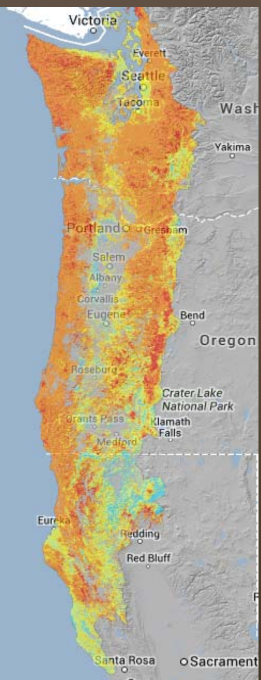
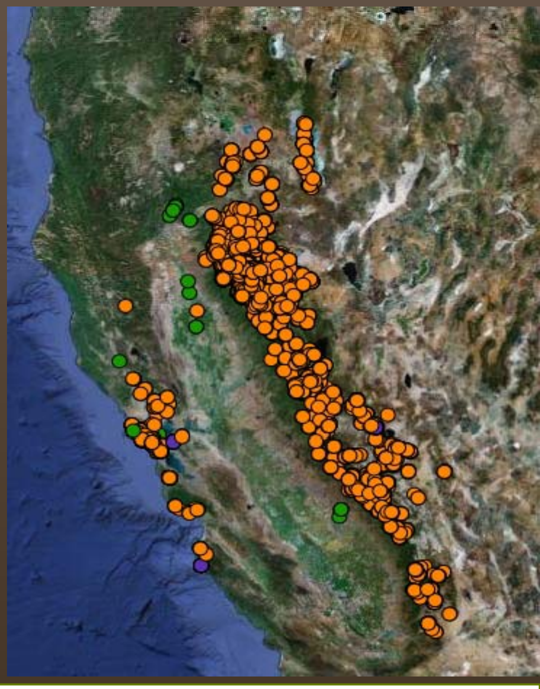


Systematic reserve design

Introduction to Marxan



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Point Blue Conservation Science for a healthy planet

CA LCC

Conservation planning

Stages in systematic conservation planning (Margules and Pressey, *Nature*, 2000):

- Compile biodiversity data for planning region
- Identify conservation goals for planning region
- Review existing conservation areas
- Select additional conservation areas
- Implement conservation actions
- Maintain values of conservation areas

Conservation planning

Stages in systematic conservation planning (Margules and Pressey, *Nature*, 2000):

- Compile biodiversity data for planning region
- Identify conservation goals for planning region
- Review existing conservation areas
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- Maintain values of conservation areas

Gap analysis

- Identify existing levels of conservation
- Compare with conservation goals
- Calculate conservation shortfalls

Conservation planning

Stages in systematic conservation planning (Margules and Pressey, *Nature*, 2000):

- Compile biodiversity data for planning region
- Identify conservation goals for planning region
- Review existing conservation areas
- Select additional conservation areas
- Implement conservation actions
- Maintain values of conservation areas

Reserve selection – optimization

- To address shortfalls identified in gap analysis
- Resources are finite, so "low cost" solutions are preferable
- Optimal "solution" vs. portfolio of "low cost" options
- Reserve selection is usually spatial, however tools can be used more broadly
- Marxan, Zonation, heuristics, other?

What is Marxan?

