Conserving Connectivity: 3 science-related tasks

1. Identify natural landscape blocks. Create a fuzzy regional map of potential linkages among them.

2. Design 1 linkage: implementable map & plan

Tasks follow a logical sequence & spatial hierarchy, but need not proceed in this order.

3. Implementation: compromise and real conservation

Paul Beier

NORTHERN ARIZONA UNIVERSITY

Task 1: The "fuzzy regional map" of natural landscapes & potential linkages.

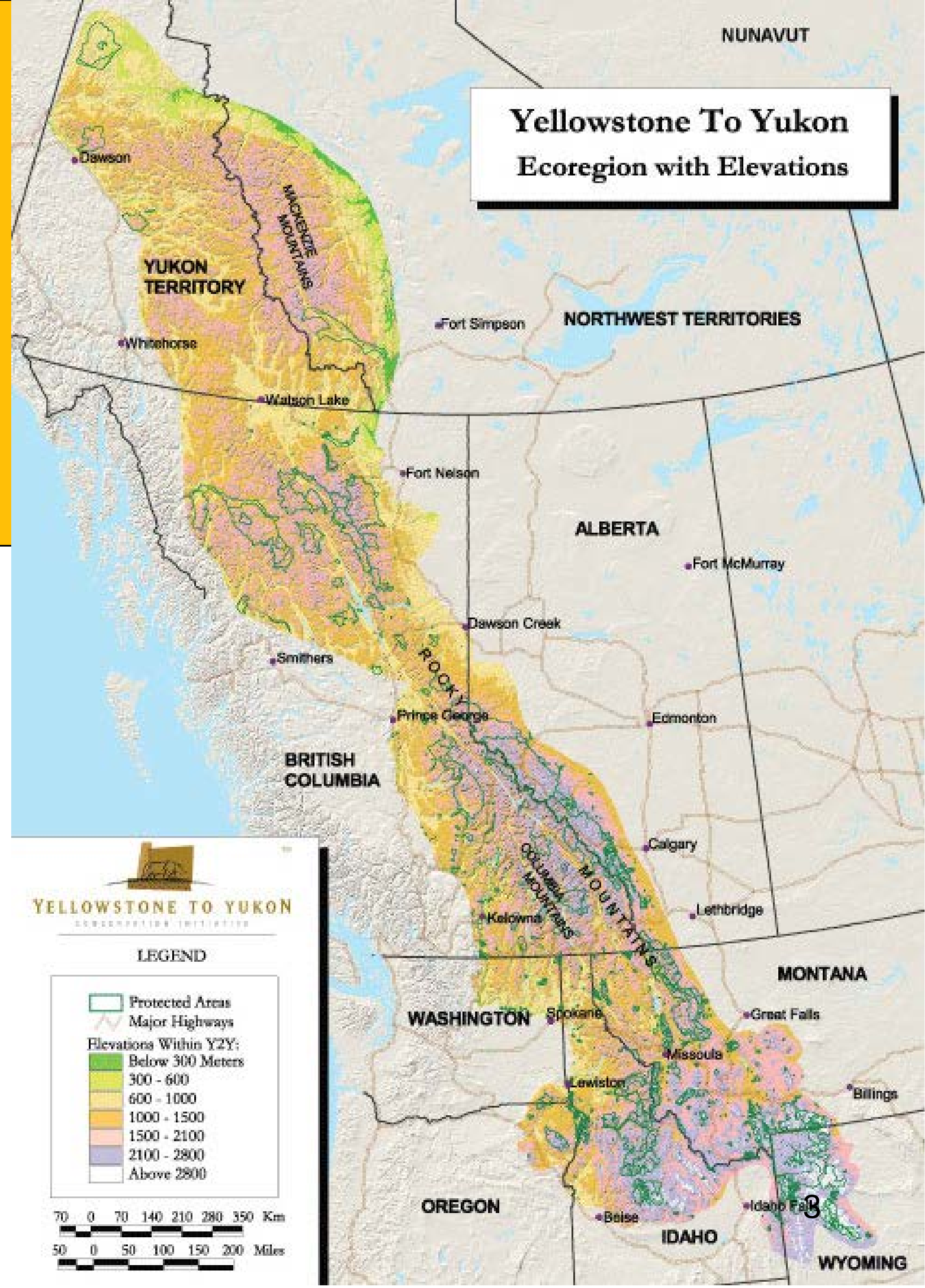
Beier, Spencer, McRae, Baldwin. 2011. Toward best practices for developing regional connectivity maps. Conservation Biology

The regional map is useful as:

- A decision support tool
- A vision for a connected landscape
- A Trojan horse

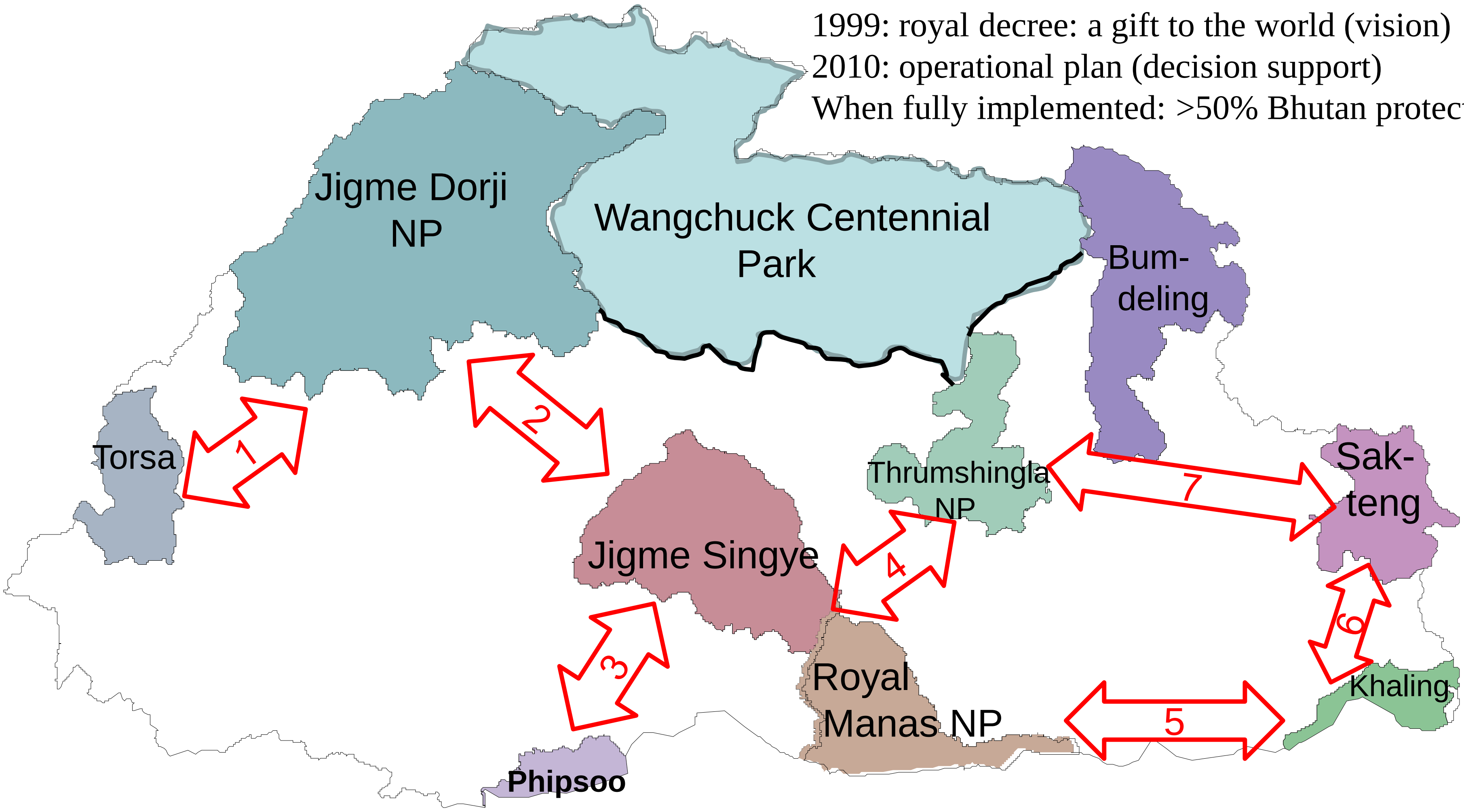
Most famous example of a fuzzy regional map: *Yellowstone-to-Yukon Initiative (1997)*

Primarily a vision map



Task 1: The “fuzzy regional map”

2nd example of a fuzzy regional map : Bhutan Biological Corridor Complex (2010)



1999: royal decree: a gift to the world (vision)
2010: operational plan (decision support)
When fully implemented: >50% Bhutan protected.

3rd example: *California Essential Habitat Connectivity* map (2010)

851 Natural Landscape Blocks (green)

1,350 Essential Connectivity Areas (yellow & brown)

Task 1: The "fuzzy regional map"

Conserving Connectivity: 3 science-related tasks

1. Identify natural landscape blocks. Create a fuzzy regional map of potential linkages among them.

Beier, Spencer, McRae, Baldwin. 2011. Toward best practices for developing regional connectivity maps. Conservation Biology

Beier, Majka, Spencer. 2008. Forks in the road: choices in procedures to design wildlife linkages. Conservation Biology

2. Design 1 linkage: implementable map & plan

3. Implementation: compromise and on-the-ground conservation.

A **Linkage Design** is an implementable plan to conserve a linkage between two natural landscape blocks

A Linkage Design includes:

- A focus on real decisions & decision constraints
- A focus on the focal species and ecological processes that need connectivity
- A map of areas to be conserved for the corridor
- A coherent set of mitigations to address highways, canals, and other linear barriers
- Management guidelines for artificial night lighting, livestock grazing, recreation, fencing, etc.

Like the fuzzy map, it is best co-produced by scientists and decision-makers.

A single Linkage Design is based on least-cost models for many focal species

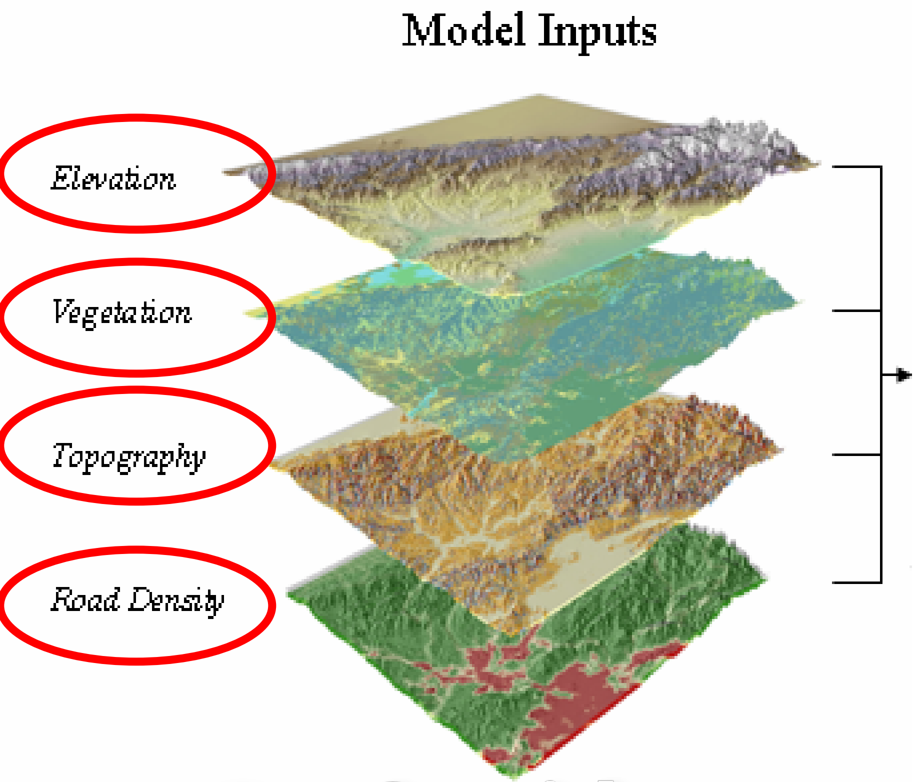
Area-sensitive species
(passage species, mostly)

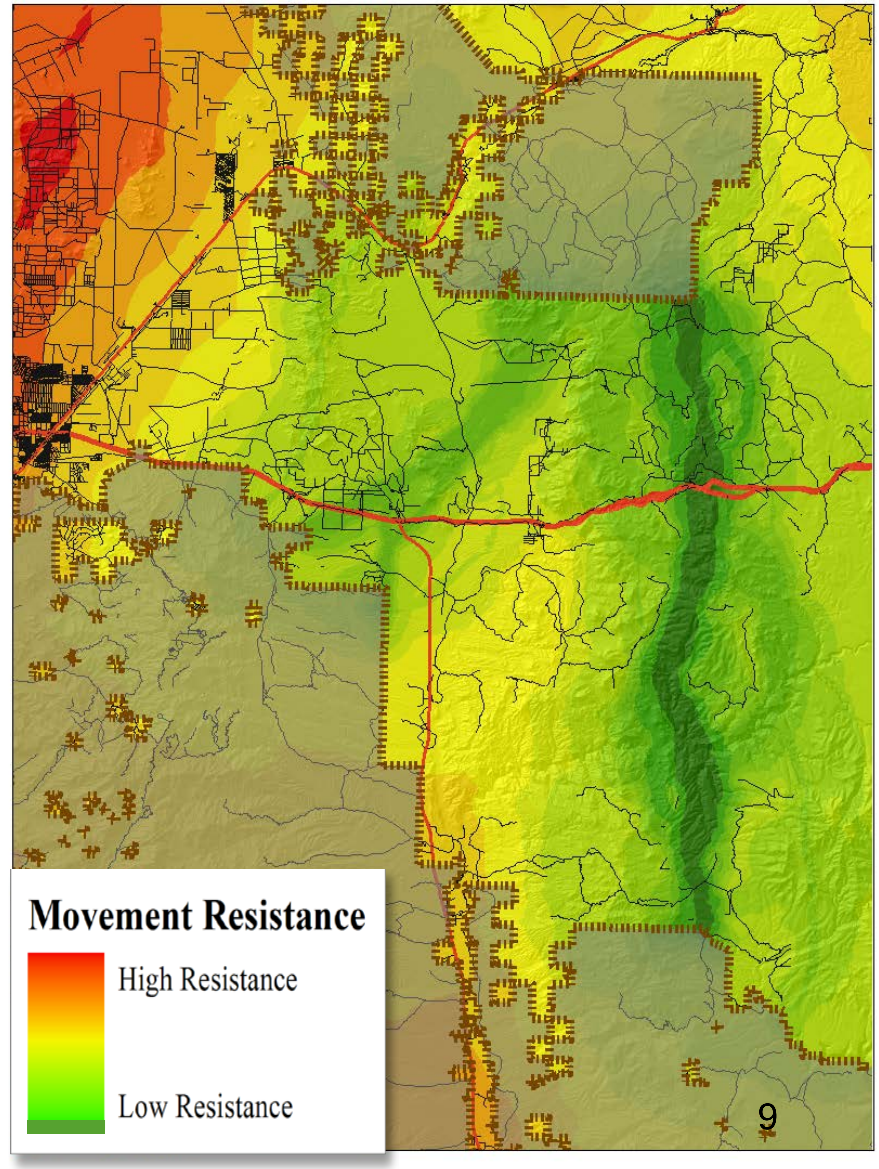
Habitat specialists
(corridor dwellers, mostly)

Nominated by stakeholders and people with local knowledge.

