

# Habitat Connectivity Planning in California

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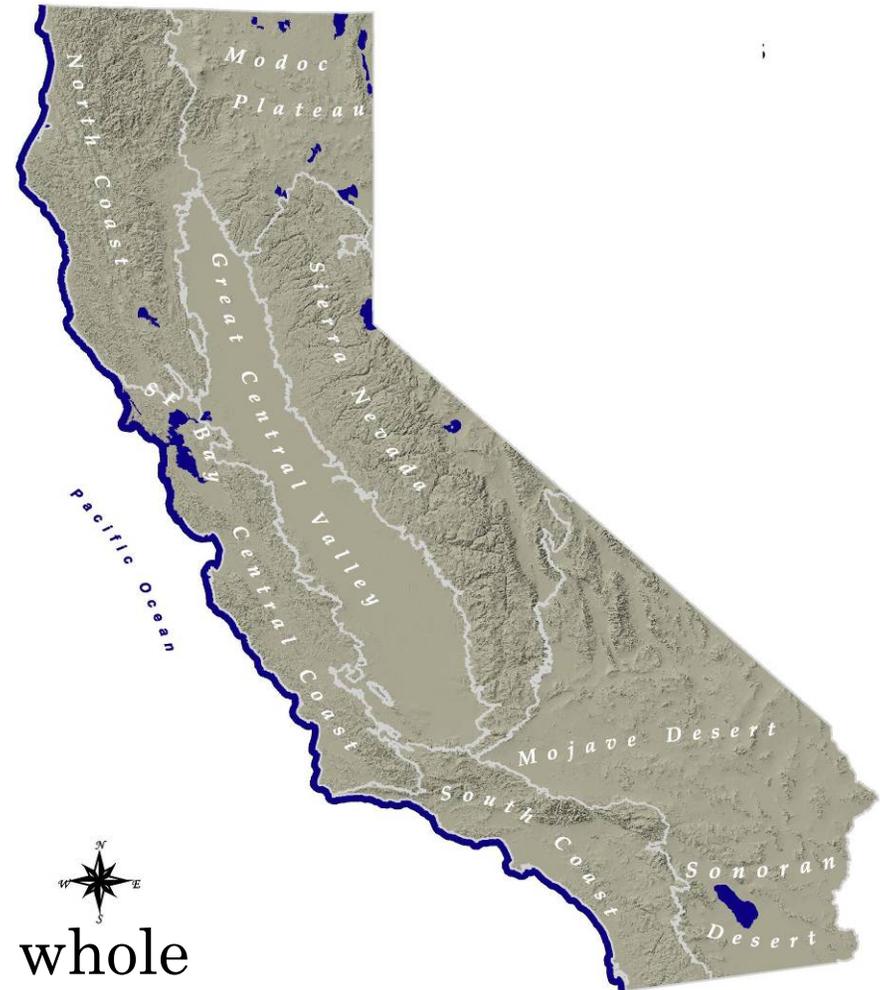
What is connectivity?

What has California done so far? Do we need more?

How does the statewide CEHC relate to regional & local efforts?

What GIS approaches can we use for *statewide* connectivity mapping?

Prioritization: we can't paint the whole state green.



# Functional connectivity: Nature needs room to roam

*Functional connectivity* is a landscape condition that promotes natural levels of:

- Individual movement to access resources in home range
- Immigration & emigration (demographic rescue) or recolonization after local extinction
- Gene flow (the ability to evolve)
- Seasonal migration
- Ecological processes and flows (e.g., disturbance, predator-prey interactions, seed dispersal)
- Population movement in response to disasters or changing climate

# Structural versus Functional Connectivity

## Functional connectivity

An interaction between a landscape and species or ecological processes; the degree to which the landscape supports certain natural flows.

## Structural connectivity

A black-&-white map (habitat *versus* non-habitat) yields statistics unrelated to biology or mobility of particular plants and animals.

A historic relict with little relevance to conservation planning (Crooks & Sanjayan 2006)

# Functional connectivity: some key terms

*Core areas* or *Wildland blocks* – what we want to connect

Can be hard to define: Do we want to connect protected areas, biodiversity hotspots, a particular habitat, populations of a particular species? (Technical meetings 2 & 3)

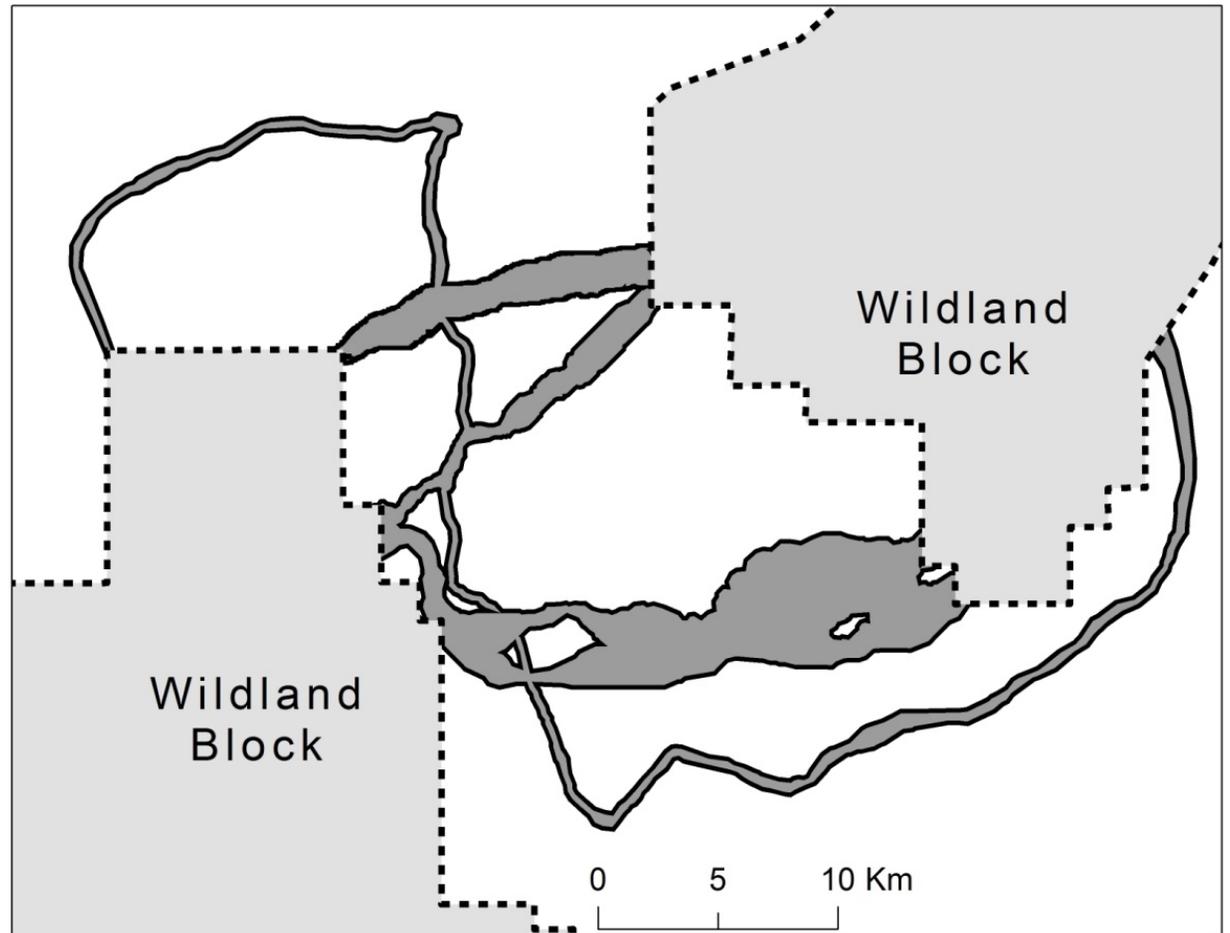
*Matrix* – the land between & around the wildland blocks

*Barriers* – highways, canals, railroads, border fences, urban areas and other things that impede animal movement.

*Linkage* – a portion of the matrix that, if conserved, can maintain functional connectivity between wildland blocks for multiple species and processes.

# “Linkage” and “Corridor”

*Linkage*— a portion of the matrix that, if conserved, can maintain functional connectivity between wildland blocks for multiple species and processes.

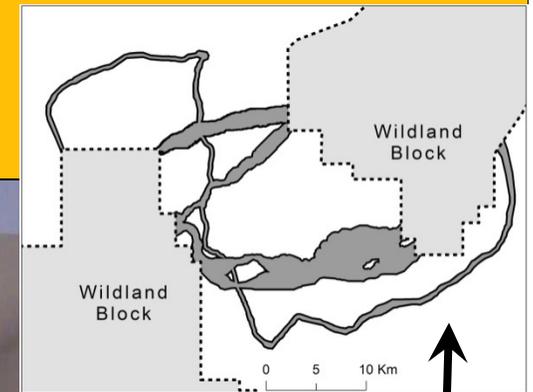


# Corridor – a synonym for *linkage*?

Yes, but “corridor” (like “hallway”)...

emphasizes  
*structure*  
(linkage  
emphasizes  
*function* )

implies a *single, highly linear, connection* (linkage may include *several, non-linear strands*)



# Linkages are not the only way to provide functional connectivity!

Best,  
most  
natural

Conserve intact natural landscapes.