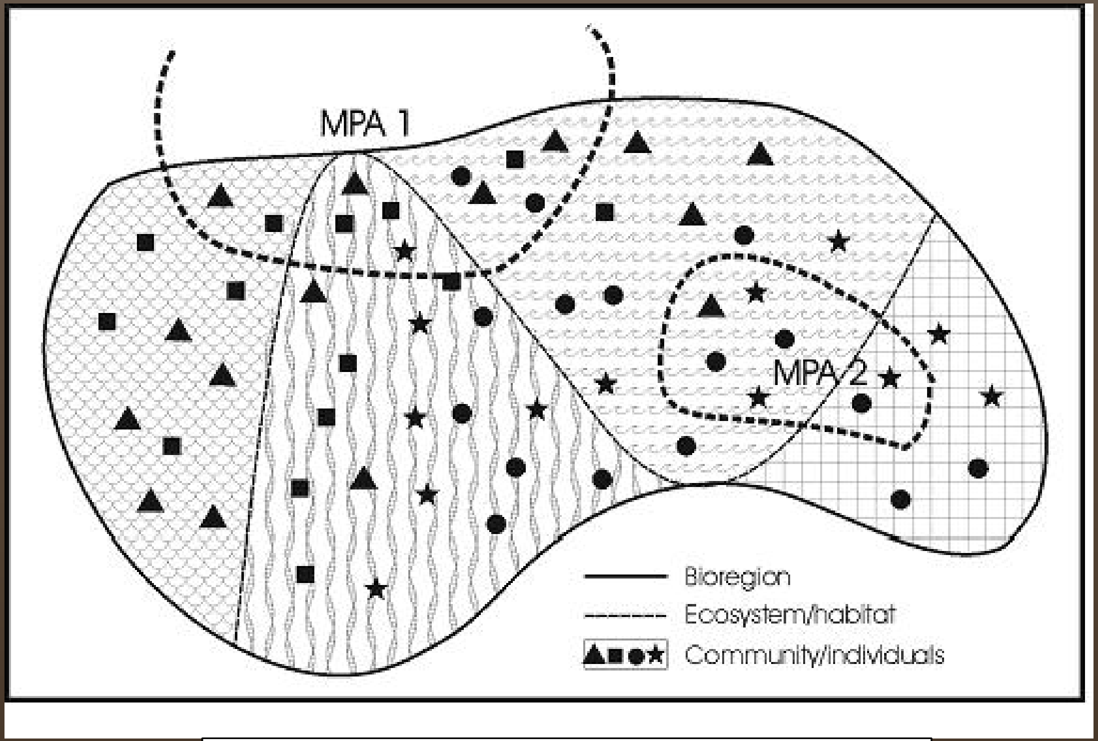
- Designed to explore trade-offs between conservation and socio-economic objectives
- Reserve System Design
- Minimum Set Problem
- University of Queensland (Ian Ball, Hugh Possingham)
- http://www.uq.edu.au/marxan/index.html
- Over 100 peer-reviewed papers using Marxan over the past decade

Key Concepts

- Comprehensiveness
- Representativeness
- Efficiency
- Spatial Arrangement: Compactness and/or Connectedness
- Flexibility
- Complementarity
- Selection Frequency vs. Irreplaceability
- Adequacy
- Optimization, Decision Theory and Mathematical Programming

Comprehensiveness and Representativeness

- Comprehensiveness: Sample the full range of biodiversity (both typical and atypical)
  - Biodiversity composition
  - Structure and function
  - Evolutionary processes
- Representativeness: Reserve systems should capture biodiversity that is representative of their surroundings



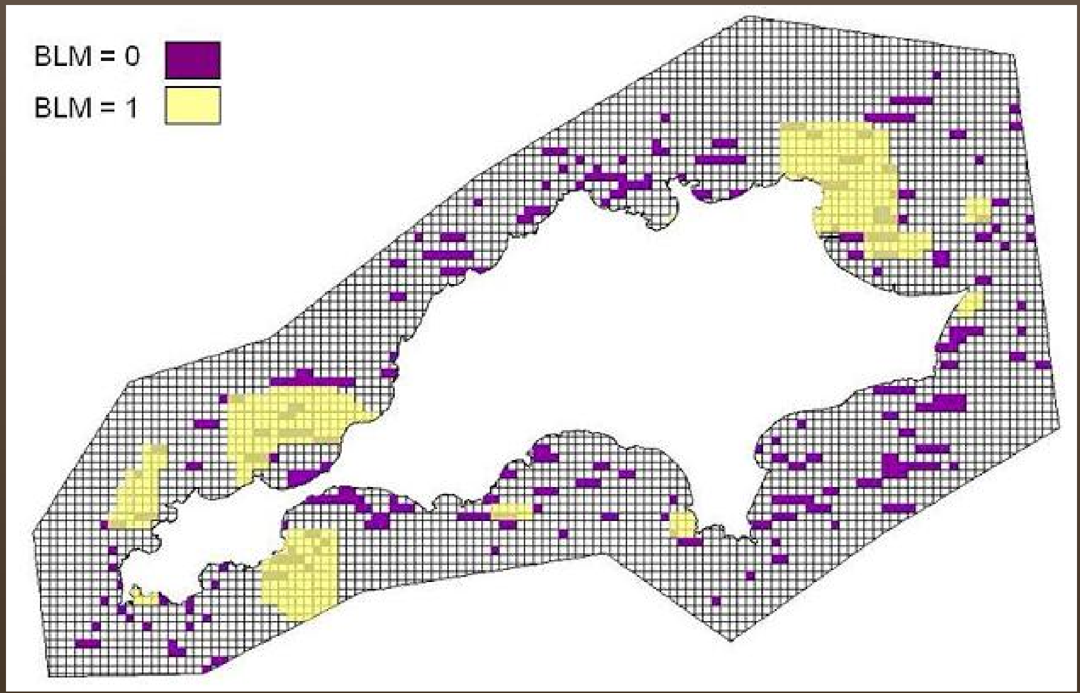
TFMPA (1999) *Understanding and applying the principles of comprehensiveness, adequacy and representativeness for the NRSMPA, Version 3.1*