Barrier-sensitive species

Corridor modeling for each focal species





Corridor Design

Free tools at www.corridordesign.org

Task 2: Linkage Design

Focal species approach to linkage design

- **Represent a variety of movement needs and ecosystem functions**
- **Umbrella species (area-sensitive, sensitive to barriers)**
- **Range of mobilities & habitat affinities**
- **Include species endemic to the corridor**

Focal Species Approach
(Beier & Loe 1992)

Steve Loe
San Bernardino NF

But how can we support dispersal & gene flow & range shift **<u>for all species</u>** when we know so little?

* most species have not been named.

* We don't know how species are distributed across our planning area today.

* We don't know how species will be distributed across our planning area in 50 years.

Answer: We use surrogates

Surrogate #1: riparian corridors.

Under ANY climate, rivers

- will facilitate movement of animals & plants
- will support some important ecological processes: flow of sediment, water, & nutrients
- can connect low (warm) to cool (high) areas (climate gradient corridor)
- Can be mapped without no stinkin' models.

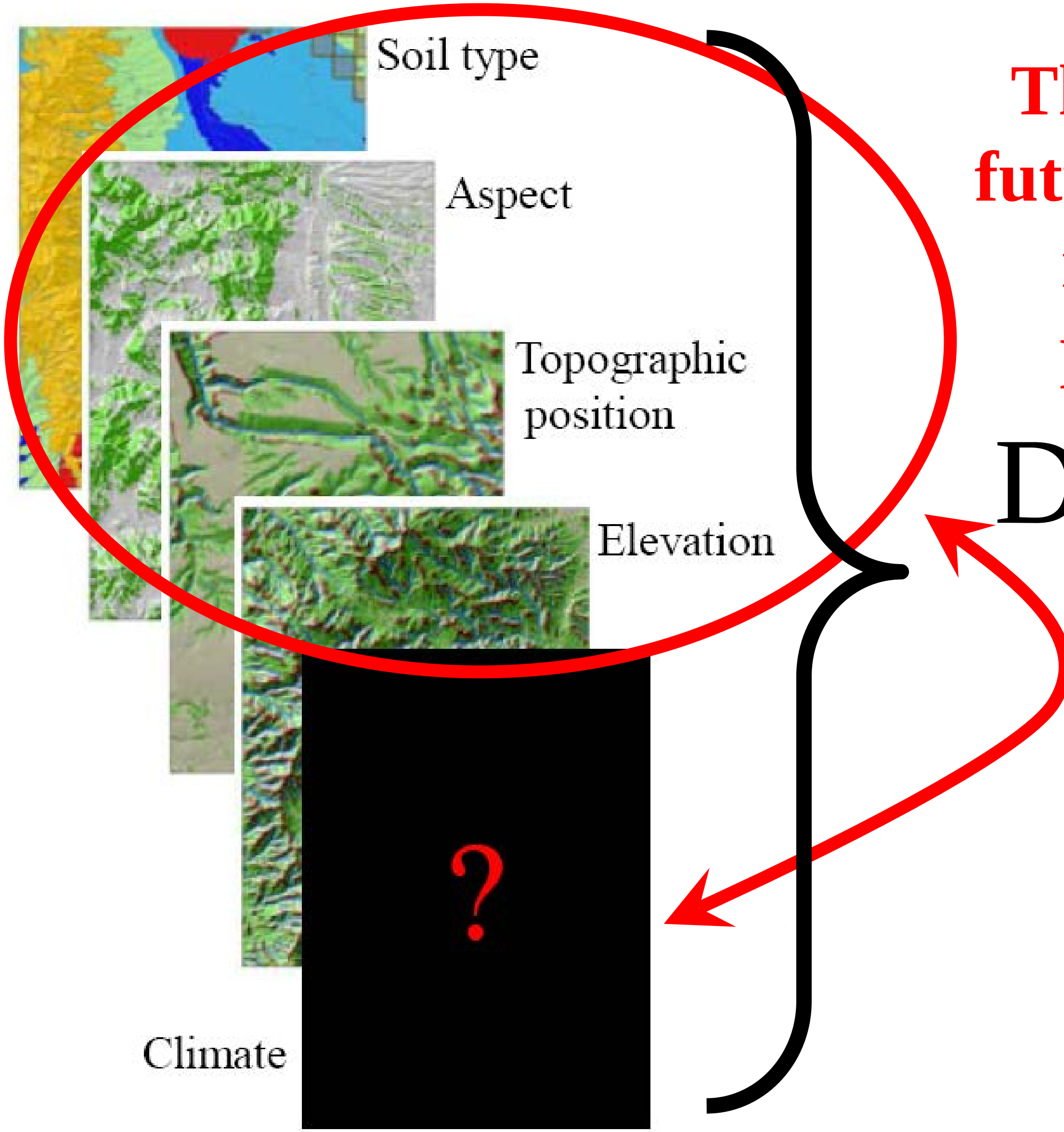
- Riparian areas have legal protection & popular support.

Surrogate #2: strands w/o cities-mines-roads-canals-farms

- An easy strategy when you can't model movement of focal species (or aren't sure what species to focus on).
- More sophisticated models will certainly produce corridors that lie within a "naturalness corridor."

Surrogate #3: Land facet corridors

These variables are stable.

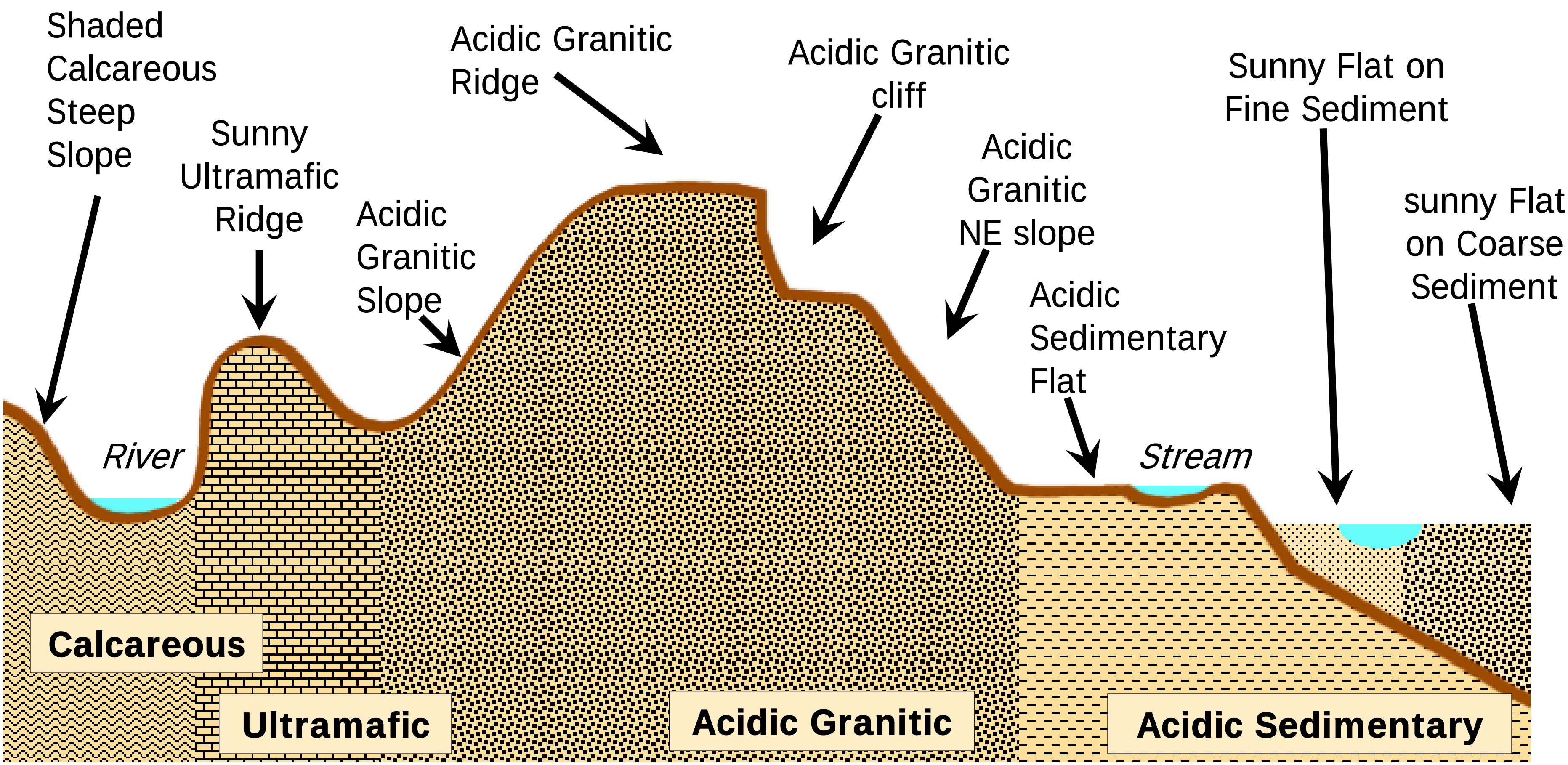


They will interact with future climate to support new assemblages of plants and animals.

Distribution of plants & animals

Brost & Beier (2012 Ecol Apps, 2012 PLoS One); Beier (2012 Ecol Restoration)

(3) Land facets defined on topography and soil



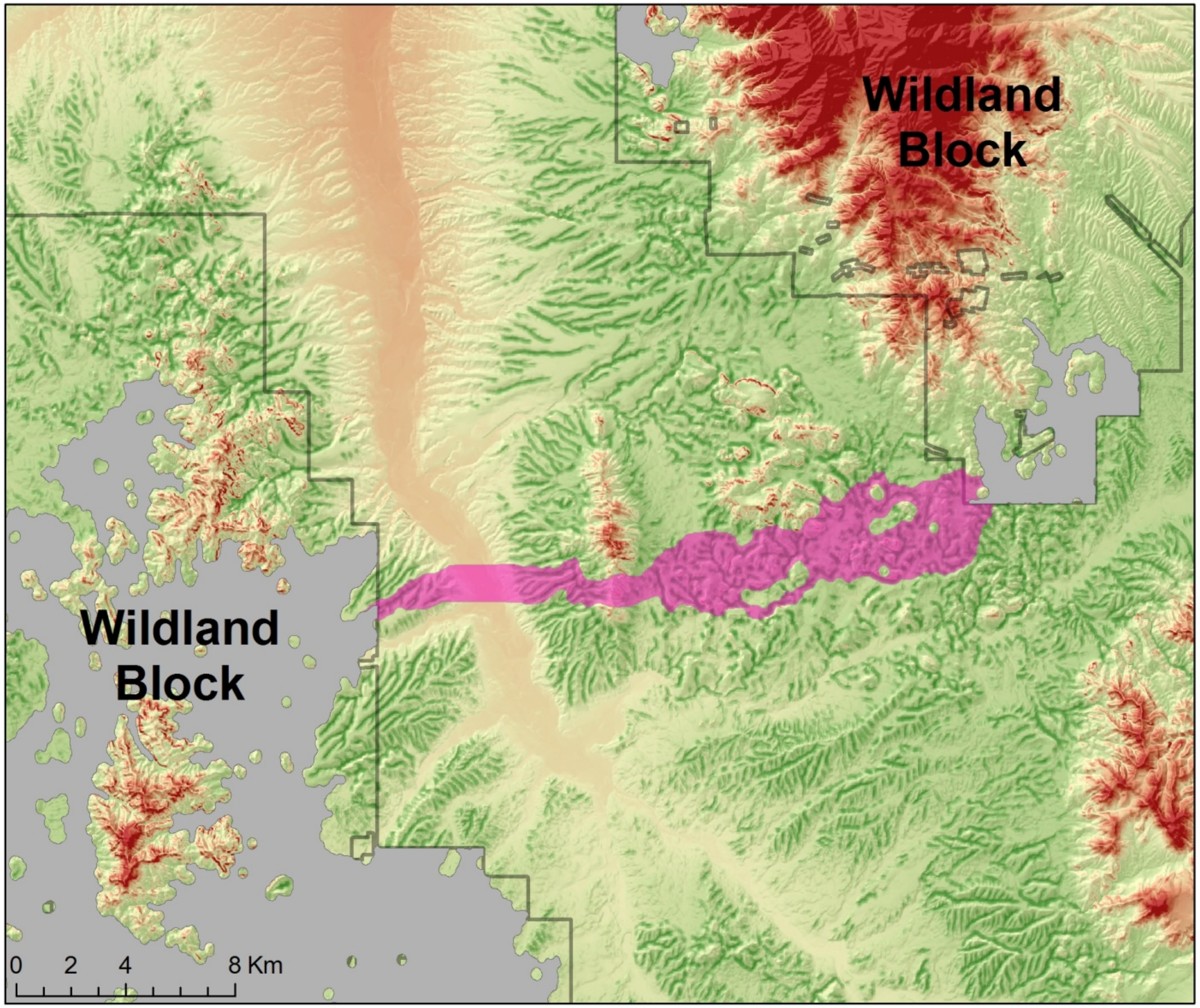
"Conserving Nature's Stage"

Synonyms: "land facet", "enduring feature", "geophysical setting", or "ecological land unit"

Figure credit: Mark Anderson

One corridor for each facet type.