Manage the entire matrix for permeability.

**Conserve or restore *linkages*.**

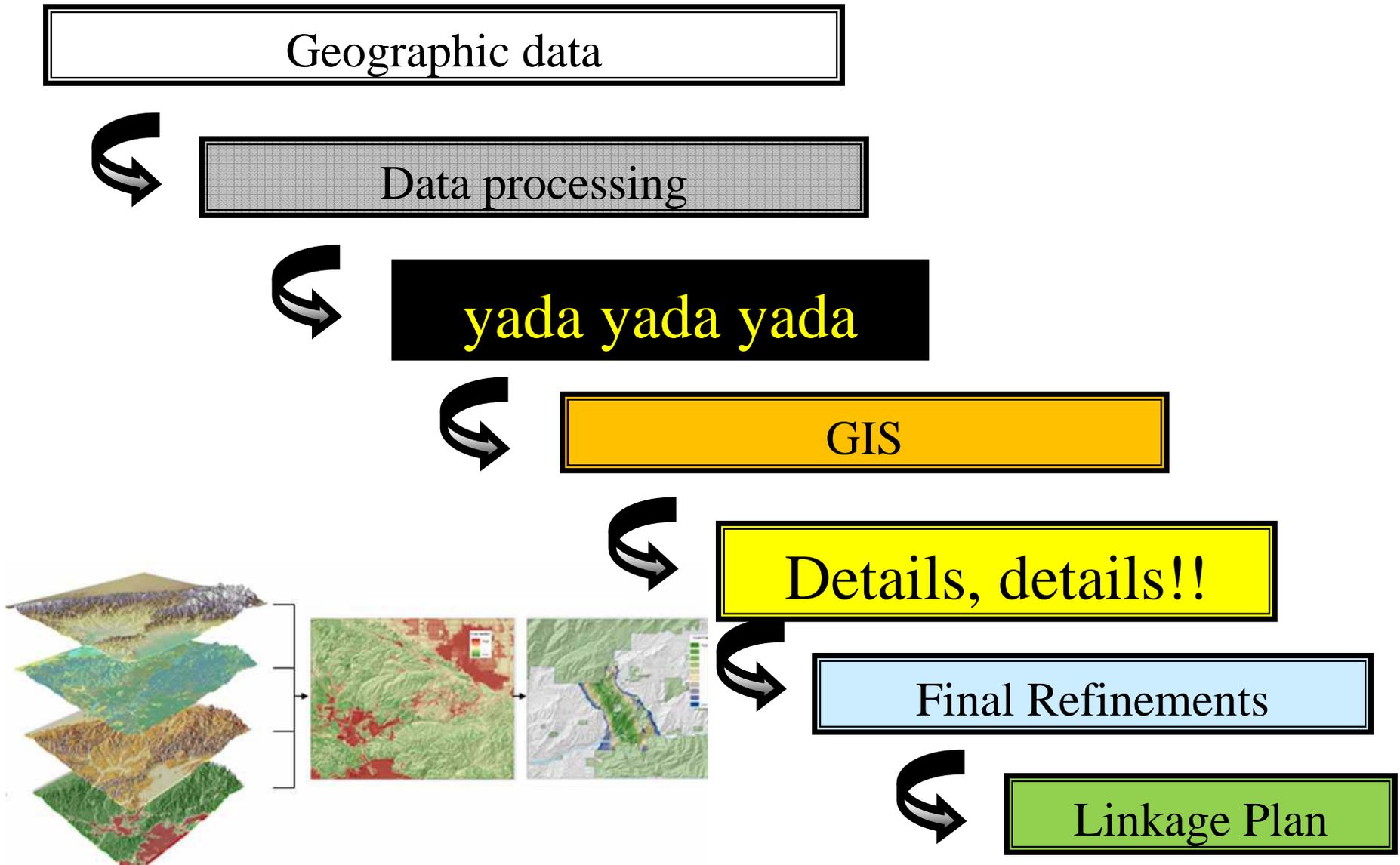
Conserve or restore steppingstones. (for species that can fly over or move through non-habitat)

Build crossing structures under highways & canals. ‘Getting the animal across the road’ is usually only a small part of the solution.

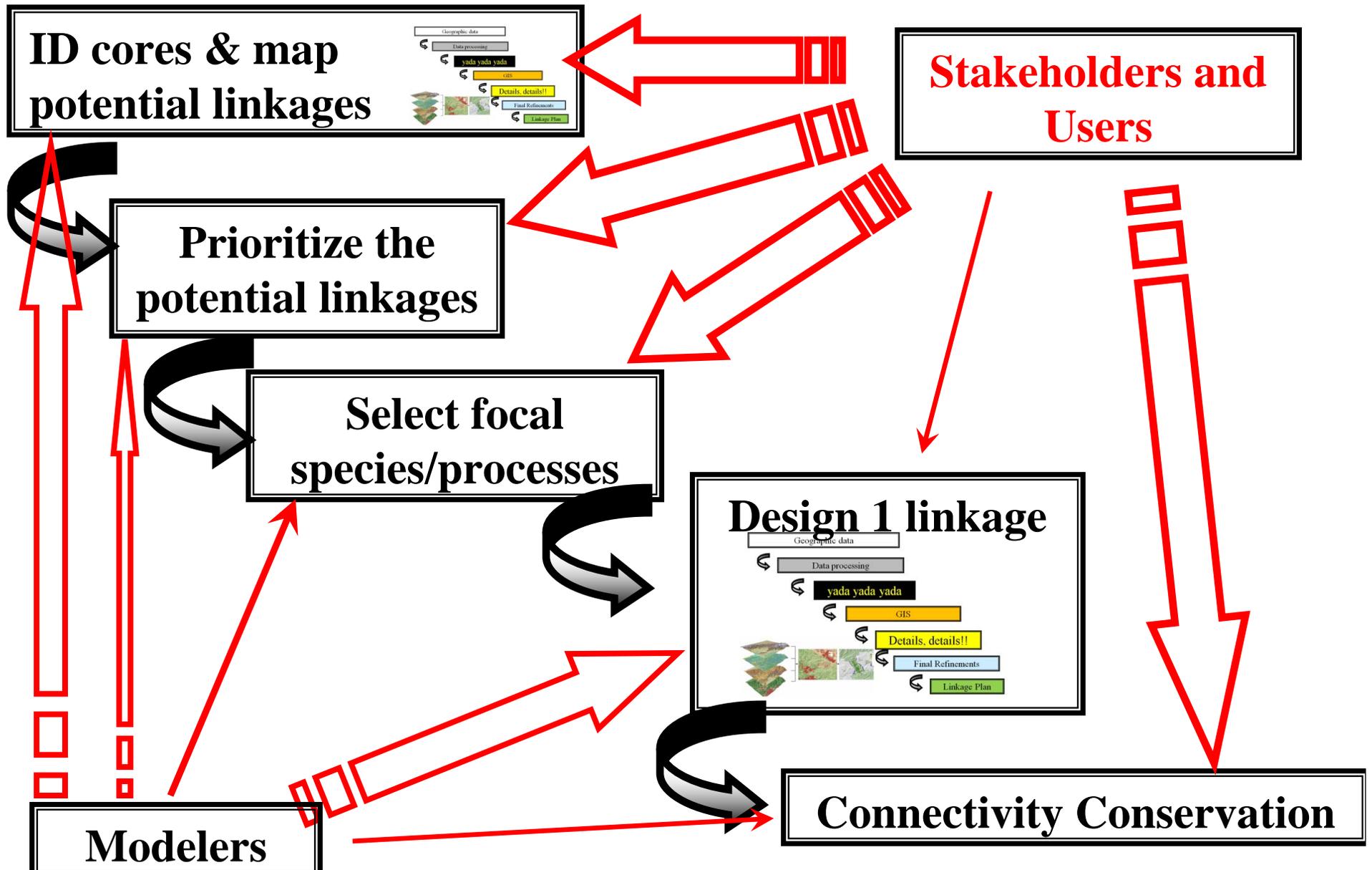
Least  
compre-  
hensive

Capture animals in one wildland block and carry them to the other wildland block.