Efficiency

- Marxan finds solutions to the minimum set problem where the objective is to minimize the cost of the reserve network while meeting all the biodiversity goals
- Factors limiting the efficiency of a reserve
  - The area available for reservation
  - Acquisition costs
  - The costs of ongoing management
  - Opportunity costs

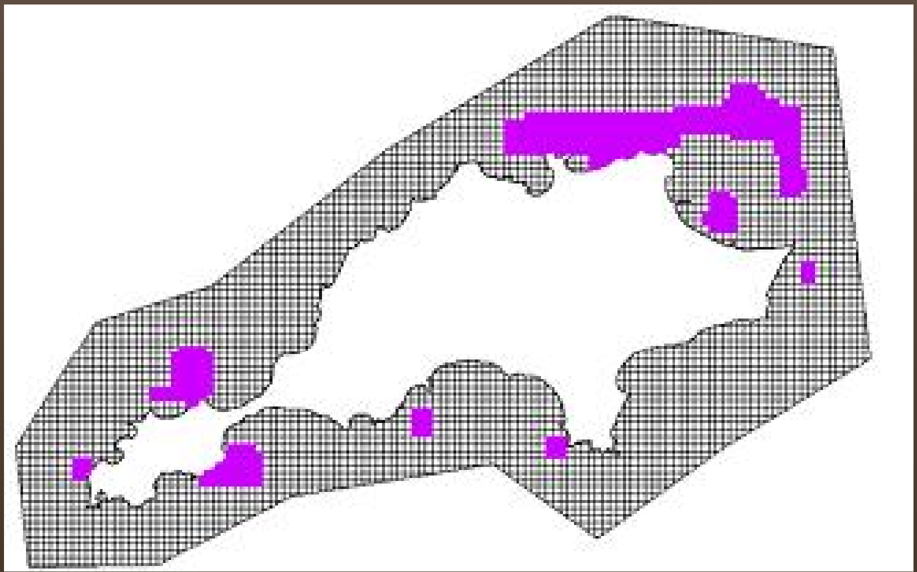
Compactness and/or Connectedness

- A compact reserve system has a low edge-to-area ratio
- Structural Connectivity
- Functional Connectivity