Each corridor should support movement by species associated with that facet type during future periods of climate quasi-equilibrium.

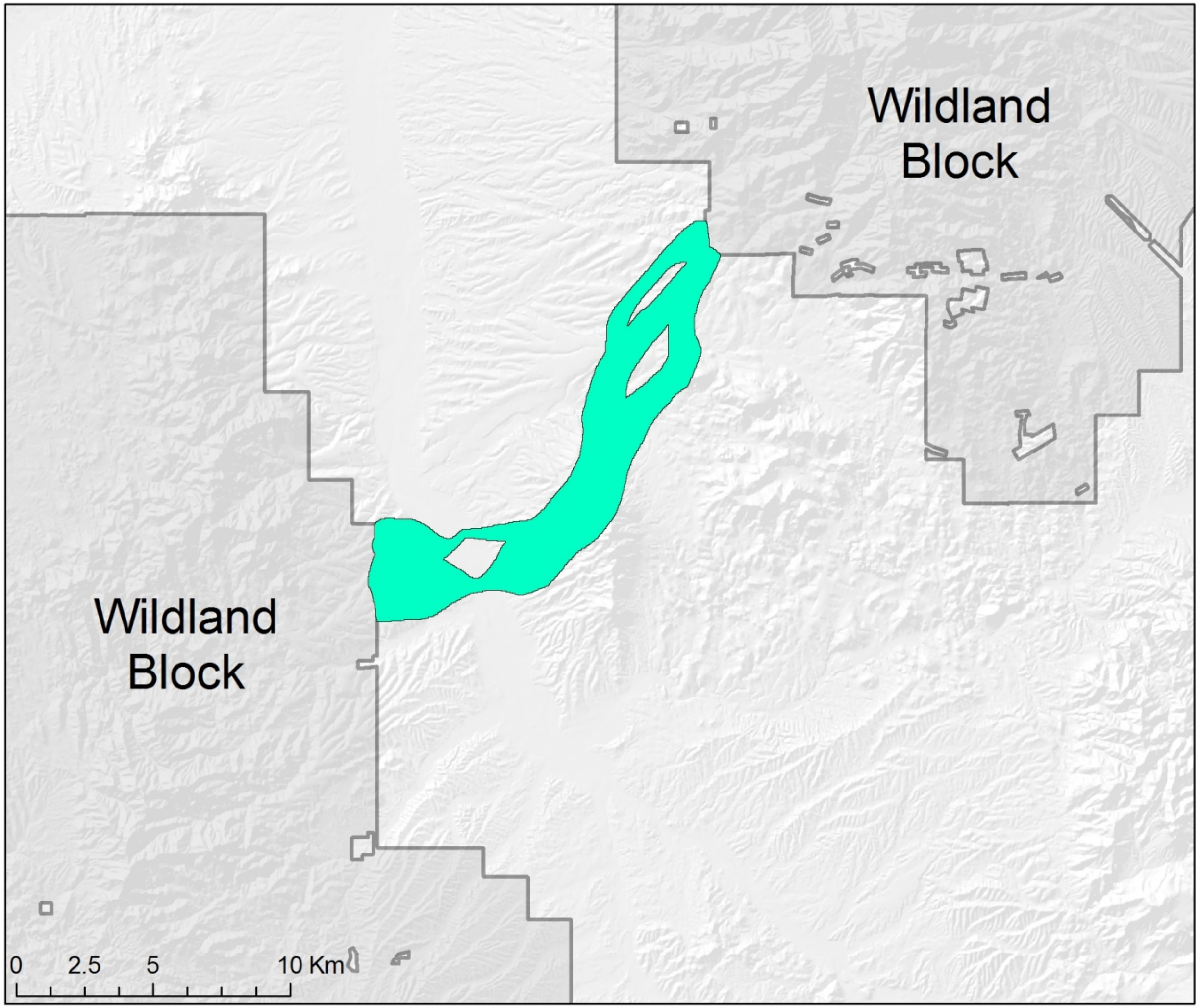


(least-cost modeling procedures)

One corridor with high interspersion of facet types.

This corridor should support rapid, short-distance range shifts during periods of climate instability.

It should also support interactions between species, and ecological processes that depend on juxtaposition.



Join all corridors into a land-facet linkage design

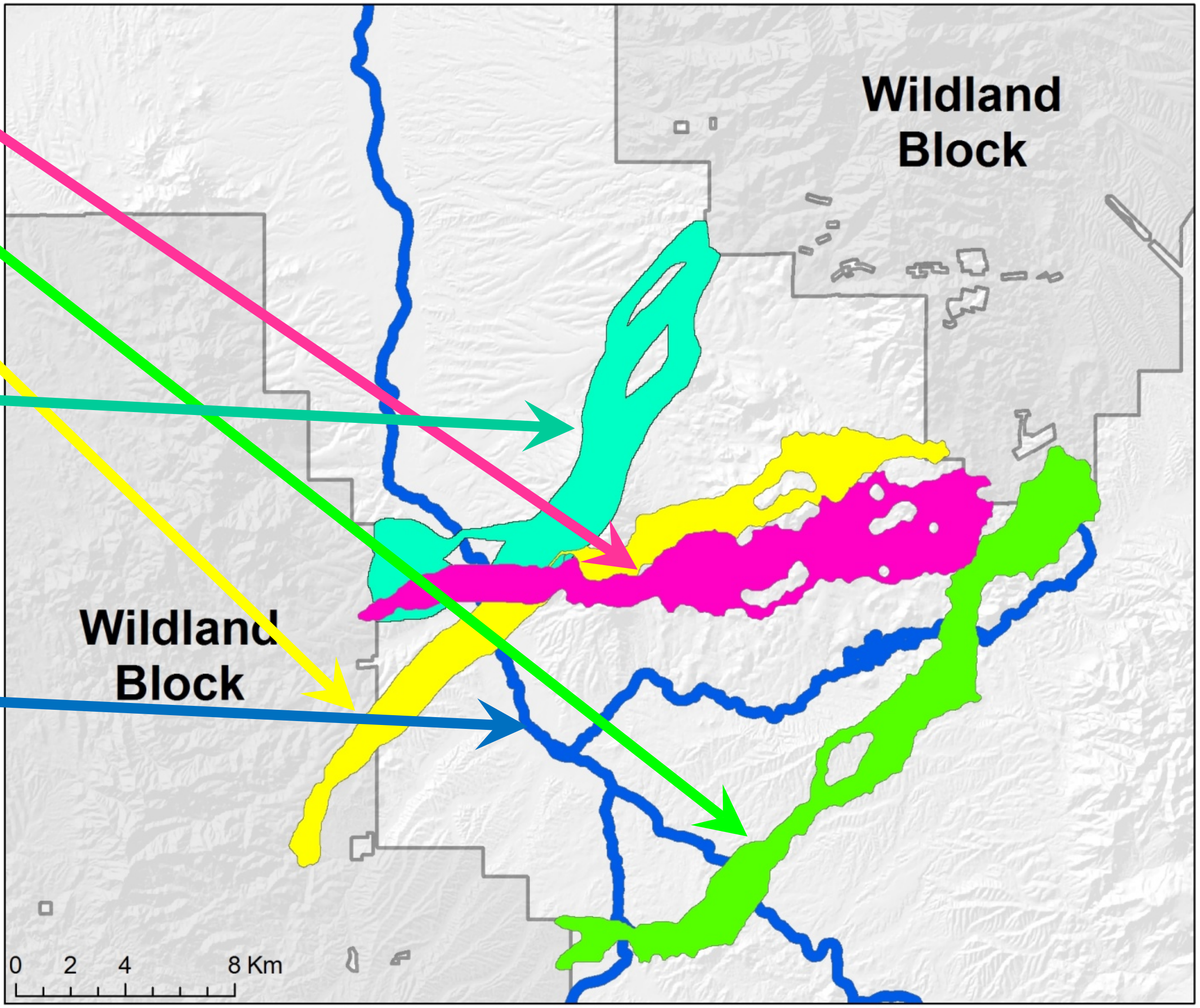
Facet A Corridor

Facet B Corridor

Facet C Corridor

Corridor with interspersed facets

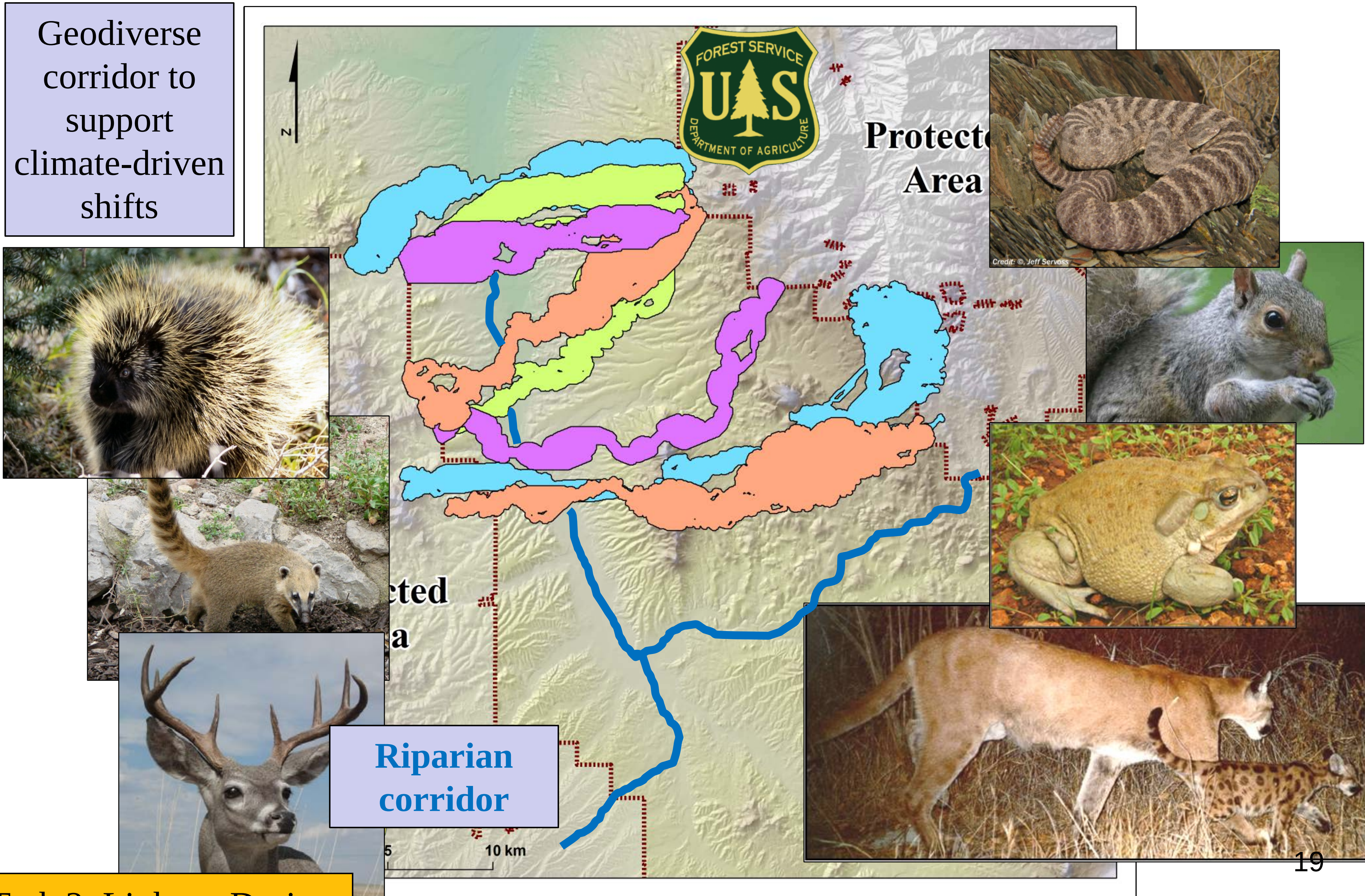
Always add a river corridor



Brost & Beier (2012 Ecol Apps, 2012 PLoS One); Beier (2012 Ecol Restoration)

Corridors for each focal element

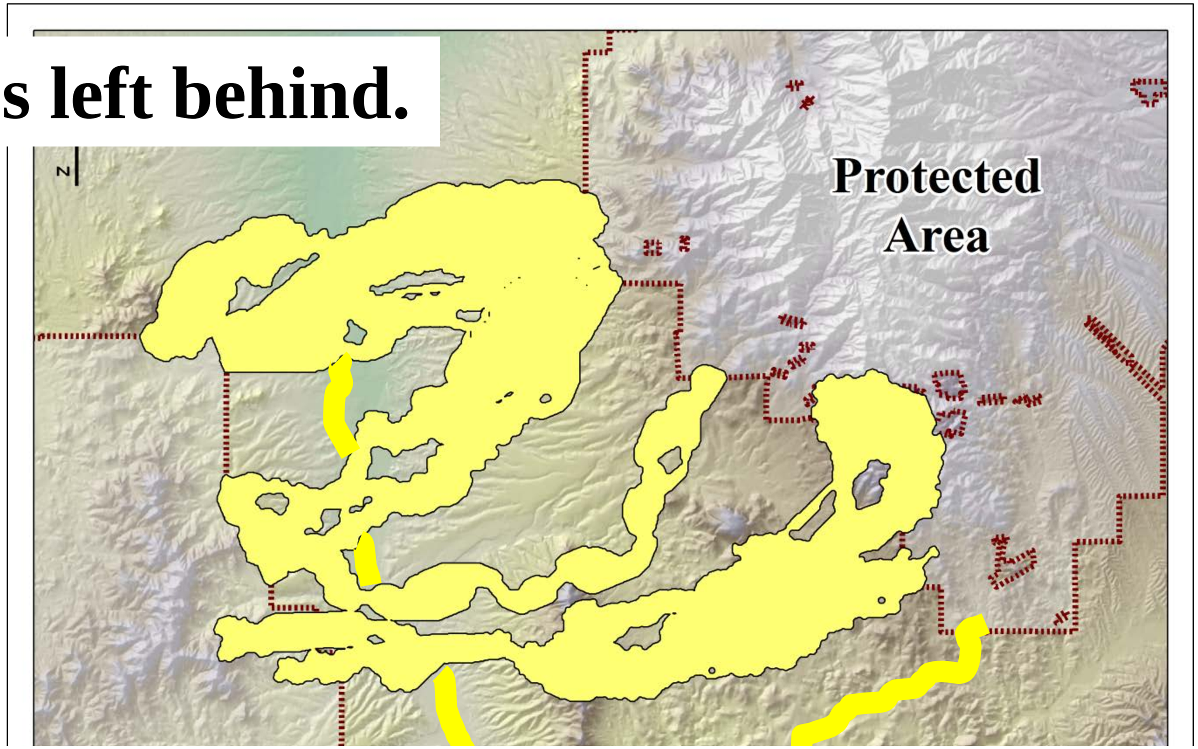
Geodiverse corridor to support climate-driven shifts



Task 2: Linkage Design

Joining corridors into a linkage

No species left behind.