# Connectivity Modeling



# Modeling occurs within a broader planning context



# What statewide connectivity planning has California done so far?

## *Missing Linkages:*

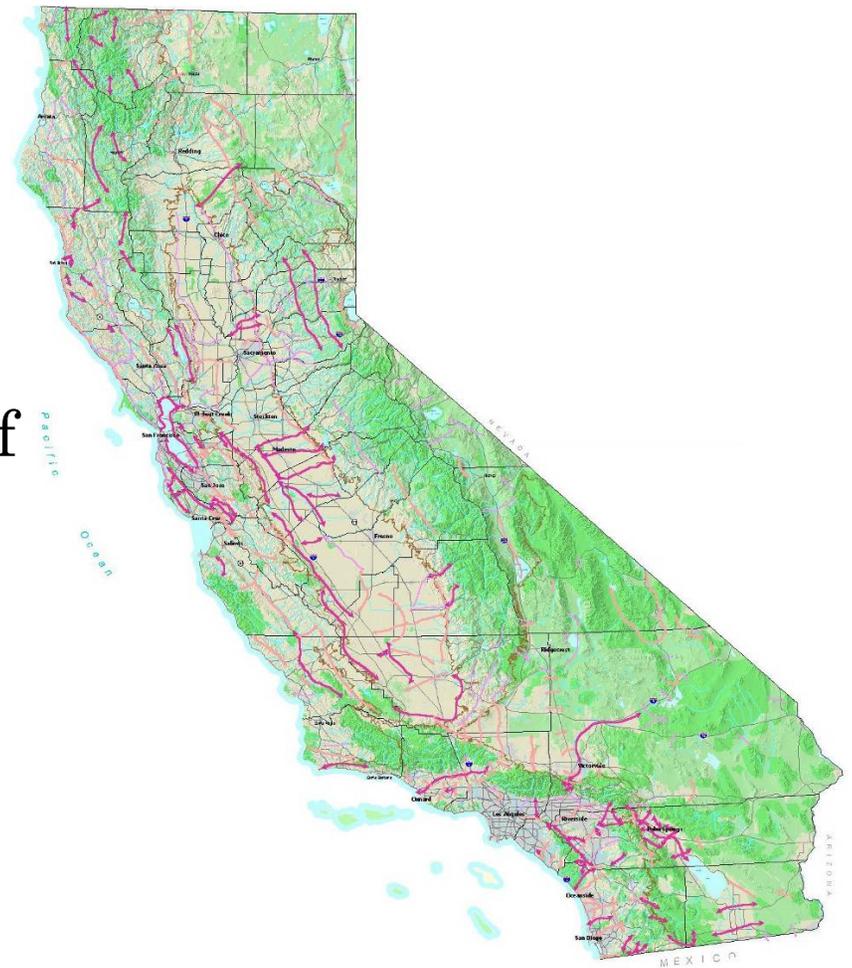
*Restoring Connectivity to the California landscape*

*August 2001*

Identified 232 linkages at risk

No prioritization; some  
“linkages” are truly “missing”

Inconsistent, ad-hoc designation of  
linkages (= a fast, efficient way to  
draw on knowledge of all)



# What statewide connectivity planning has California done so far?

## *Missing Linkages:*

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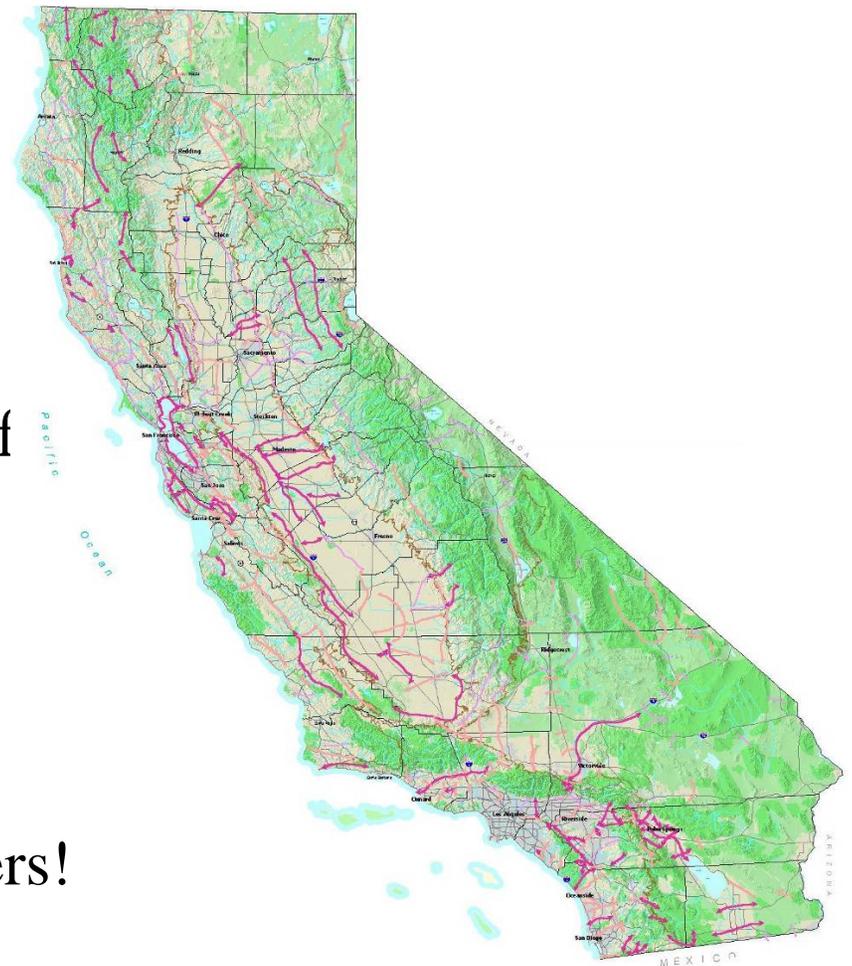
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No prioritization; some “linkages” are truly “missing”

Inconsistent, ad-hoc designation of linkages (= a fast, efficient way to draw on knowledge of all)

Hand-drawn place-holder arrows alert planners to develop a detailed plan

... but users forget these are placeholders!



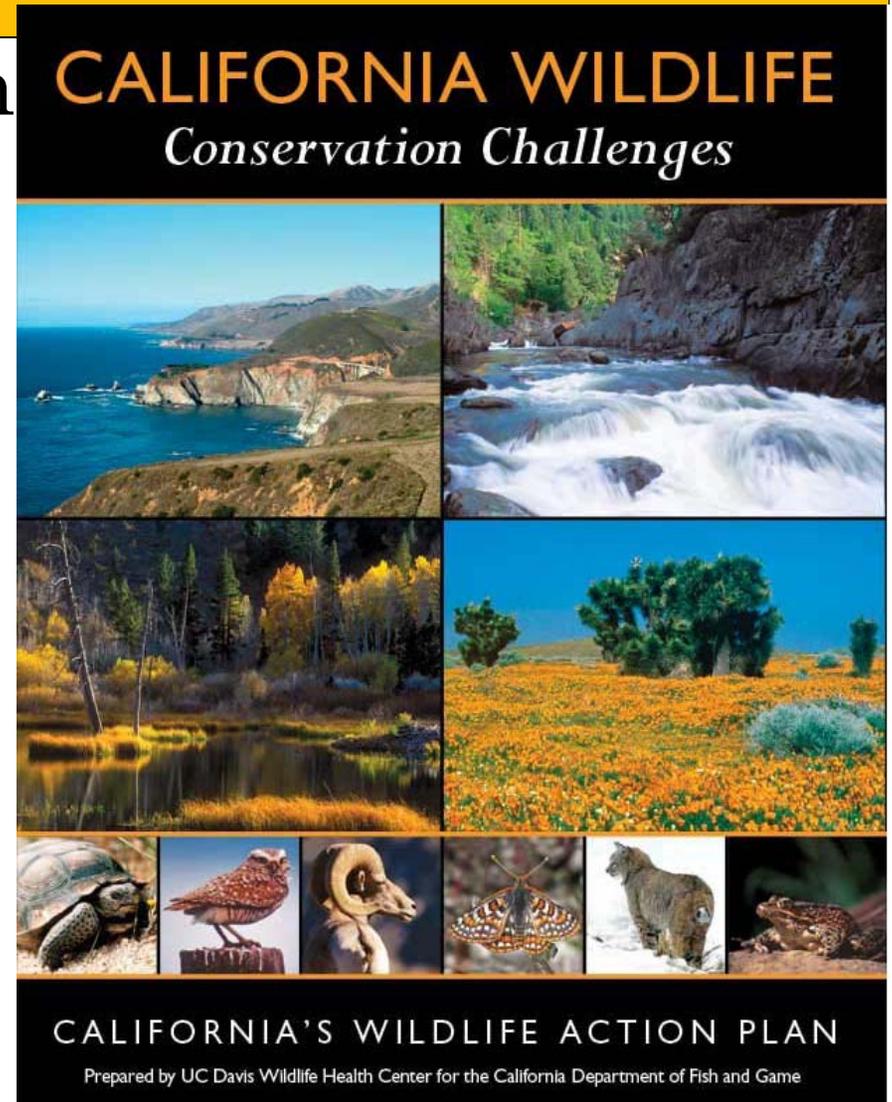
# What statewide connectivity planning has California done so far?