Flexibility

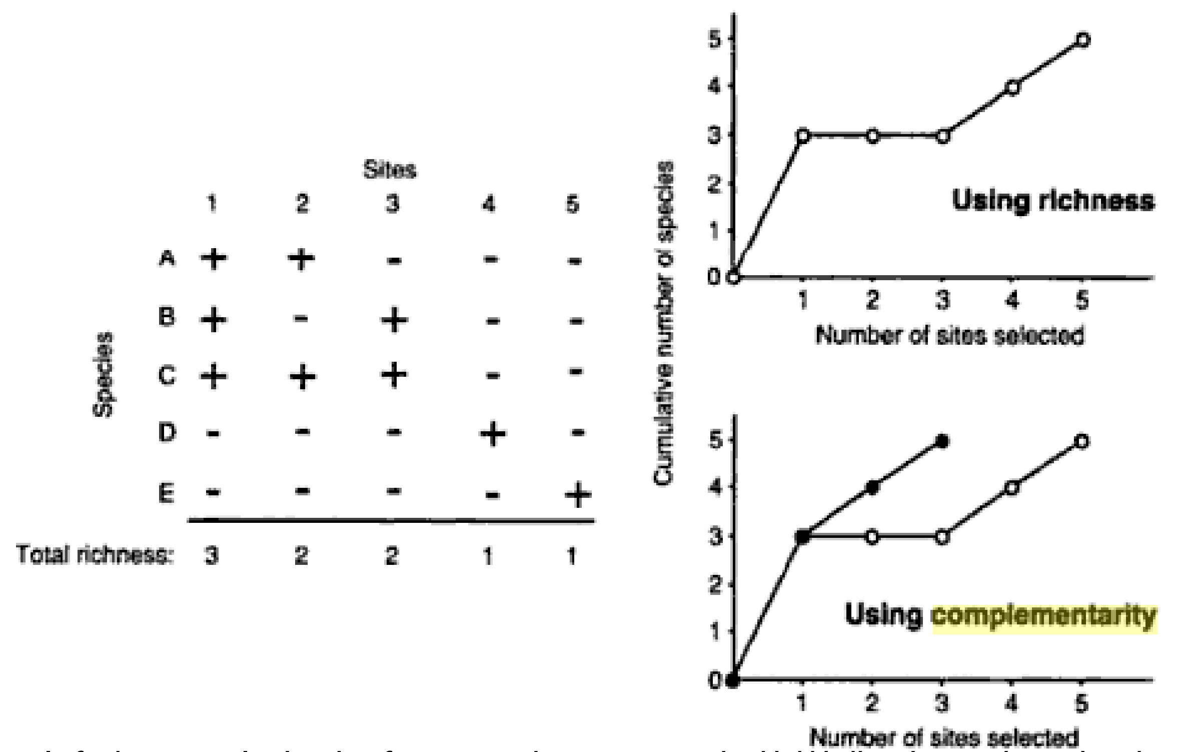
- Options to achieve the conservation objectives in a number of ways