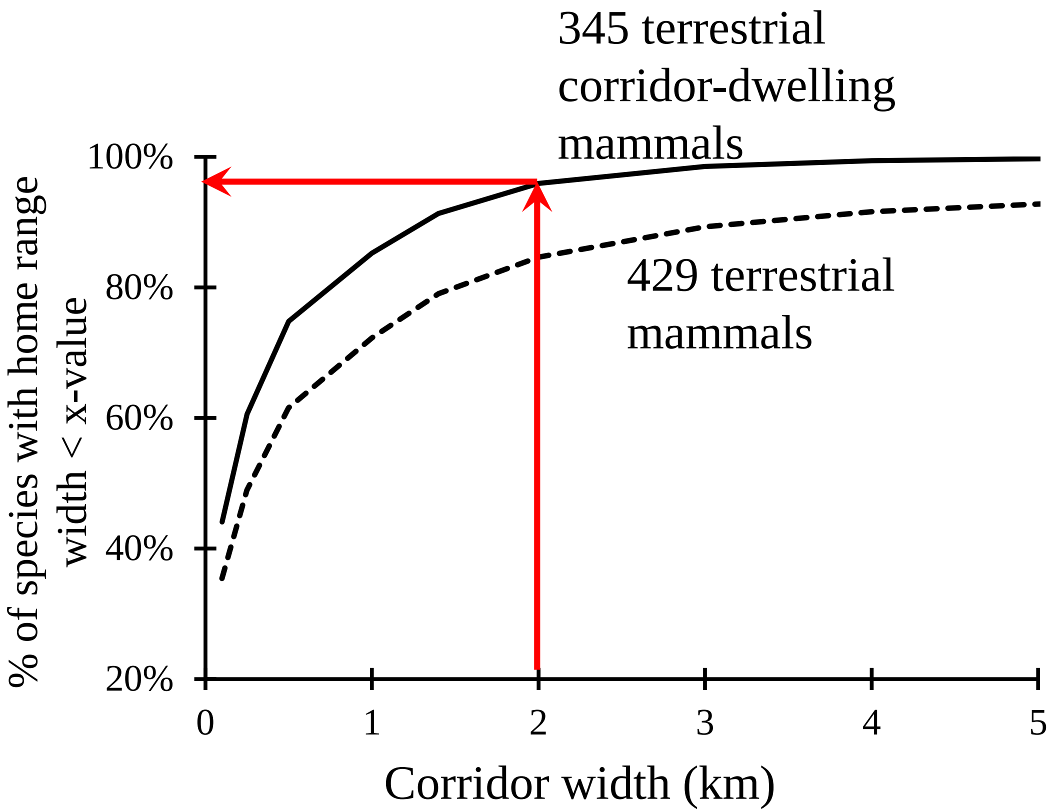
Broad strands minimize edge effects and serve species & processes not modeled.

The question of minimum width is the #1 unresolved issue in linkage design.

The question of minimum width is the #1 unresolved issue in linkage design.

I advocate a 2-km minimum for corridors > 5 km long

- No-regret standard
- Accommodate corridor dwellers
- Edge effects (300 m)
- Accommodate recreation
- Accommodate non-focal species (including unknown climate refugees)



Beier. In Review (2018). How wide should a wildlife corridor be? Conservation Biology

Conserving Connectivity: 3 science-related tasks

1. Identify natural landscape blocks. Create a fuzzy regional map of potential linkages among them.

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2. Design 1 linkage: implementable map & plan

Beier, Majka, Spencer. 2008. Forks in the road: choices in procedures to design wildlife linkages. Conservation Biology

3. Implementation: compromise and on-the-ground results

Task 3: Implement!

Task 3. Implementing wildlife linkage designs: the art of making good compromises

Compromise!?!?

Why should we accept anything less than full implementation of the best corridor design?

We can accept compromises because <u>during dispersal and mate-seeking,</u> resistance is low for all but the very <u>worst landscape features</u>.

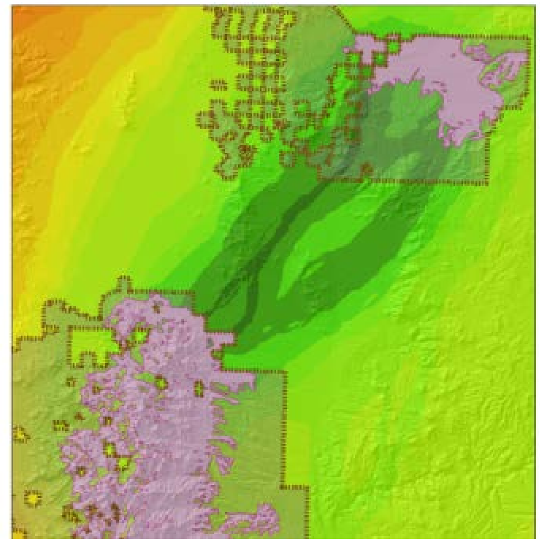
the type of movement corridors must support

roads, canals, developed areas

Even if the corridor as implemented is not the "best" one, it can still be a "good" (low cost) corridor.

Why compromise can be OK

32	38	75	17	13	Reserve 2	
42	37	44	12	50		
53	51	75	44	68	19	55
26	10	73	35	23	64	17
24	33	48	64	17	51	59
Reserve 1		35	12	11	59	18
		25	12	13	84	86



Resistance values are critical to all corridor models.

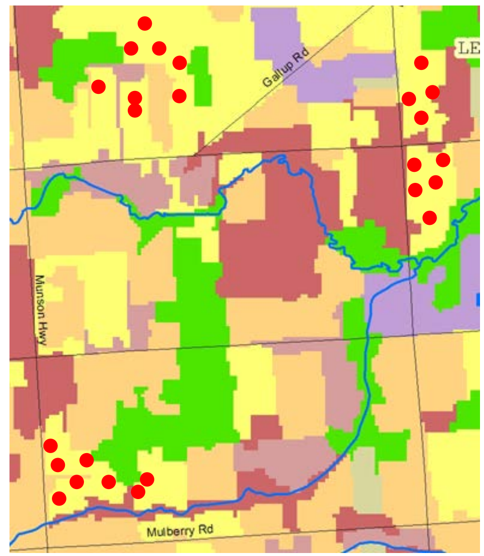
Task 3: Implement!

Why compromise can be OK

We usually estimate resistance by

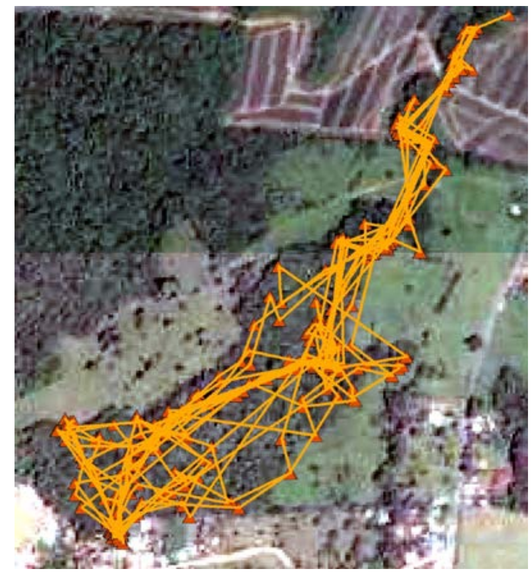
(1) estimating **suitability of habitat features** from

Expert opinion



Animal locations within home range

or



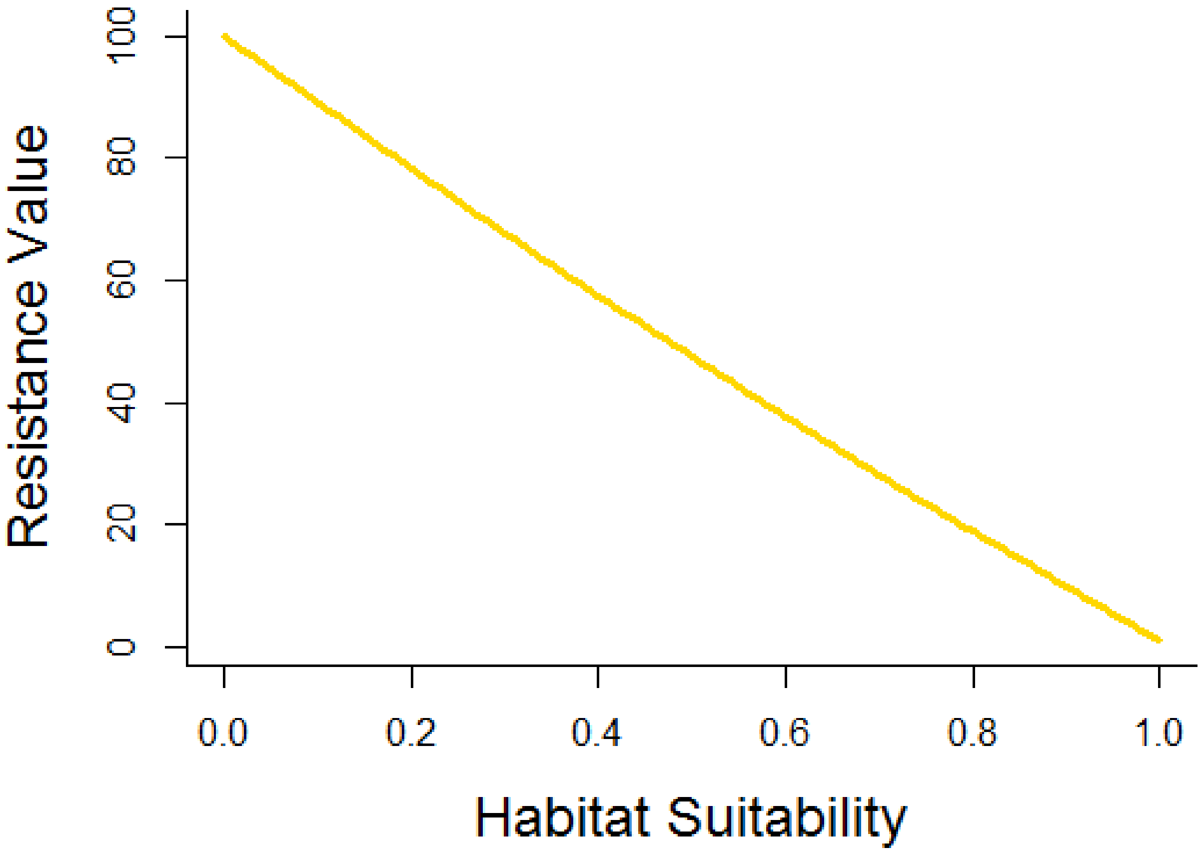
Movements within home range

(2) assuming that resistance = 1/suitability.

Task 3: Implement!

Why compromise can be OK

almost all corridor models estimate resistance as 1/suitability

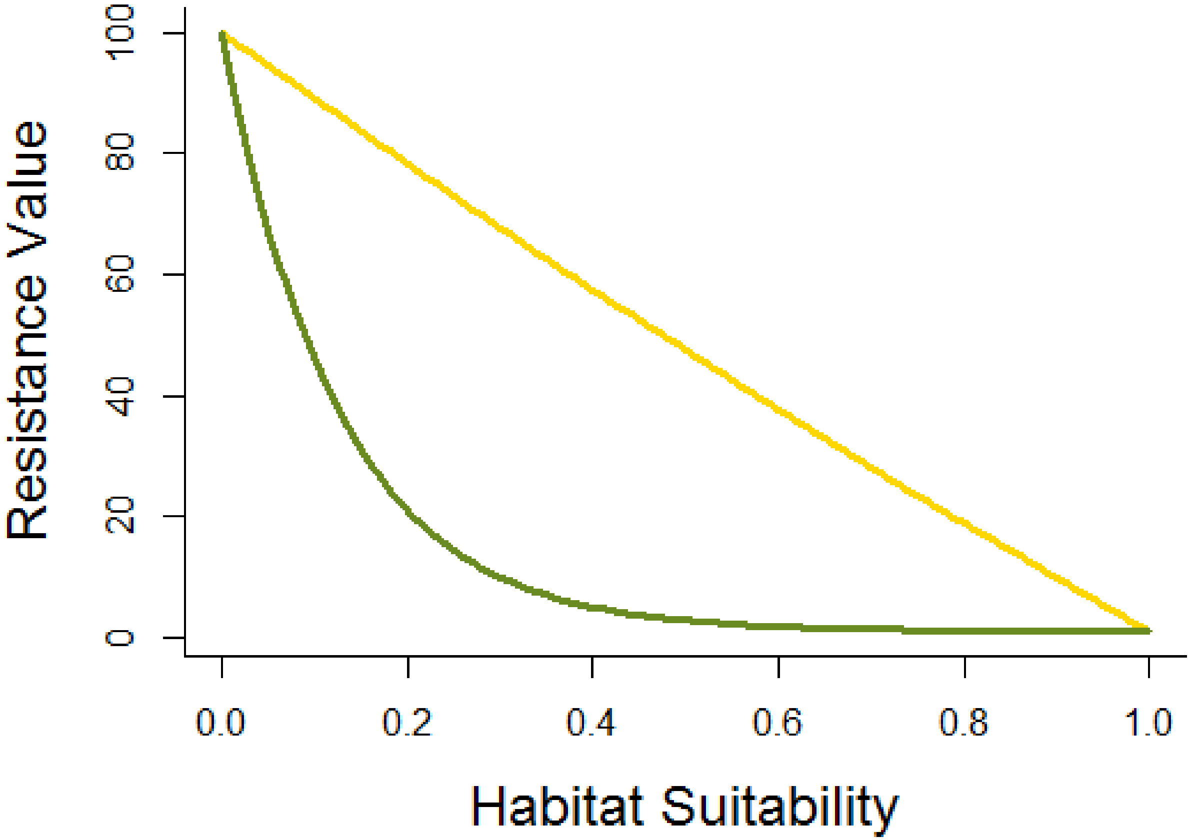


Modified from Trainor et al. 2013. Landscape Ecology 28

Task 3: Implement!