## State Wildlife Action Plan

4 of 17 “recommended statewide conservation actions” focus on connectivity (#1, 3, 4, 14).

Connectivity a key action in 4 of 8 terrestrial ecoregions (South Coast, Central Coast, Central Valley & Delta, Sierra Nevada-Cascade)

No map of linkages, no prioritization.



# What statewide connectivity planning has California done so far?

## California Legacy Project 2001-2003



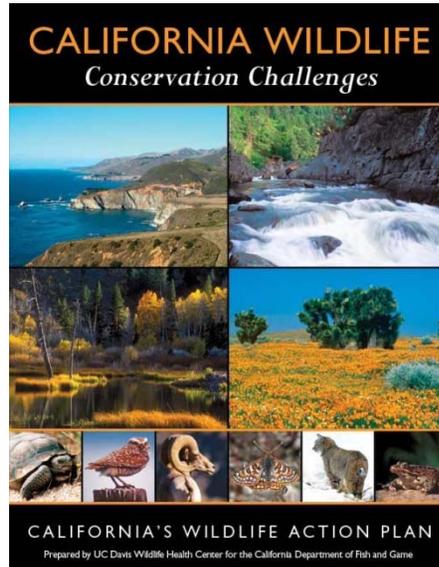
CALIFORNIA LEGACY PROJECT  
SPOTLIGHT ON CONSERVATION

Connectivity was a key concern.

No map of linkages, no prioritization.

California has only 3 statewide connectivity efforts.

## *Missing Linkages*



Davis & Cohen (2008: SFSU report to Caltrans):

Over 40 Regional or Single-linkage plans & studies in California.

# Will our new map “erase” regional or single-linkage connectivity plans?

No. In fact some may be imported.

We’ll examine existing plans to help us select comprehensive criteria.

If our new map misses many important existing plans, we may need to revise our map-making rules.

Some mis-match is expected due to differences in scale and purpose of each plan.

# Existing mapping: lessons learned

Be clear about WHAT you are trying to connect. Emphasize how linkages add value to existing conservation investments.

Use clear criteria and a transparent process.

Involve end-users early in the design phase (what you want to connect, criteria for prioritization, select approach, type of outputs needed).

Linkage depiction should minimize risk of misinterpretation.



# CALIFORNIA ESSENTIAL HABITAT CONNECTIVITY

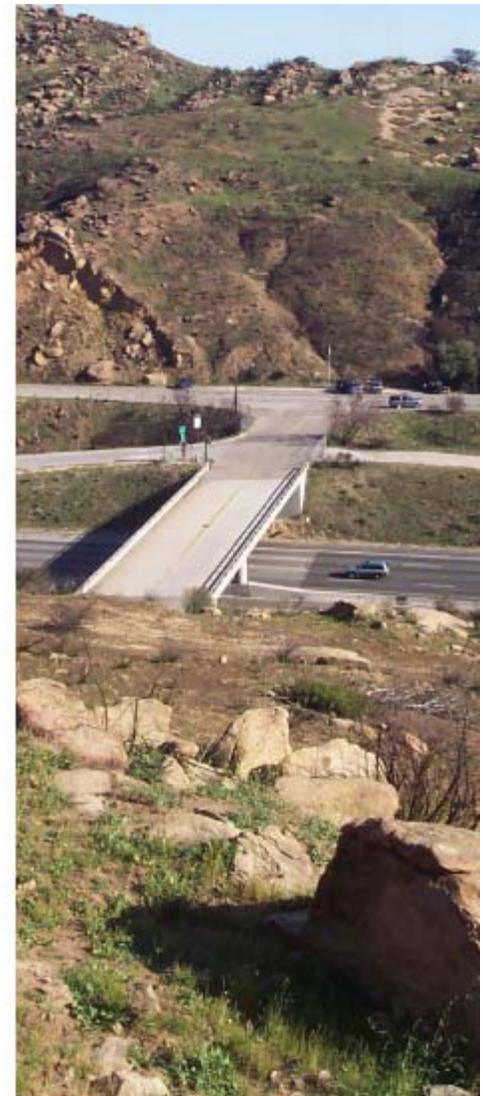
A *statewide* map of areas important for connectivity

A method to prioritize regions or individual linkage areas

It *won't* be a set of detailed, implementable plans for individual linkages



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# *CALIFORNIA ESSENTIAL HABITAT CONNECTIVITY*

Will replace the 2001  
*Missing Linkages* map

2010: Display linkage designs where available; elsewhere use symbol that reflects our level of (un)certainty.

2010: Consistent, criteria-driven way to designate linkages.

2010: a prioritized map that depicts the most important linkages.

2010 map will be easy to update as the landscape changes.



# What approaches can we use to develop a *statewide* connectivity map?

- Least-cost modeling
- Circuit theory
- Expert workshop
- Simulated annealing
- Graph theory
- Spatially explicit population modeling
- Individual-based movement model

# Utility of each approach depends on 4 things

## 1. Basic product:

- descriptive statistics *only* ← ☹️ **less useful for planners**
- map of linkage areas ← 😊 **what planners need**

## 2. Procedure

- ad hoc, not repeatable ← ☹️
- rigorous, transparent, repeatable, updateable ← 😊

## 3. Applicable at statewide level?

- no ← ☹️
- yes ← 😊

## 4. Linkage depicted as:

- path or line (1-pixel wide) *only* ← ☹️ **unrealistic**
- path or corridor (swath) ← 😊 **much better**

# Utility of each approach depends on 4 things

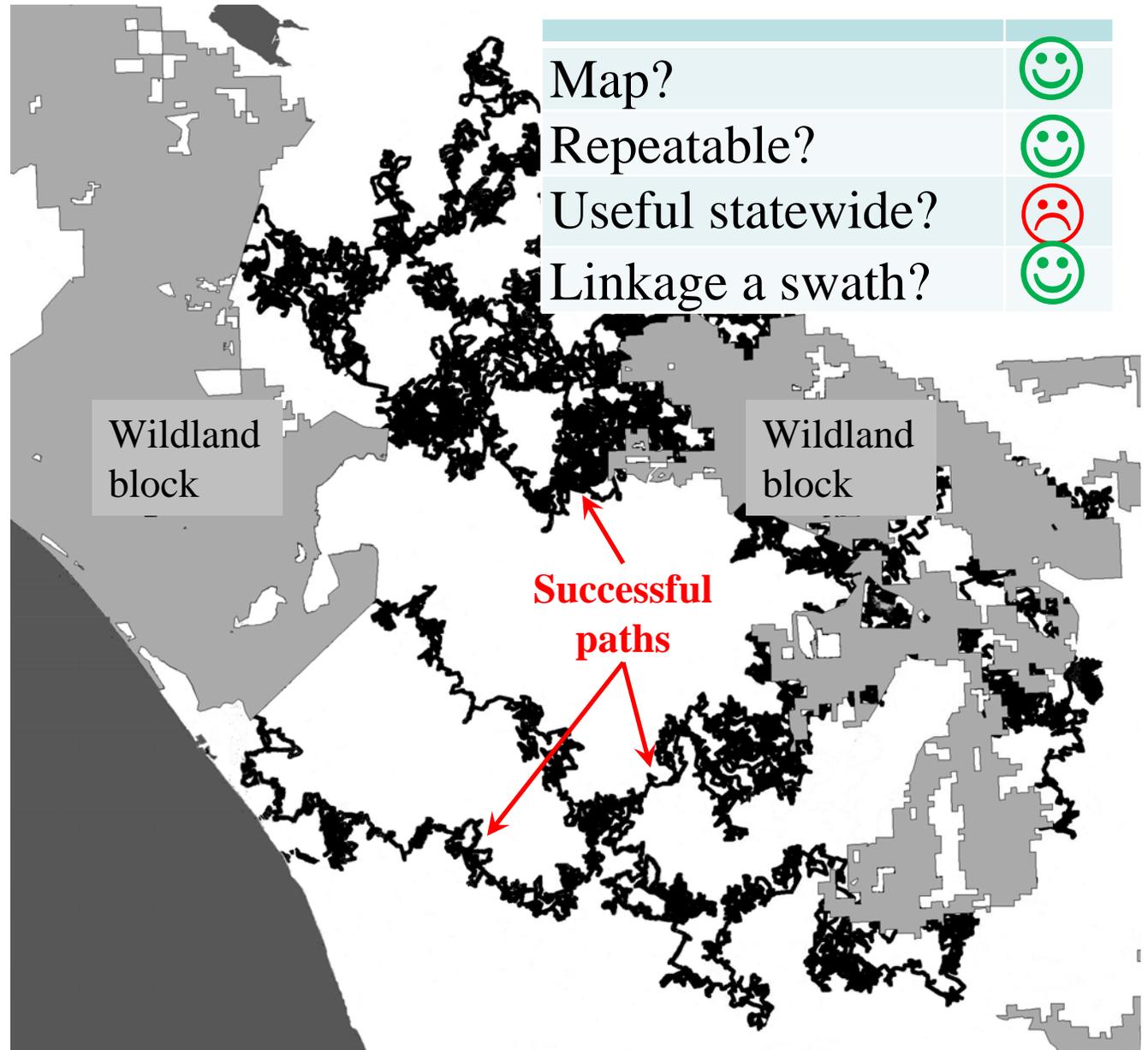
	 <b>or</b> 
Produce map (not just statistics)?	
Rigorous & repeatable?	
Useful statewide?	
Linkage a swath (not path)?	