Option 1

Option 2

Complementarity

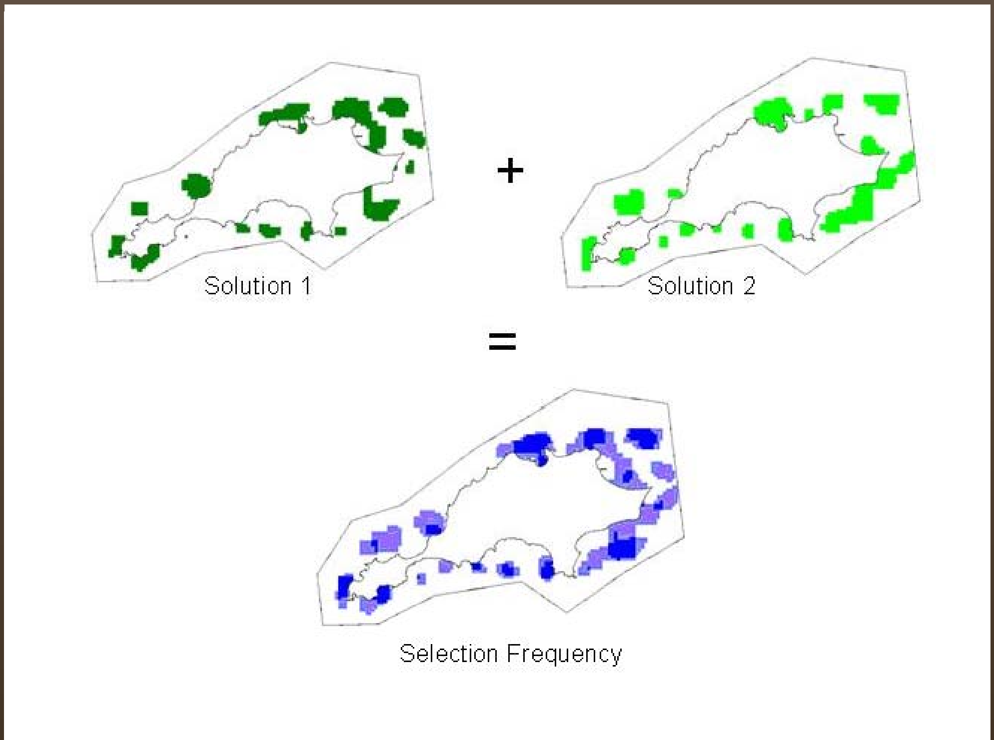


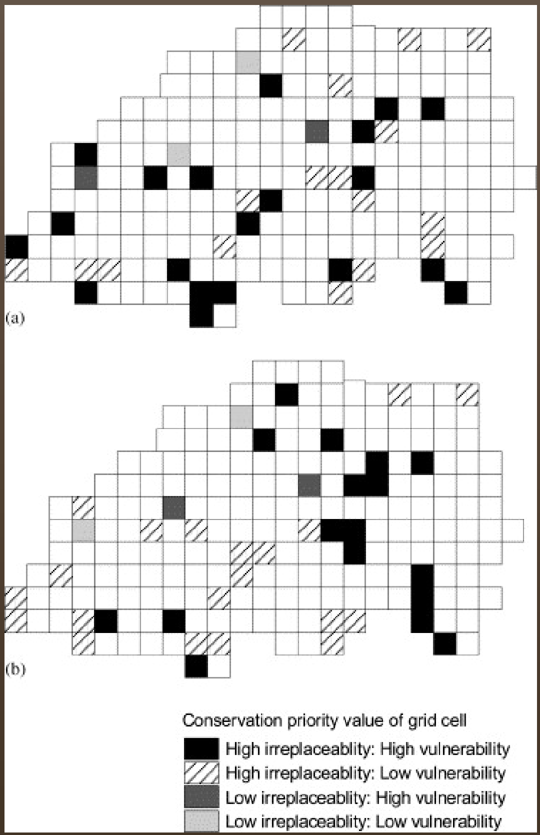
Balmford, 2002, "Selecting sites for conservation", In: *Conserving bird biodiversity*, Norris & Pain, eds.

- Complementarity: the extent to which a reserve advances the goal of representing biodiversity in a network, by contributing unique elements

Selection Frequency as Irreplaceability

- **High irreplaceability = High priority**

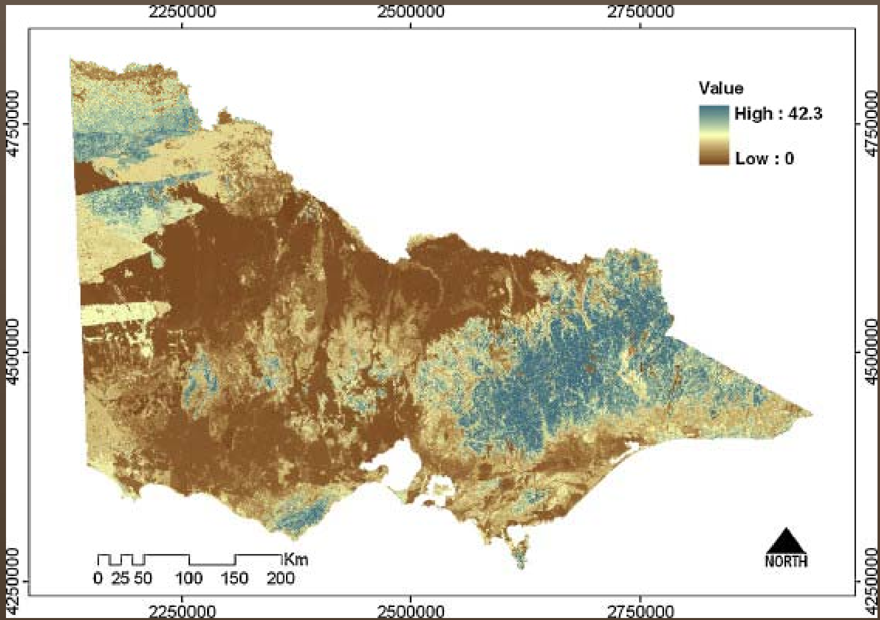




Reyers, 2004.

Adequacy

- The selected reserve system should be adequate to ensure the persistence of all features contained within
  - population viability
  - ecological processes
  - interaction between species, ecosystems, and landscape dynamics
- Adequacy can be addressed in Marxan by
  - Minimum patch area
  - Boundary length modifier
  - Replication and the minimum distance function
  - Planning units can be used to lock in areas that are 100% critical to species persistence and lock out highly threatened areas



Map of adequacy, measured by the proportion of each unique class (combination of environmental variables) that is represented in the reserve system. Sharafi et al. 2012.

