardless of the mitigation measures implemented," or the Environmental Planning Group's contrary conclusion, proves correct. Whichever the case, the basic fragmenting elements for these "wildlands" of the LSPRV and the NMA are unquestionably paved thruways and the ensuing continuous development. Such an outcome would threaten this home to an enormous range of native species, including such iconic species as Bighorn Sheep, Sonoran Coues Deer, Gila Monsters and Sonoran Desert Tortoises.

The LSPRV and the NMA have a patchwork of ownership representing the interests of numerous federal and state agencies, NGO's and private interests. Awareness of the critical importance of connectivity to the large conservation investments made in the valley helps discern which actions (or non-actions) honor those investments and help make them sustainable. At the same time, it is important to honor the valley's resident Native American, Hispanic and Old West cultural histories and livelihoods. Tremendous biodiversity still exists within this landscape that has been home to humans for millennia, and within the limitations of good stewardship the defining conflict is not human's presence, but how they relate to the landscape.

The science of island biogeography and its related fields allows the voice of nature herself to participate in the discussion of what good stewardship entails. "Wilderness-compatible" standards of connectivity are necessary for the health and sustainability of some areas, but applying that measure across the board helps define these well-watered desert valleys, where human and natural communities routinely intermingle, as already fragmented and ripe for exploitation. A "wildland" standard of connectivity better accounts for the relative permeability of barriers for most species and is better suited to the realities of lowland areas. Recognizing and conserving these basic thresholds of connectivity can allow these rich wildlands of the Northern Madrean Archipelago and the Lower San Pedro River Valley to remain as both an environmental treasure and a working landscape, especially if integrated with the potentials of a sustainably designed ecotourism, recreation and restoration-based economy.[65]

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