Why compromise can be OK

But resistance to dispersal movements might not be 1/suitability….

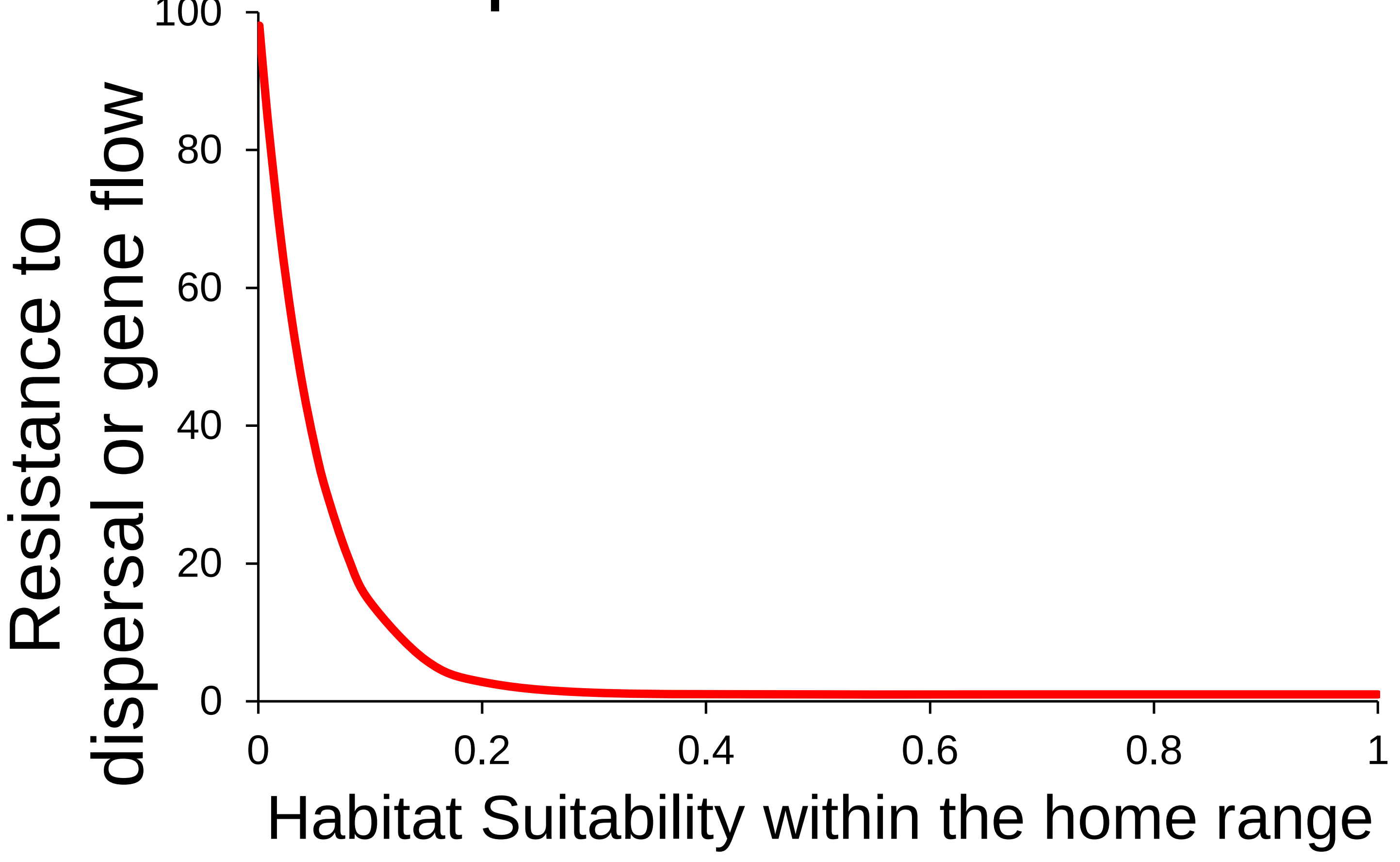


Modified from Trainor et al. 2013. Landscape Ecology 28

Task 3: Implement!

Why compromise can be OK

News Flash!!! A steep exponential function best fits all species studied to date.



Task 3: Implement!

Animals perceive the landscape as more connected during dispersal and mating movement than in the home range.

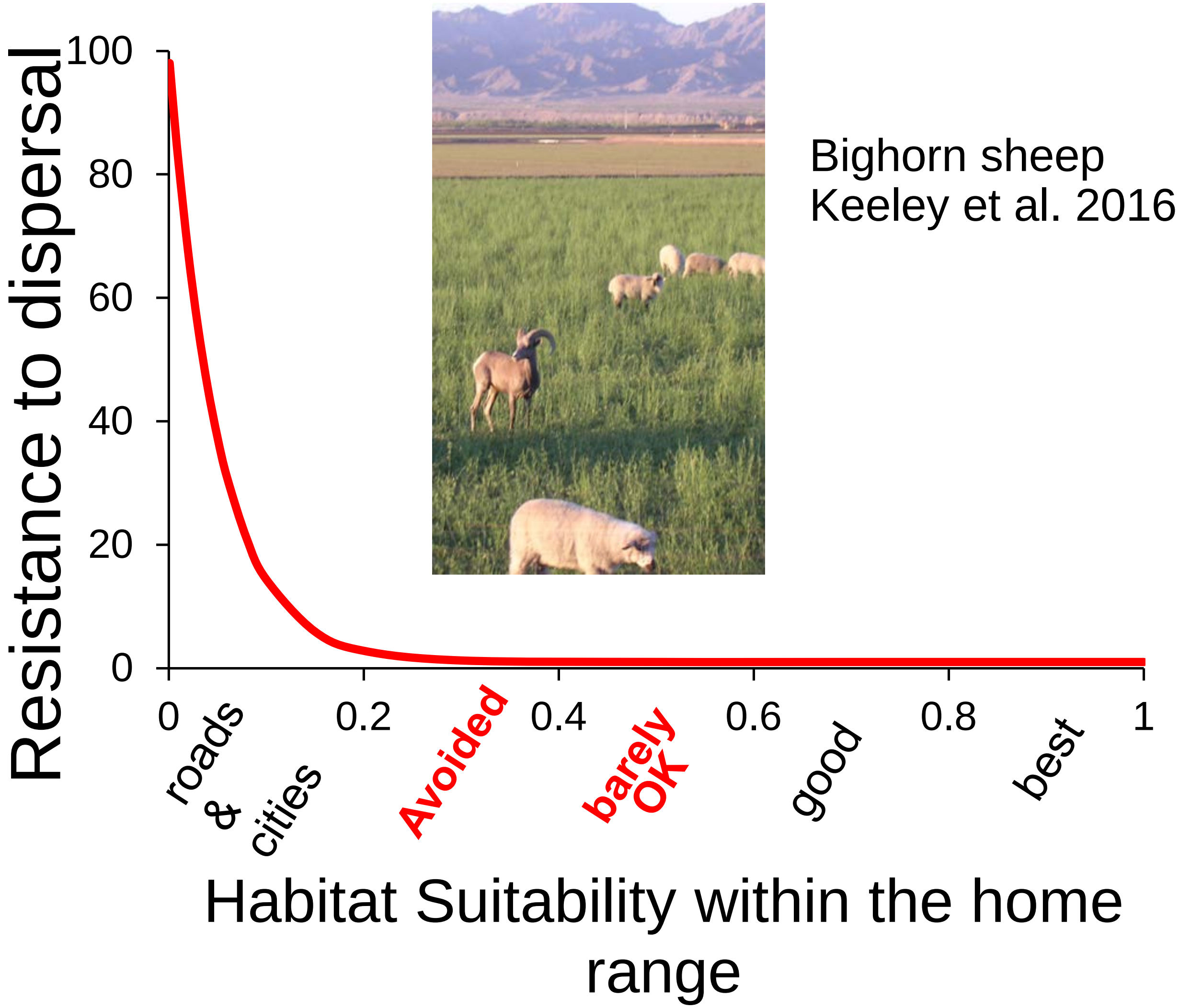
Kinkajou
Keeley et al 2017

Red-cockaded woodpecker
Trainor et al. 2013

Brown bear
Mateo-Sanchez et al. 2015

Iberian lynx
Blazquez-Cabrera et al. 2015

Elk
Keeley et al. 2016



Bighorn sheep
Keeley et al. 2016

Why compromise can be OK

Why compromise can be OK

During dispersal and mate-seeking (the behaviors corridors are intended to support), resistance is low for all but the very worst landscape features.

Mitigating linear barriers (road, rail, fences, canals) and managing for human tolerance, are the critical issues.

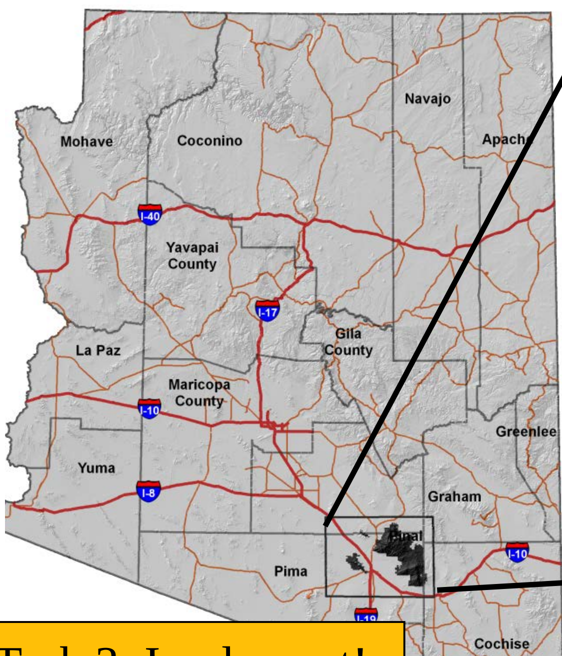
More study is needed to determine size at which a low-suitability cover type (e.g. farm) becomes impermeable.

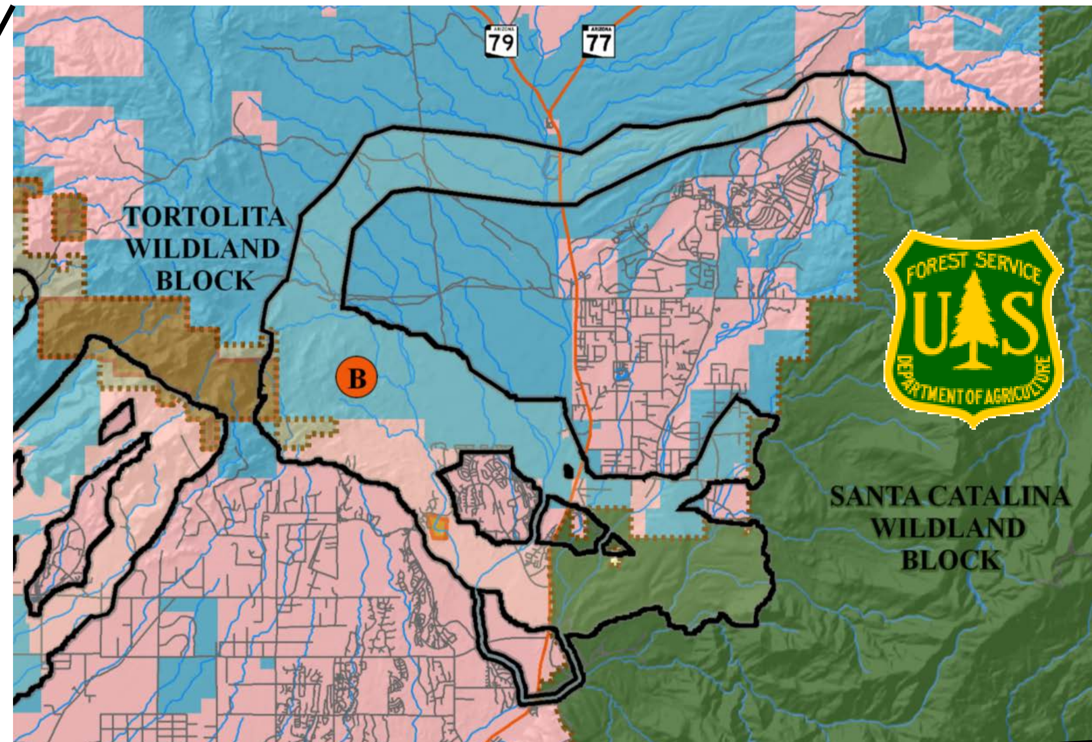
More study is needed to determine critical width. Until then, use a safe min width of 500 m (for length < 1 km), 1 km (lengths 1-5 km), or 2 km (lengths 5-80 km).