# Individual-based movement models

Model movement of 1,000 simulated dispersers leaving each wildland block. Retain only the paths that reach the other wildland block.

Required data:

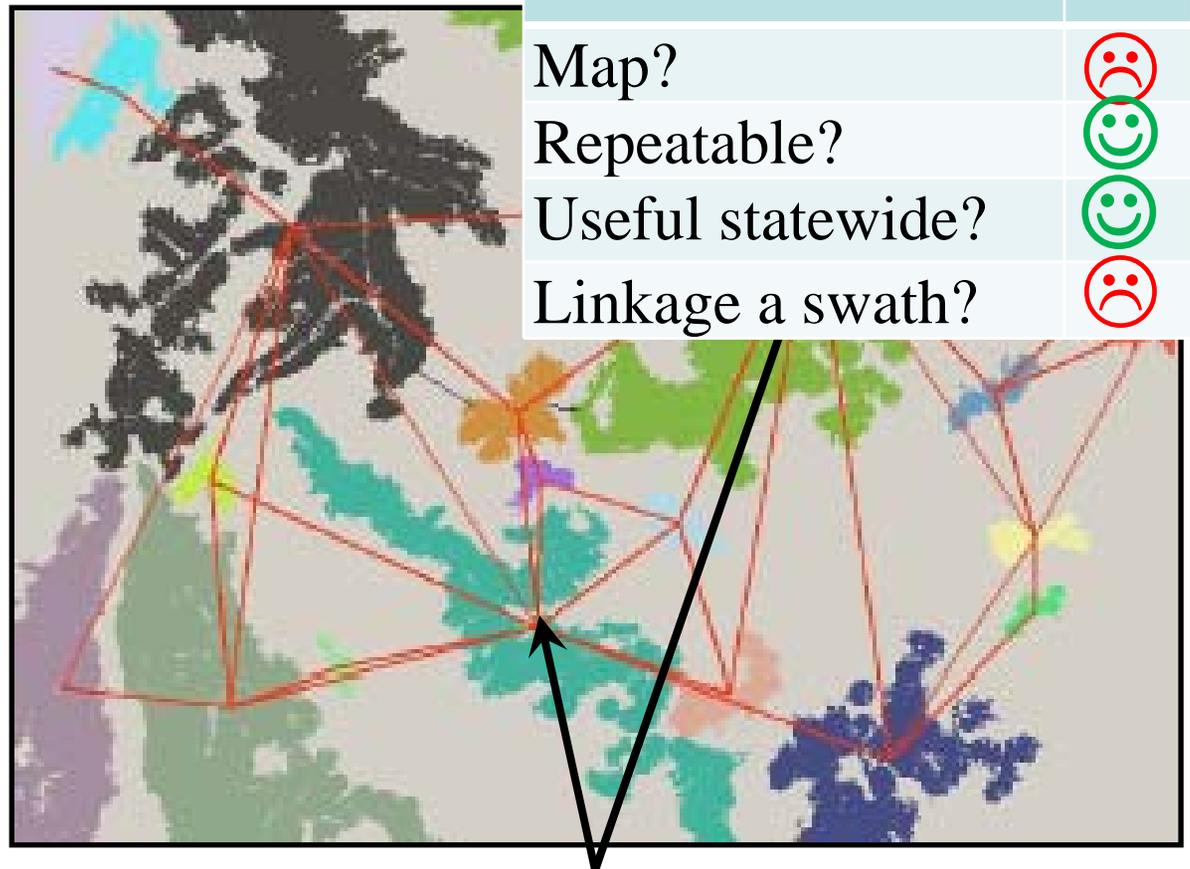
- travel speed
- turning angles
- energy costs
- mortality risk in each habitat.



# Graph Theory

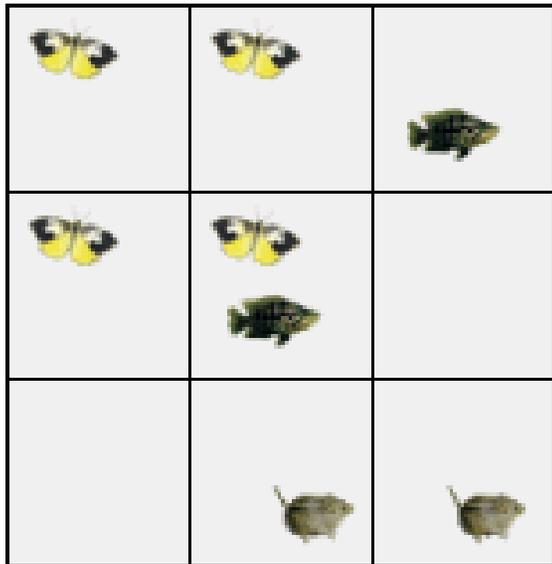
Represent each wildland block as a point (node) & each linkage as a straight line (edge). Describe connectivity of the landscape. Identify most important nodes & edges.

But useful 😊 for prioritization after linkages identified and mapped by another approach



**Important (“high centrality”) nodes: landscape connectivity statistics get much worse if you take these out. You can also identify important linkages.**

# Simulated annealing (MARXAN, SITES)

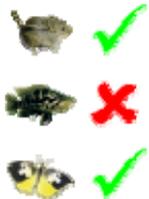


Grab a random group of cells/polygons.

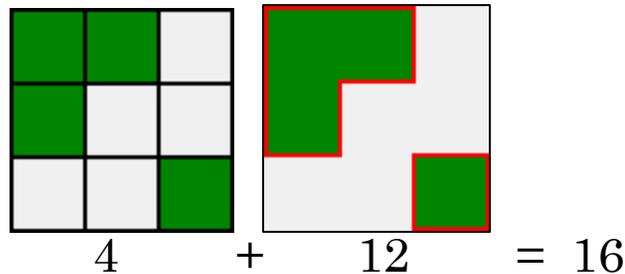
Determine if it meets goals (species or communities covered).

Calculate costs. Repeat 1,000 times. “Solution” is set that meets goal with least cost.

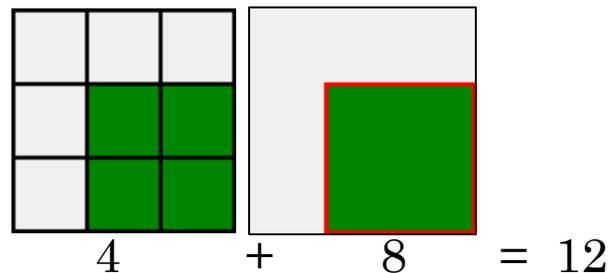
Meet goal?



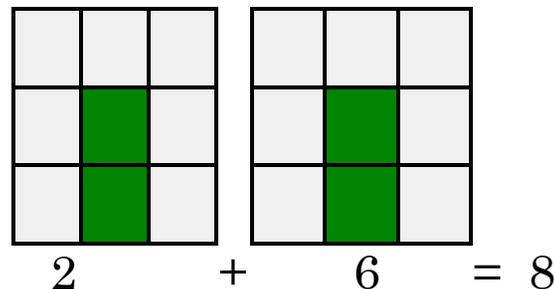
land cost + edge cost = total cost



Failed to meet goal

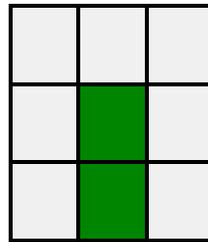
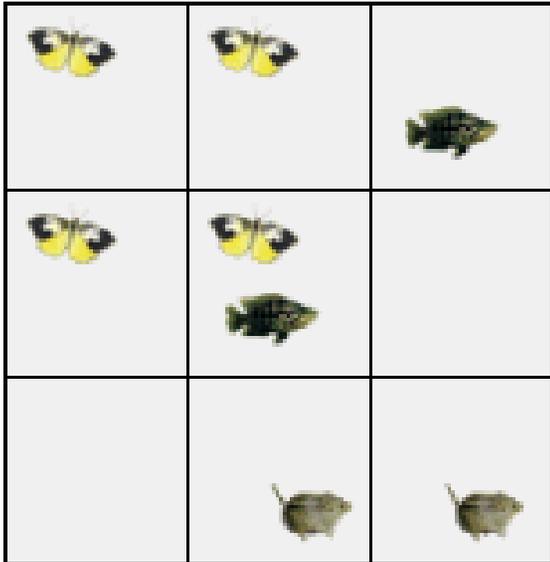


Met goal.  
Cost = 12.