Linkage Design: Tortolita Mountains to Santa Catalina Mountains, near Tucson, Arizona

released June 2008
10 focal species

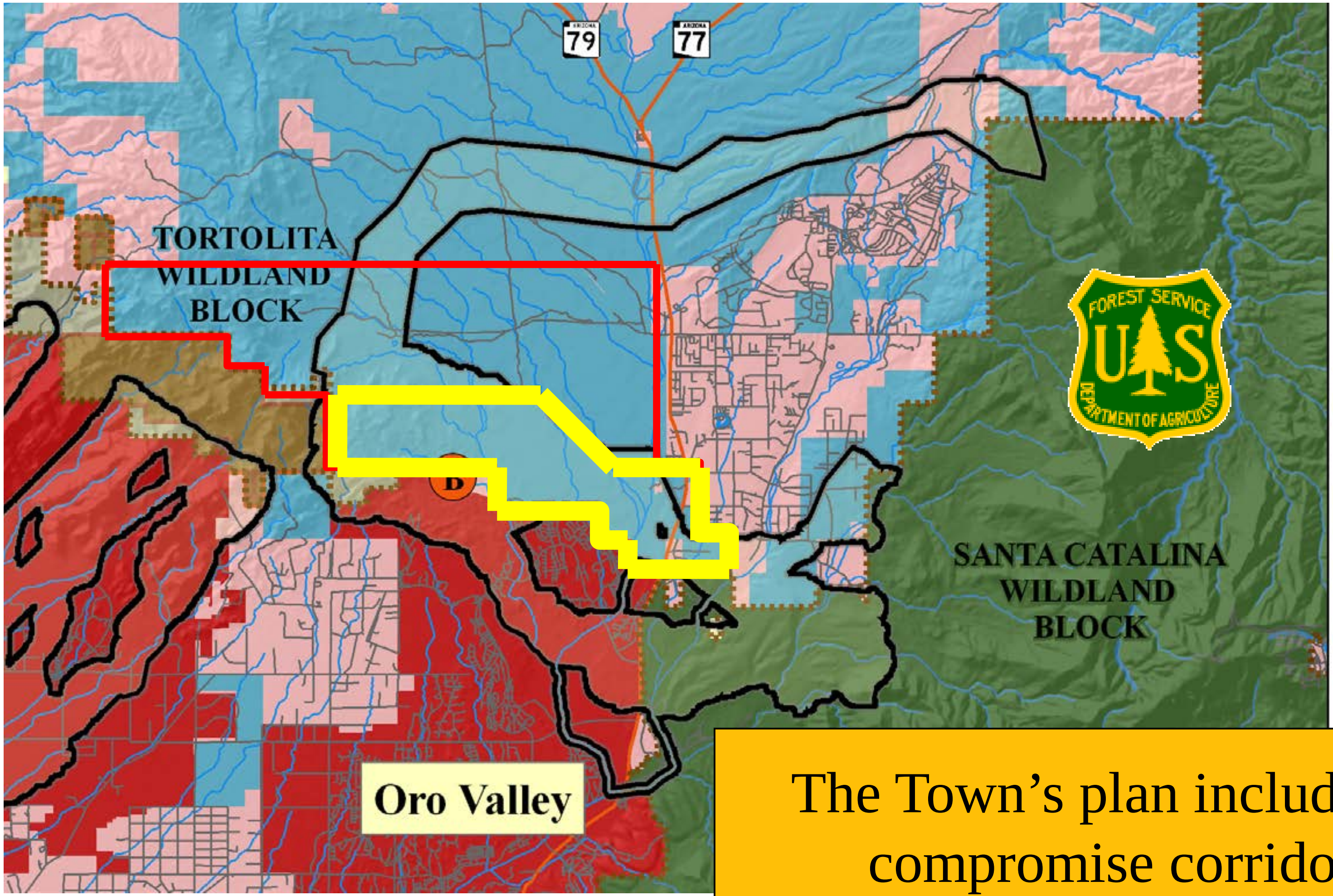
protected wildlands
pristine private land
rural or urban





Task 3: Implement!

The Linkage Design was used by Town or Oro Valley when they annexed 5600 ha of pristine land.

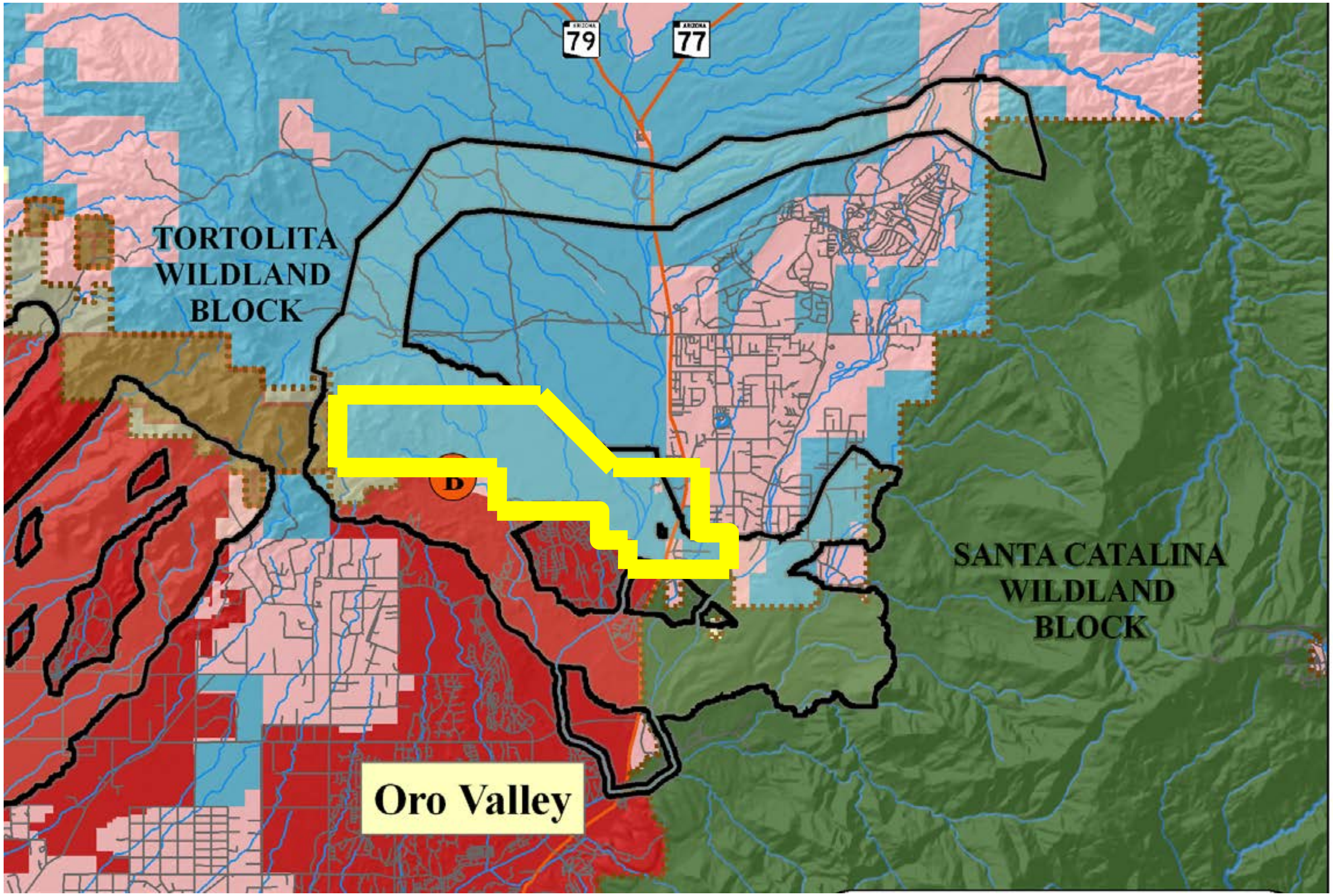


The Town's plan included a compromise corridor

Task 3: Implement!

So… Is this a good compromise – or a bad one?

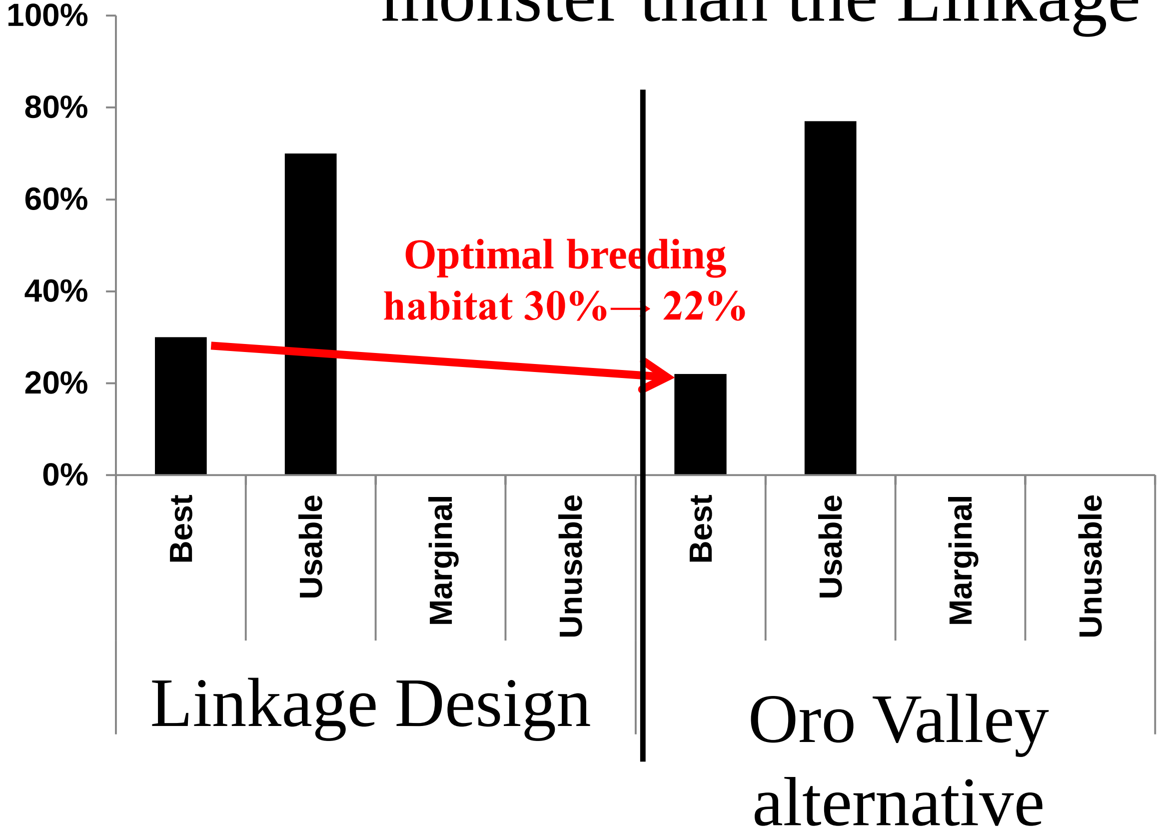
"Corridor Evaluation Tools" provides 3 metrics…



Task 3: Implement!

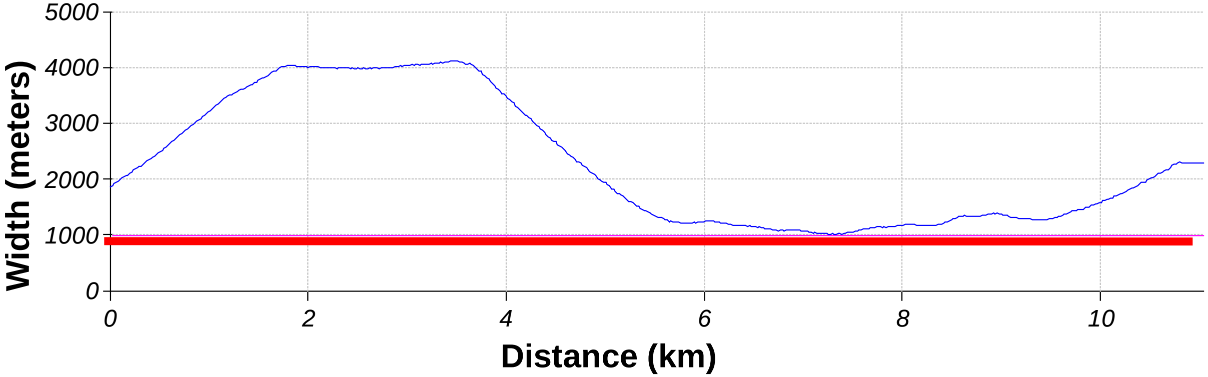
1st metric: habitat quality for each focal species.

The alternative corridor had less breeding habitat for Gila monster than the Linkage Design.

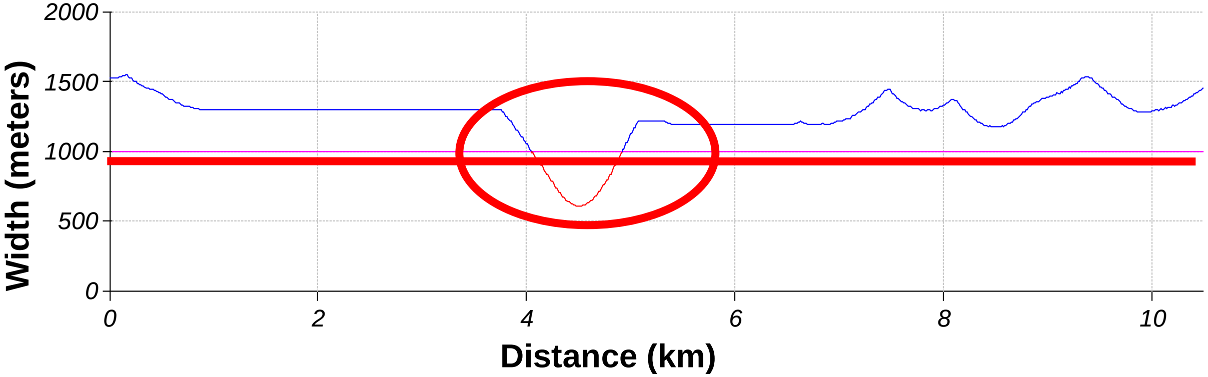


Task 3: Implement!