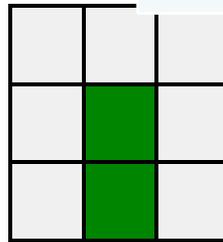


Met goal at least cost.  
The “solution.”

# Simulated annealing



+



= 8

Map of linkages?



Repeatable?



Useful statewide?



Linkage a swath?



Met goal at  
least cost.

The “solution”

The optimal solution often does not include linkages.

But useful 😊 for identifying wildland blocks to be linked.

# Spatially-explicit population model (PATCH)

Evaluate a potential reserve network (selected group of polygons) in terms of population size, range extent, or viability of focal species.

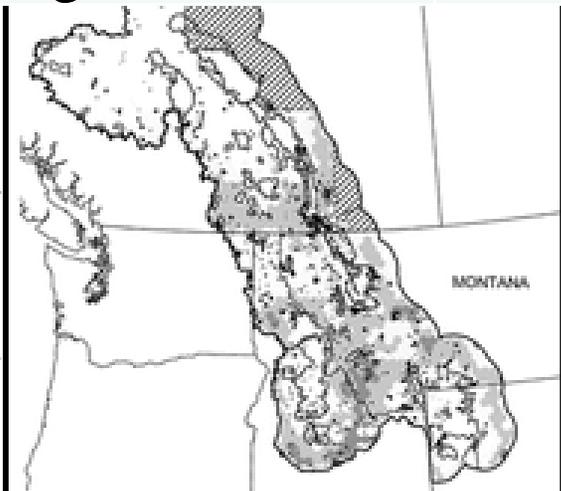
Linkages may or may not emerge from the analysis.



Scenario A

40% extinction risk

Predicted N = 800



Scenario B

10% extinction risk

Predicted N = 1200

Linkage map?



Repeatable?



Useful statewide?



Linkage a swath?



# Expert workshop

Get people who know various ecoregions into a workshop and have them hand-draw areas where connectivity is at risk, producing a map.

Perhaps 😊 for selecting wildland blocks, or prioritizing linkages.



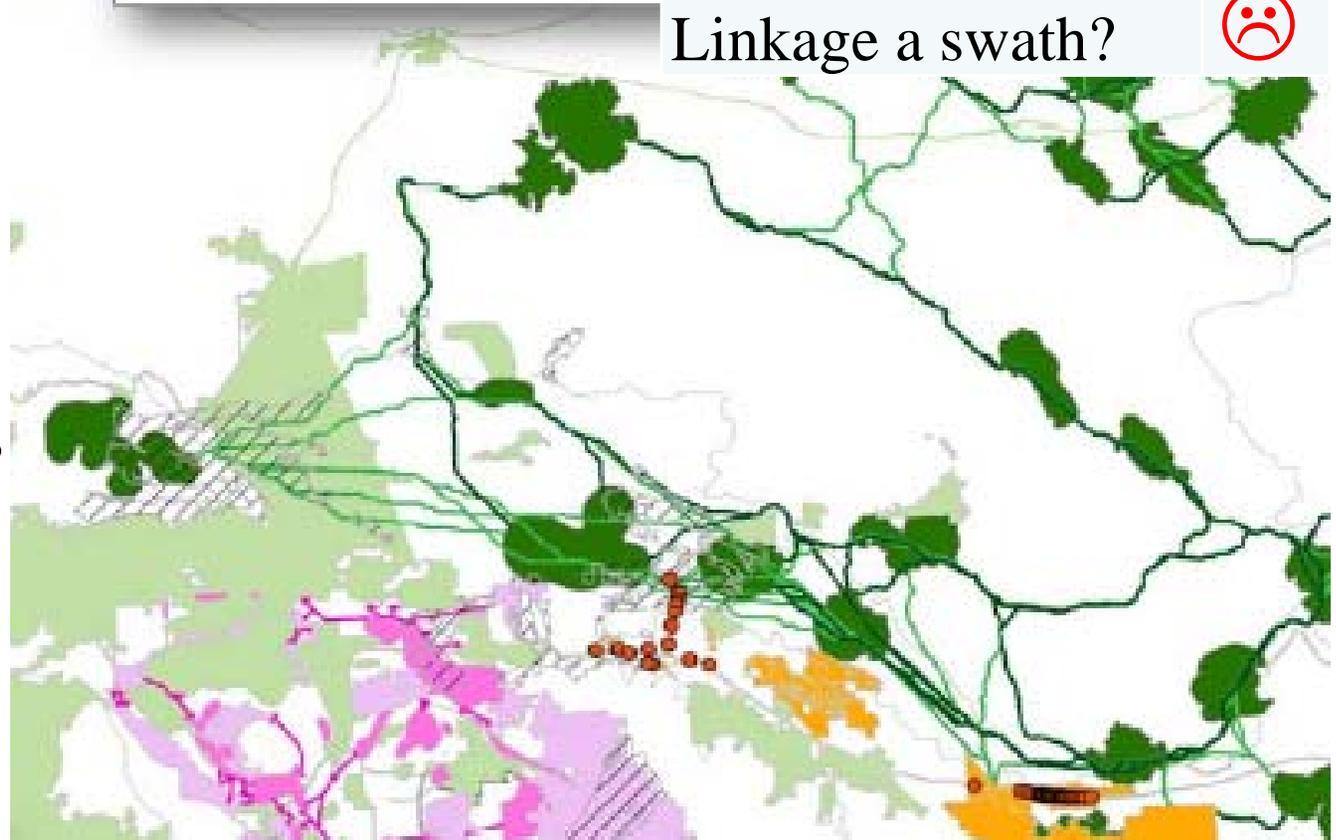
# Least cost **path** modeling

Assign resistance values to each habitat class.

Cumulative resistance = travel cost.

Lowest-cost pixels = path (1 pixel wide)

Bighorn sheep corri	Map?	😊
Mohave Desert	Repeatable?	😊
(Clint Epps, UC Ber	Useful statewide?	😊
	Linkage a swath?	😞



# Least cost **corridor** modeling

Assign resistance values to each habitat class.

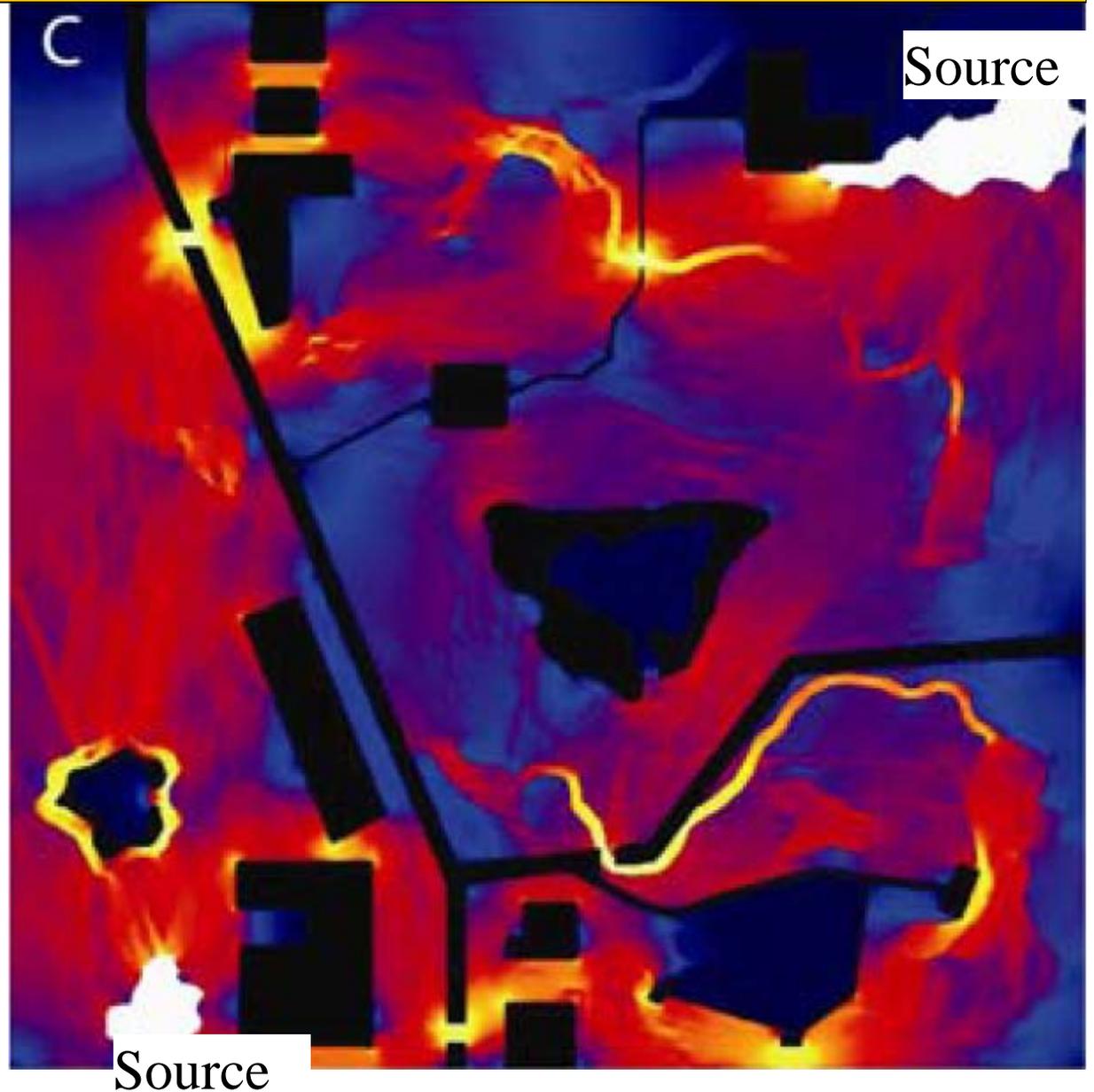
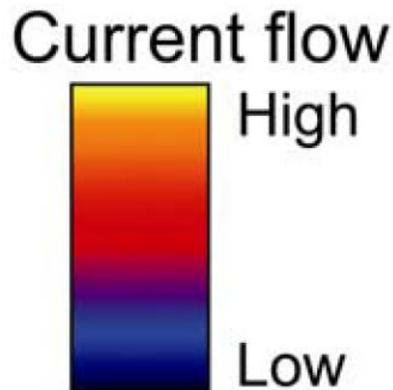
Cumulative resistance = travel cost.