2nd metric: bottlenecks:
The alternative had one bottleneck < 1 km wide



Full linkage design

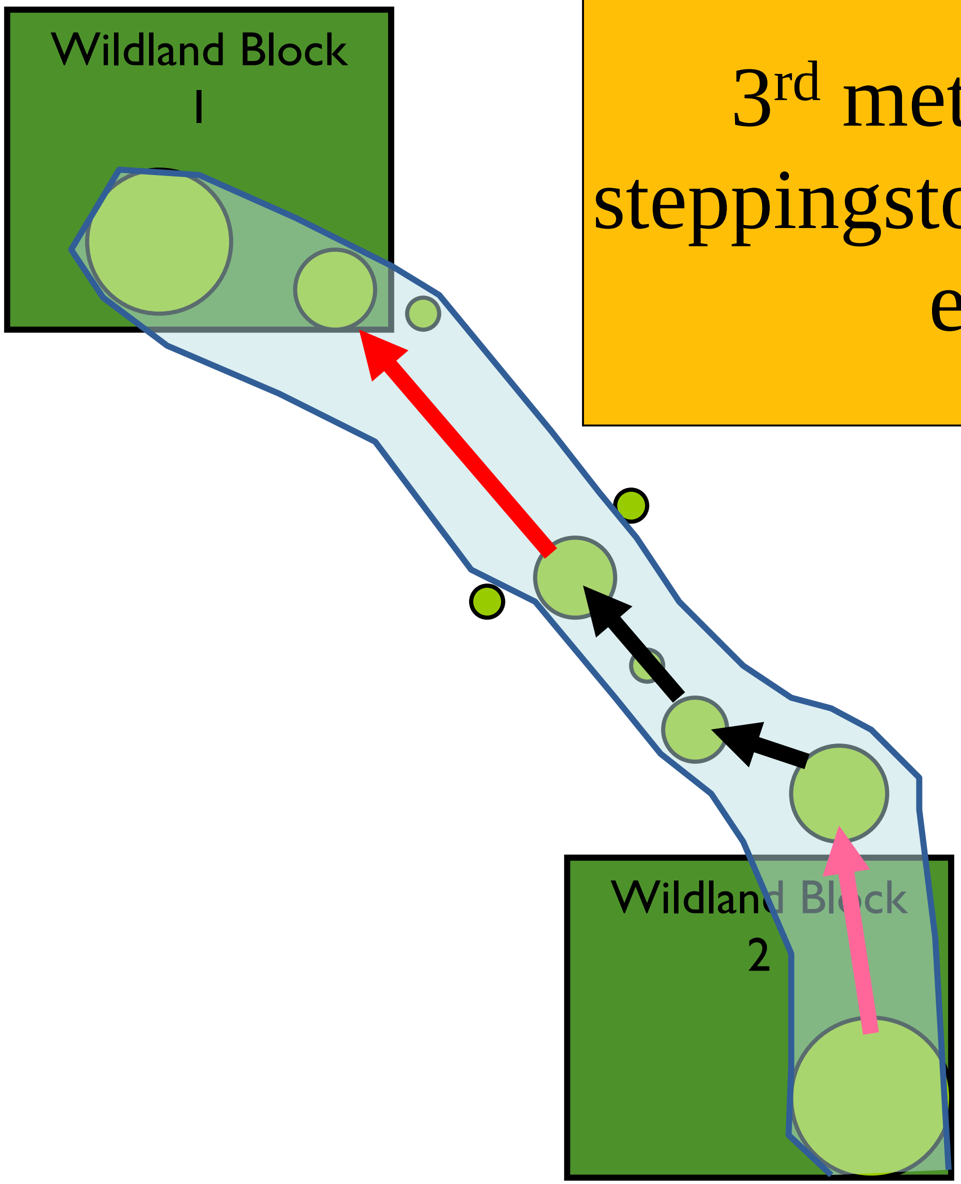


Alternative:

1 bottleneck; mean width 1300 m

Task 3: Implement!

3rd metric: Distances between steppingstones of breeding habitat for each focal species



Task 3: Implement!

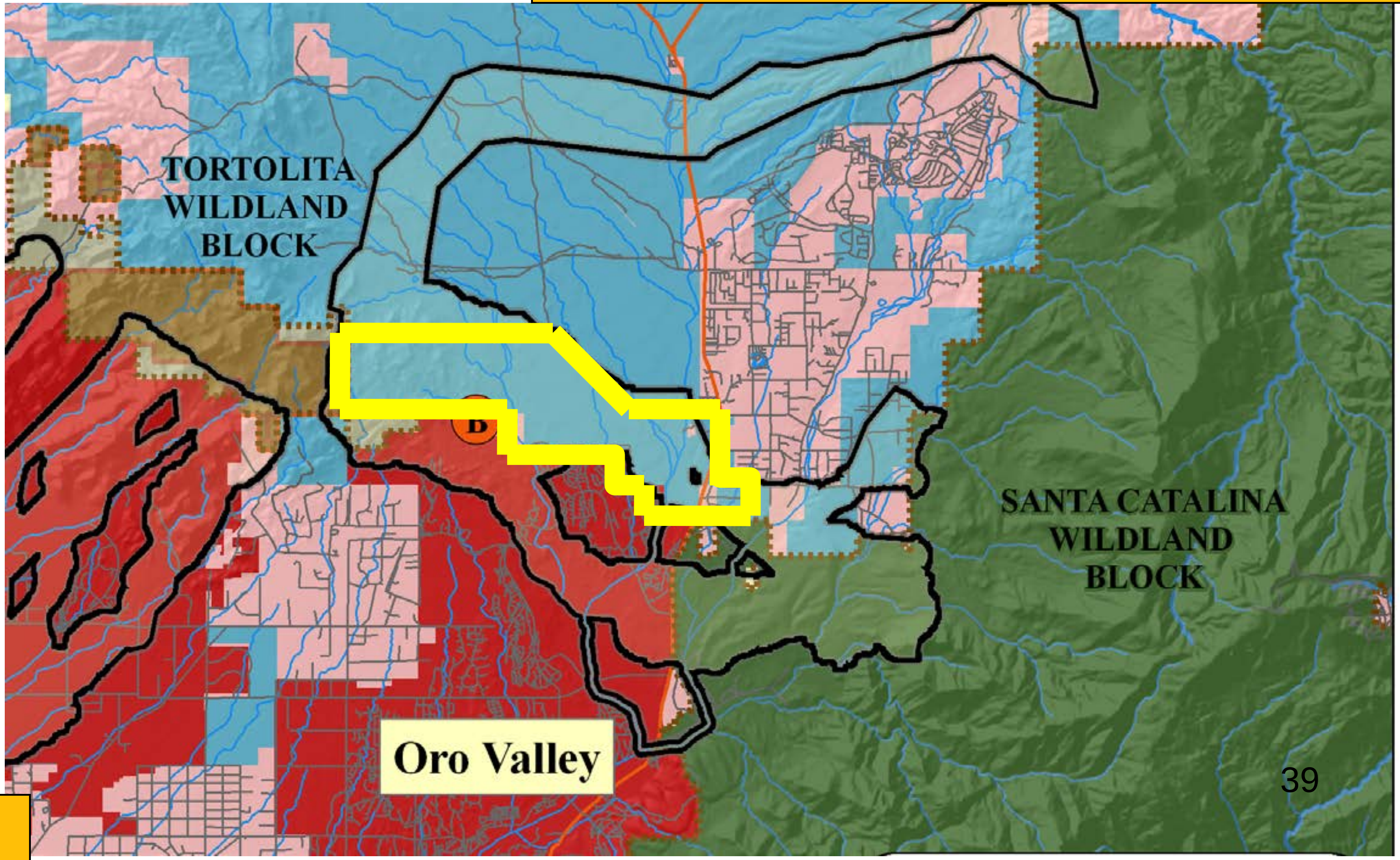
The alternative corridor had one 570-m interpatch gap for desert tortoise, compared to no gap in tortoise breeding habitat in the Linkage Design.

But desert tortoises can move > 20 km.

Task 3: Implement!

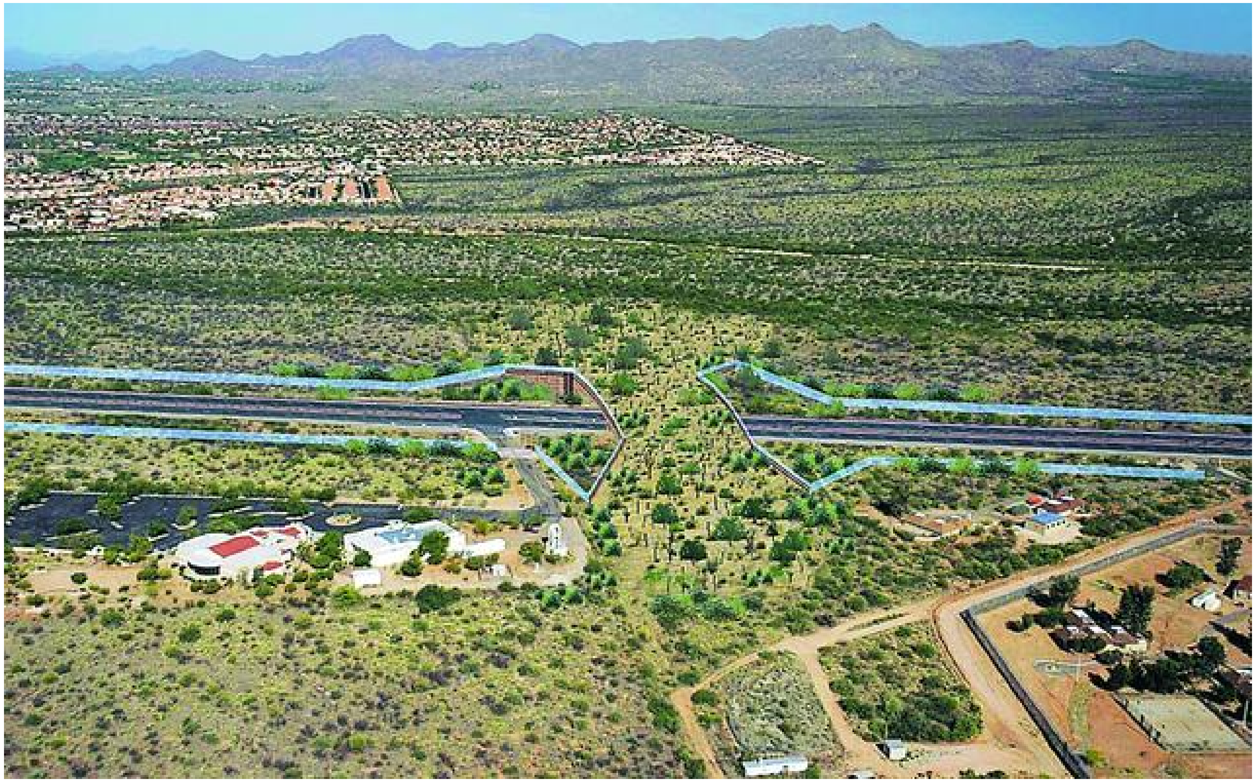
- Slightly narrower
- Worse habitat for gila monster
- Longer gap between between breeding patches for tortoise
- Politically feasible
- 10% of dollars

I called this a good compromise: 90% of benefit for 10% of cost. The plan is being implemented.



Task 3: Implement!

1 year later (Dec 2009): $8.2M approved for 2 wildlife crossings on the only highway crossing the linkage.



rendition of planned wildlife overpass

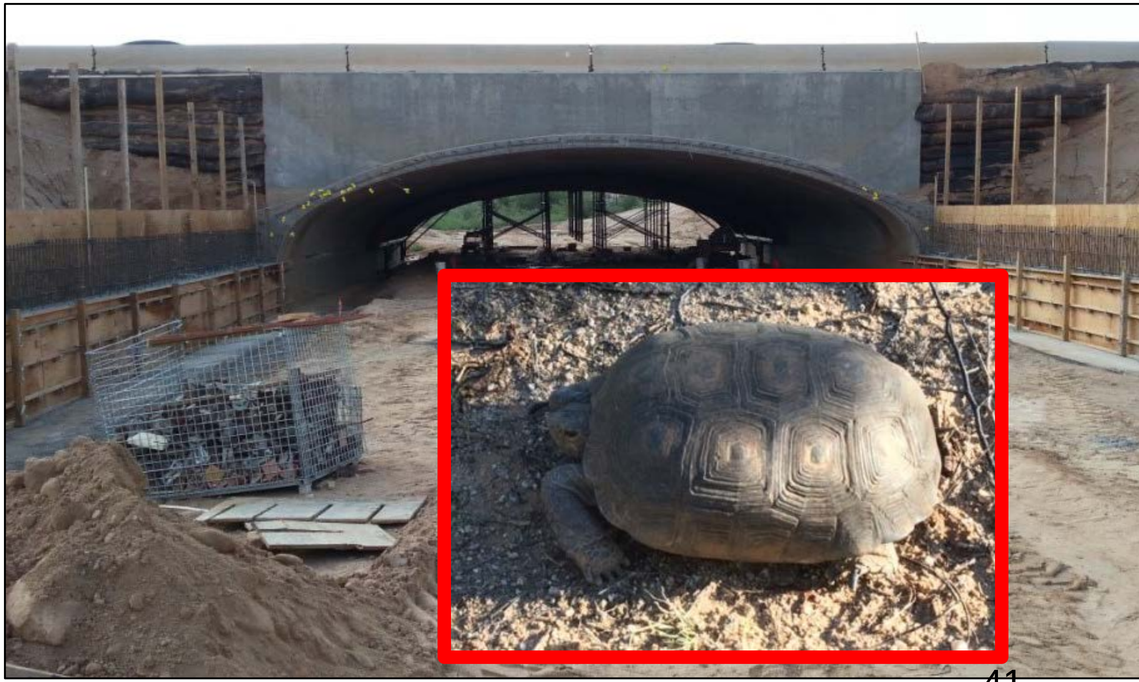
Task 3: Implement!