Lowest-cost pixels = linkage.



# Circuit theory

Assign resistance values to each habitat class. Apply “current” and “ground” at source populations. Observe current flow. “Pinchpoints” glow bright.



# Circuit theory map is ambiguous as a linkage map.

Current flow

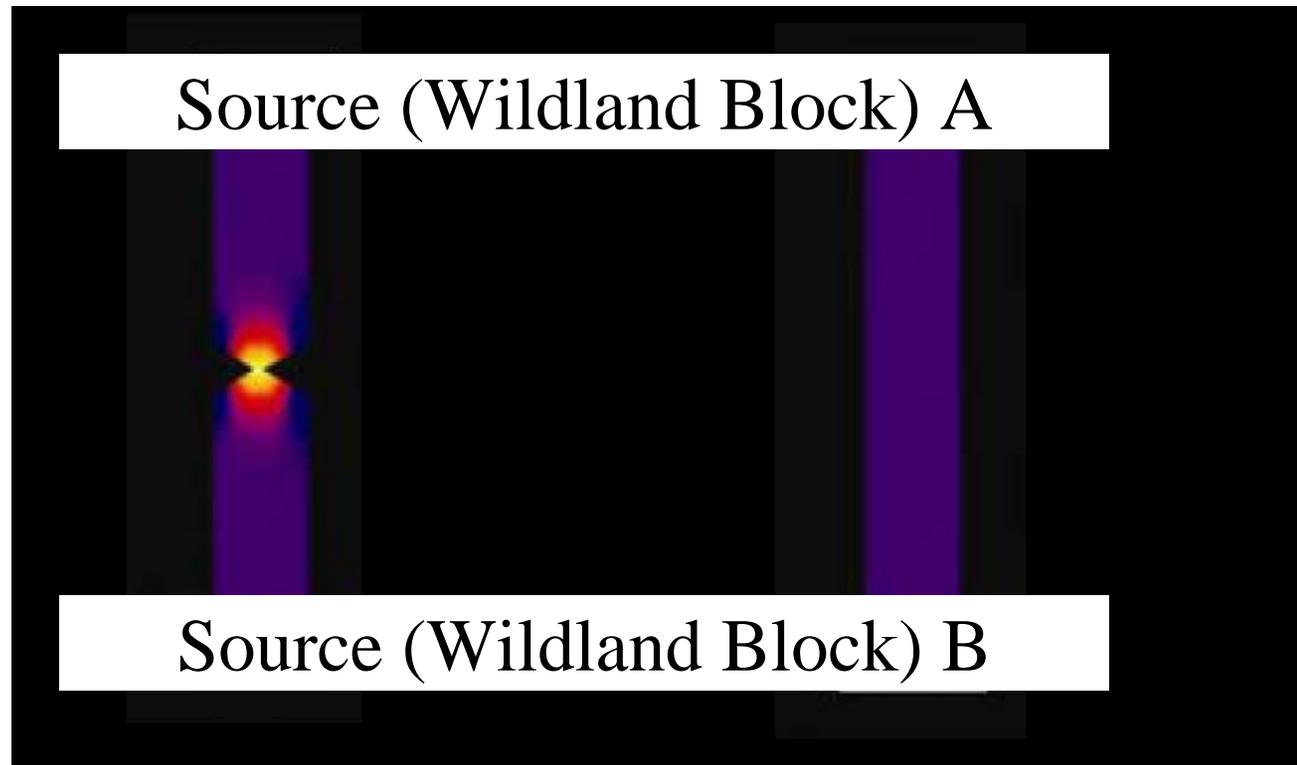


High

Low

Swath with pinchpoint  
("hot" area of  
constricted flow)

"Cooler" swath" (area of  
broad unimpeded flow)  
would be a better linkage.



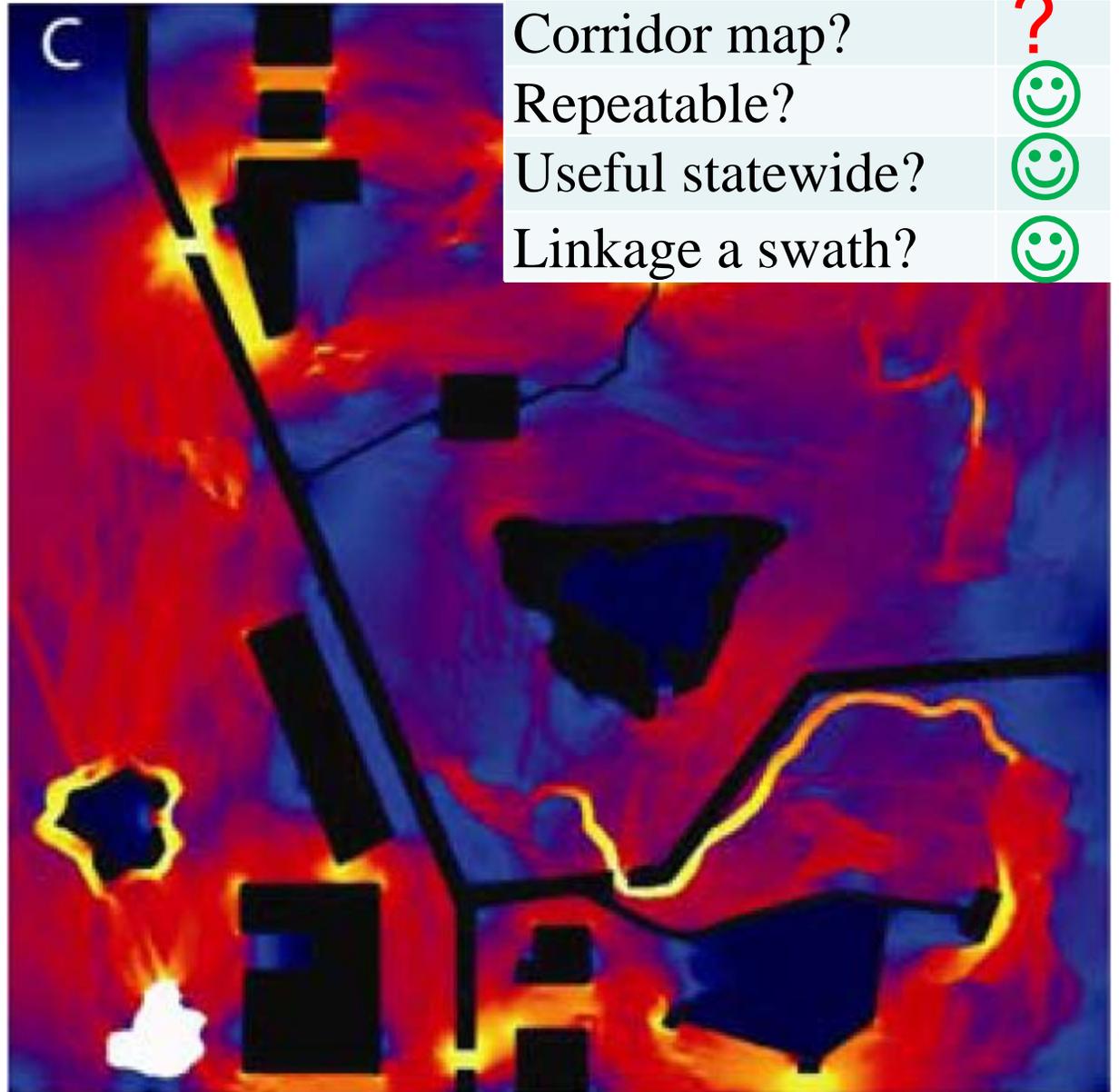
Source (Wildland Block) A

Source (Wildland Block) B

# Circuit theory

Pinchpoints (“hot” areas of constricted flow) may be worse linkages than broad “cool” areas with unimpeded flow.

😊 For identifying areas of high threat, and thus for prioritizing

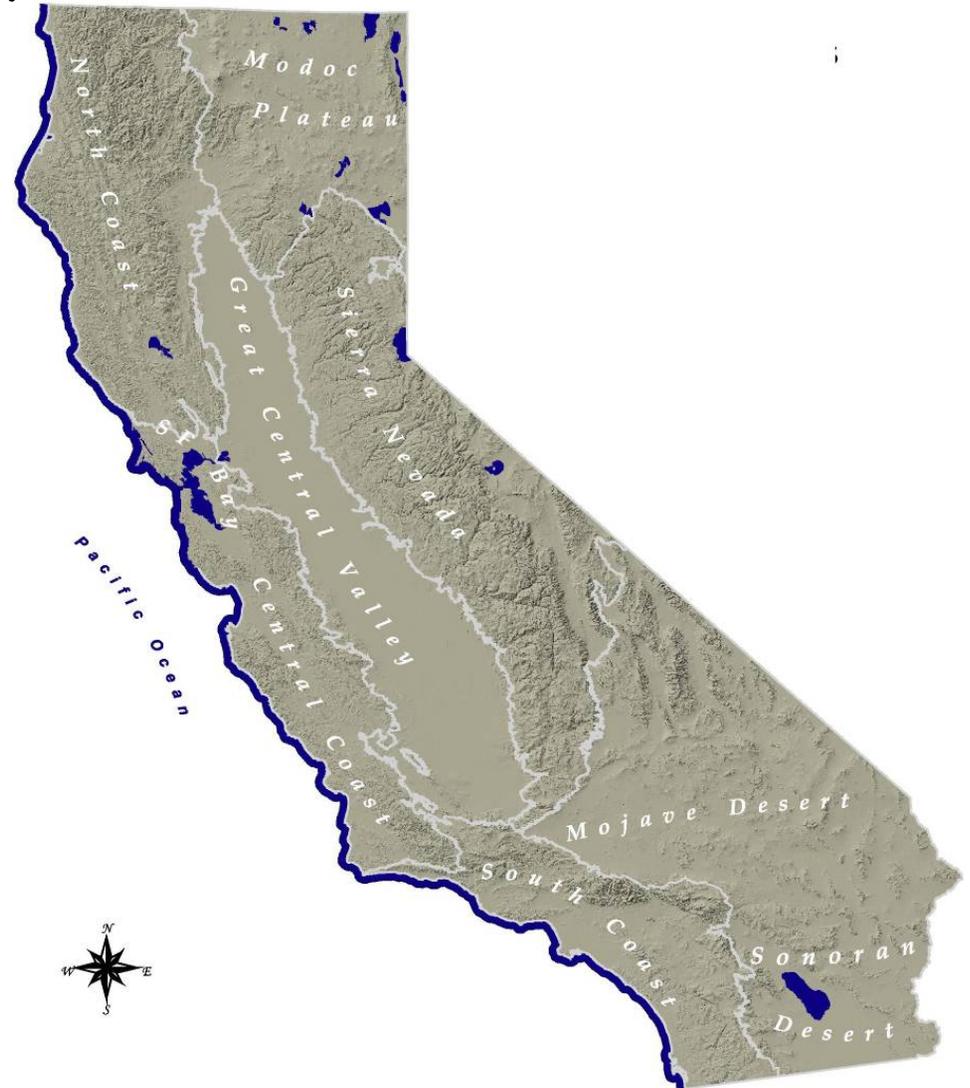


<b>Approach</b>	<b>Define wildland blocks</b>	<b>Statewide linkage map</b>	<b>Prioritize linkages</b>	<b>Design linkages</b>
Large protected areas	Likely	No	No	--
TNC, SWAP, other biodiversity maps	Likely	No	No	--
Major roads	Maybe	No	No	--
Simulated annealing	Likely	No	No	No
Expert workshop	Unlikely	No	Maybe	No
Graph theory	No	No	Likely	No
Circuit theory	No	Maybe	Likely	Maybe
Least-cost modeling	No	Likely	Likely	Likely
Indiv movement model	No	Unlikely	No	Maybe
Spatial population model	Maybe	No	Maybe	No

# Prioritization: We can't paint the whole state green!

“It's all important” – it really is!

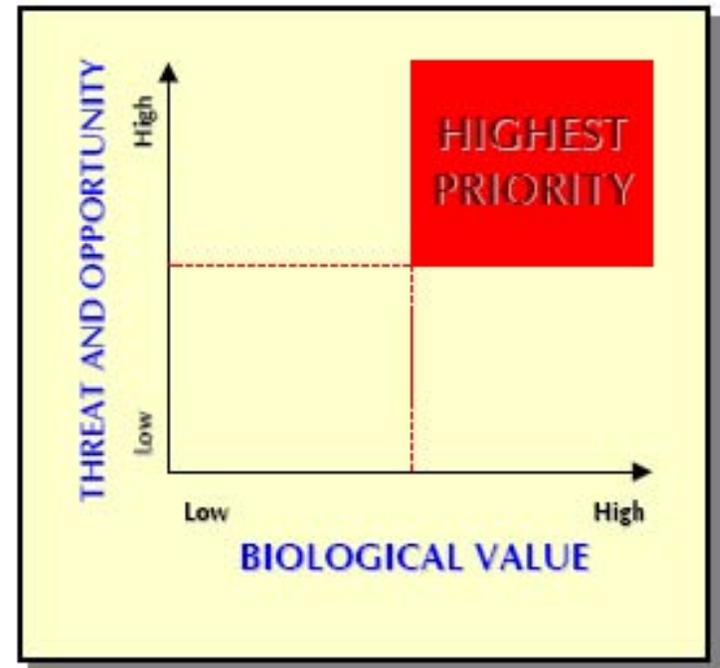
But a transportation planner, a county land-use planner, or conservation planner needs guidance on where to focus effort.



# Prioritization: one possible approach

## Biological importance

- size of the wildlands connected
- habitat quality in smaller wildland
- restorable habitat quality in the potential linkage
- many other potential criteria



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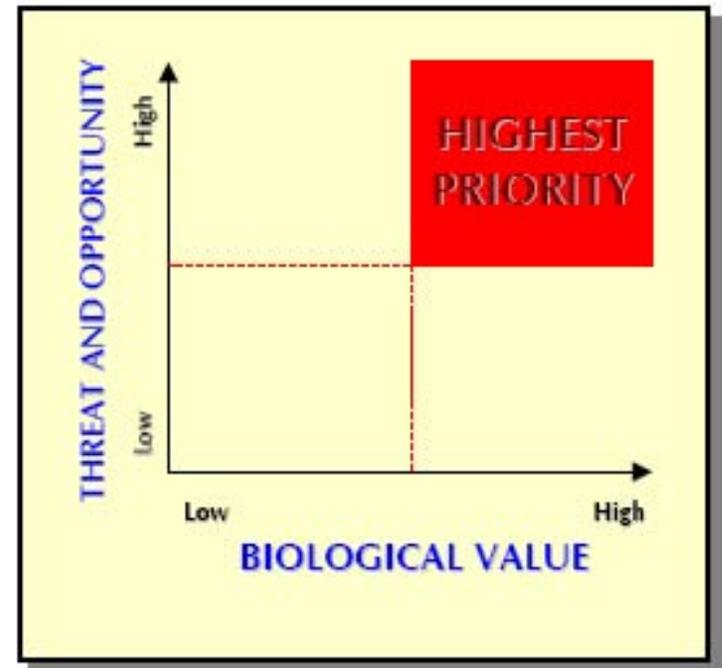
# Prioritization: one possible approach

Biological importance

- \* size of the wildlands connected
- \* habitat quality in smaller wildland
- \* habitat quality in the potential linkage

## Threat and opportunity

- risk that roads or urbanization will sever the linkage if we do not act now
- active conservation effort
- In DOT 5-year plan



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# Summary of unresolved issues for CEHC

## **1. What are we connecting?**

- Protected areas (what level of protection?)
- Habitats (which habitats or species?)
- Hotspots (how mapped?)

# Summary of unresolved issues for CEHC

## **2. What approach – or combination of approaches – shall we use to produce a statewide map of linkages?**

Regardless of the approach, what landscape traits or focal species should drive the model?

# Summary of unresolved issues for CEHC

## **3. What criteria shall we use to prioritize linkages on the statewide map?**

- Criteria related to biological value
- Criteria related to threat & opportunity
- Should we prioritize individual linkages within state, individual linkages within regions, or entire regions?