Catalina-Tortolita linkage: highway crossings

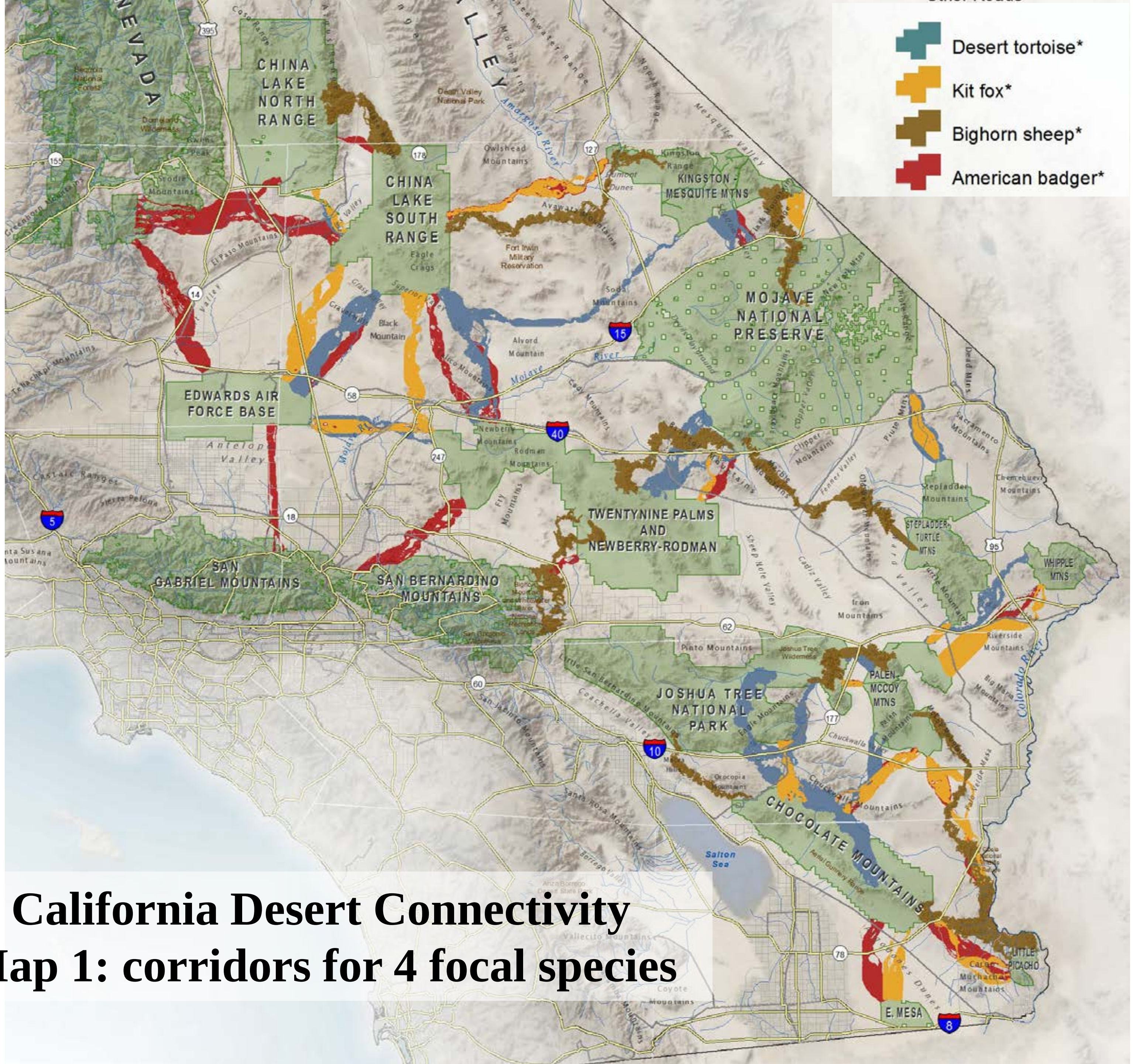
50-m wide overpass MP 84.8 (Oct 2015)

Underpass (Sep 2015)

Tortoise in underpass (Oct 2015) <u>during construction</u>.



Task 3: Implement!



California Desert Connectivity
Map 1: corridors for 4 focal species

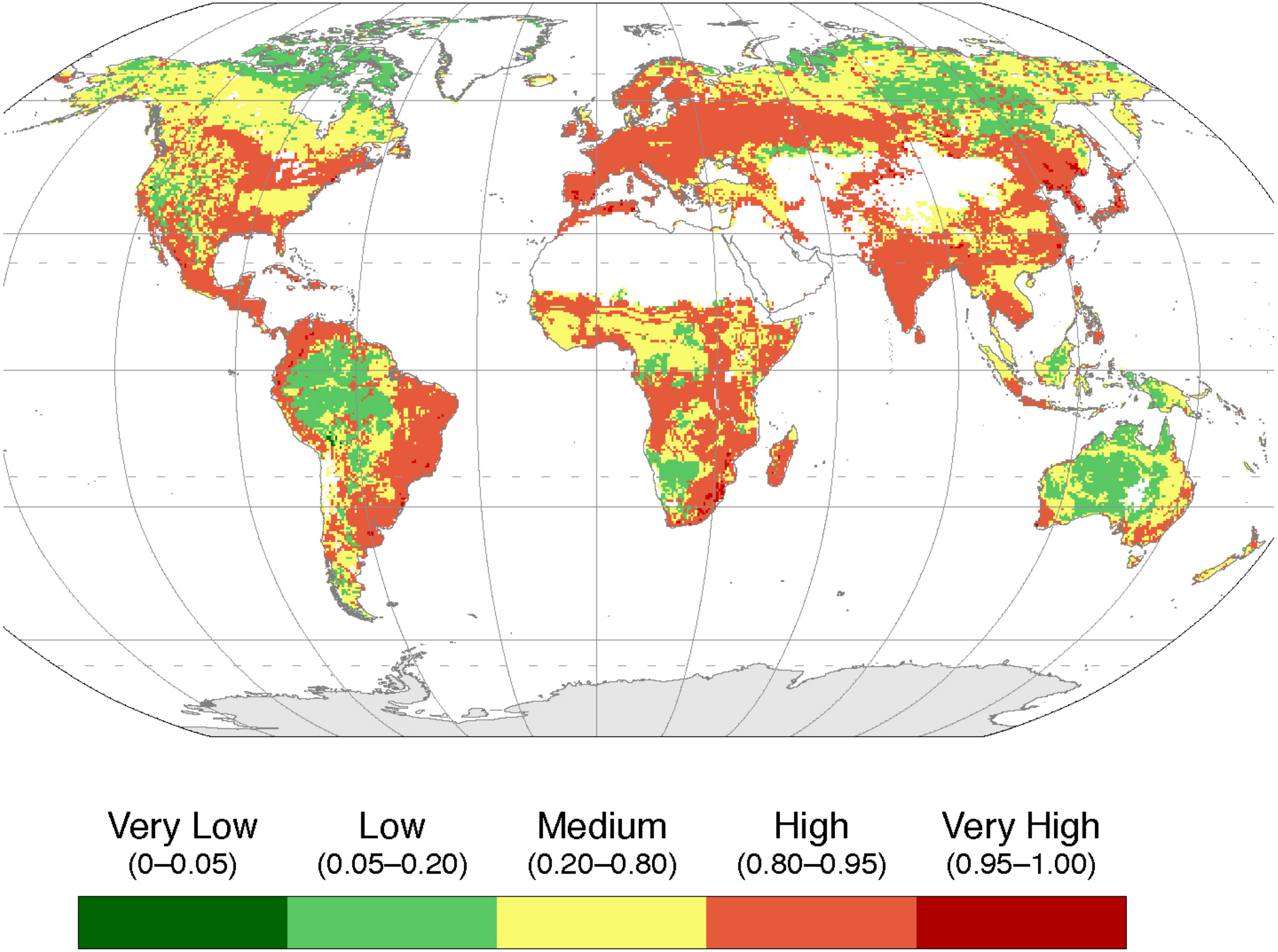
California Desert Connectivity Map 2: corridors for land facets

California Desert Connectivity Map 3: combined corridors for species and land facets

Discussion

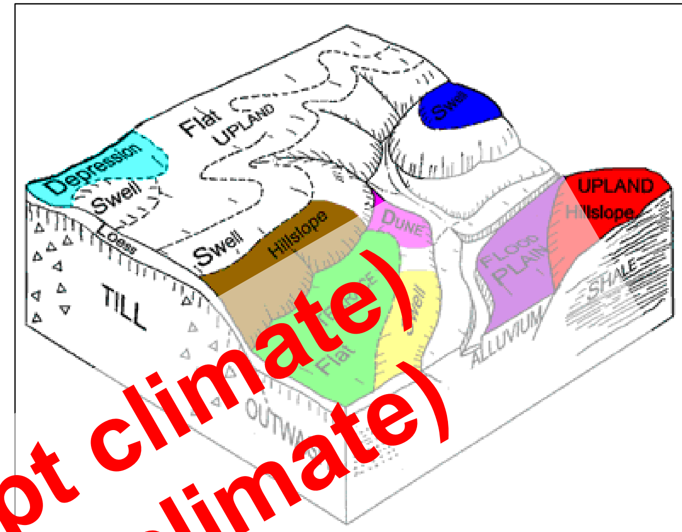
Climate change will explode our current surrogate (vegetation types)

Risk that **biome** (e.g., tundra, forest, grassland) will change



Chung et al. 2014. PNAS doi10.1073/pnas140959111

Geodiversity Variables



10- to 30-m resolution:

elevation
topographic wetness
insolation (total, seasonal)
topographic position
slope
ruggedness
curvature (several)
cold air pools
eastness
northness

250m resolution:

soil water storage capacity
soil depth
cation exchange capacity
% clay, silt, sand, gravel
total exchangeable nutrients
soil lime content
soil gypsum content
soil salinity
soil organic carbon
soil pH
human footprint

1-km resolution:

39 climate variables

Hi resolution (except climate)
Hi accuracy (except climate)
Free

Many species are endemic to **rare geofeatures**.

a) caves
b) cliffs & talus
c) limestone pavement
d) dunes
e) frost sites
f) tufa towers
g,h) waterfalls
i) river bars
j) desert springs
k) deep-sea thermal vents
(Not shown) vernal pools, metalliferous soils (serpentine)

Hjort et al. 2015. *Conserv Biol* ***Special Section*** 29:630

Hunter. 2017. *Biol Cons* 211:1

Pattern-based evidence for geodiversity as a surrogate for biodiversity

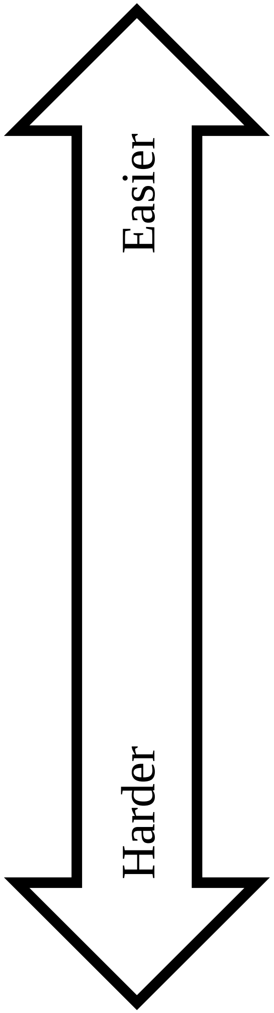
Geodiversity ("Environmental Diversity" - Faith & Walker 1996) is a good coarse-filter surrogate

Dataset	Improvement on # species represented (compared to random site selection)
Europe, reptiles	84%
Europe, amphibians	69%
Zimbabwe, plants	67%
Europe, vertebrates	40%
Arizona, birds	35%
Europe, birds	34%
Spain, birds	26%
Europe, mammals	No better than random

Beier & Albuquerque. 2015. *Conservation Biology*: 29:1401

See also: Anderson & Ferree. 2010. PLoS ONE

Some ways to use geodiversity **to select sites for conservation**



* geosites like springs, vernal pools, metalliferous soils…
* interfaces between acidic and alkaline soils
* low elevation mollisols and vertisols (used for farming, and hence poorly represented in any region's conservation portfolio)

* other enduring features that are poorly represented in the region's conservation portfolio (requires analysis)
* areas of cold air pooling (Daly et al. 2009. Internat J Climatology DOI: 10.1002/joc)
* sites that can increase local topo-diversity, and thus allow short shifts in response to changing climate

Conserving Nature's Stage is a low-cost strategy to conserve species today and in a changing climate.

Potential climate adaptation strategies:

- Enhance connectivity
- Enlarge protected areas
- Assisted colonization
- Mobile reserves
- Model shifting climate space
- **Conserve nature's stage**

Part III: Using geodiversity in conservation planning

Conserving Nature's Stage is a low-cost strategy to conserve species today given our ignorance about species. It may also prove useful for conservation in a changing climate.

Potential climate adaptation strategies:

- Enhance connectivity
- Enlarge protected areas
- Assisted colonization
- Mobile reserves
- Model shifting climate space
- **Conserve nature's stage**

Compared to other strategies, Conserving Nature's Stage:

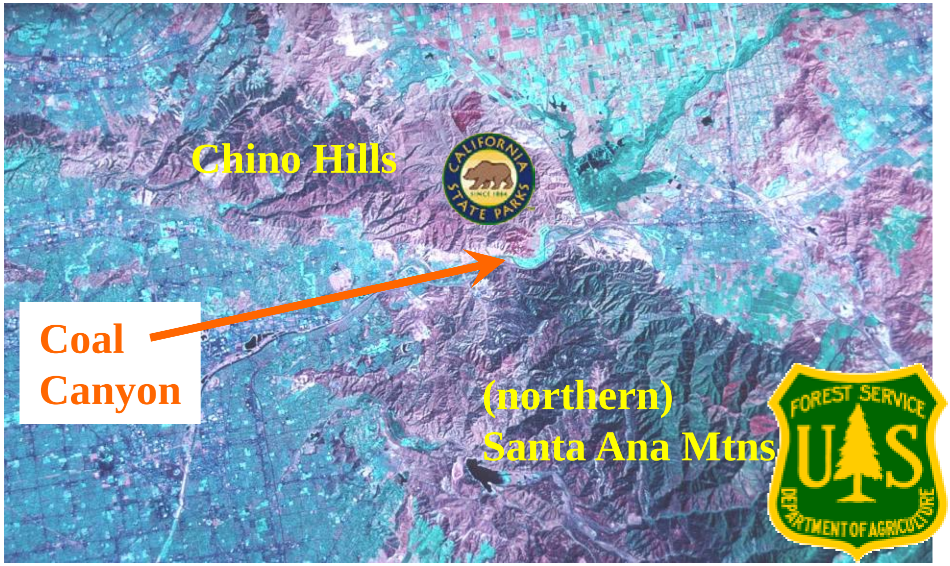
- **Does not rely on climate projections**
- **Does not require knowledge of responses of each species to climate change (or even knowledge of current species distributions)**
- **Uses data available for free everywhere on earth**

Part III: Using geodiversity in conservation planning

The Linkage Design is not just a map – it's a plan.

Example: Coal Canyon, California

The Coal Canyon Corridor would not have been conserved without a Plan…



The last parcel is bought.

1st interchange in U.S. to be removed for conservation.

Asphalt-breaking ceremony: 10 Dec 2002

The Linkage Design does not aim to *mitigate* (slow down the rate at which things get worse), but to *improve* connectivity.