Marxan – how it works

- Simulated annealing vs. heuristics (greedy, richness, rarity, etc.)
- Input text files: species, planning units, puvrsp, boundary
- Random seeds
- Sum solutions, best solution
- An absolute optimum is unlikely to be found in a typical planning situation, so the goal is to identify core sites + other opportunities

Marxan – Input files

Marxan

- Planning units
- Features
- Planning unit vs. features
- Boundary (optional)

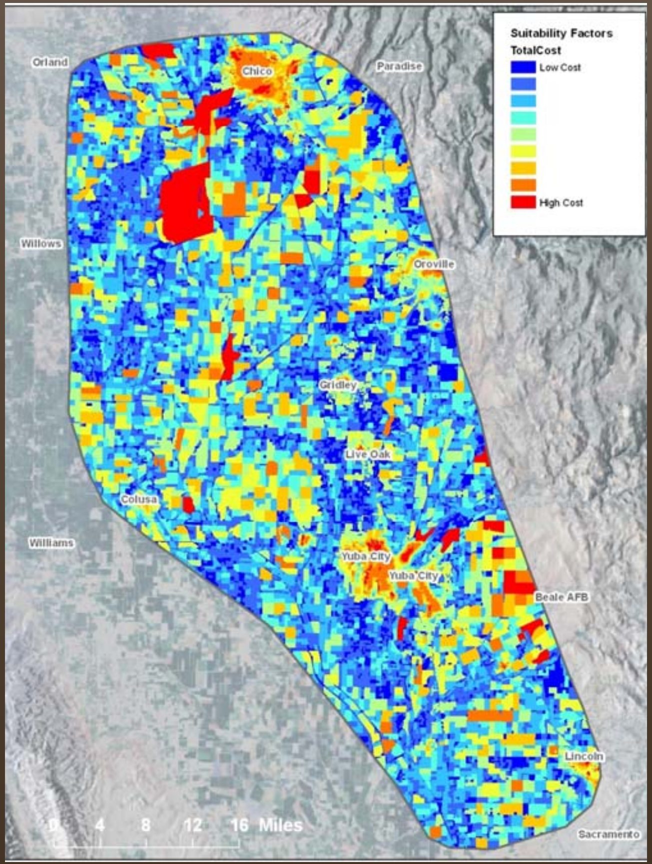
Marxan with Zones

- Planning units
- Features
- Planning unit vs. features
- Zones
- Costs
- Zone cost
- Boundary (optional)

Planning units

Planning units – “cost”

- “Cost”: inverse of “suitability”
- Can be $, does not have to be
- Example:
  - Area
  - Road density
  - Urban density
  - Crop value
  - Urban growth



Features

spec-esf.dat - Notepad

File Edit Format View Help

id	type	target	spf	target2	sepdistance	sepnum	name	targetocc
110	0	2293073.774	1	0	0	0	Saltwater	0
120	0	4609324.004	1	0	0	0	Mudflat	0
130	0	4369162.863	1	0	0	0	Saltmarsh	0
210	0	588148.5387	1	0	0	0	Freshwater	0
220	0	1842347.477	1	0	0	0	Freshwater Wetlands	0
240	0	2196362.067	1	0	0	0	Riparian	0

Planning unit vs. features

puvsp_ag.dat - Notepad

File Edit Format View Help

```
amount,species,pu
1,312,1
2089,400,1
2495,400,2
1064,312,3
1646,333,4
6398,312,4
14788,331,4
73,400,5
346,331,5
6639,312,5
13632,332,5
1729,312,6
7725,331,6
5673,333,7
```

312 = grassland
331 = oak woodland
333 = eucalyptus
400 = disturbed

Boundary

bound.dat - Notepad

File Edit Format View Help

id1	id2	boundary
1	392	17
1	411	40
1	421	61
1	425	65
2	366	44
2	439	44
2	440	56
2	445	55
3	3	64
3	27	28
3	28	50
4	7	300
4	81	66
4	125	119
4	134	229
4	156	6
4	158	64

Example: Conservation Project

- The planning area contains several conservation features - fish, butterflies, and rodents.
- Each planning unit has a cost of 1.
- The boundary length modifier (BLM) has been set at 1.5.
- The species penalty factor (SPF) for all three conservation features is 10.
- The target is to have at least one occurrence of each conservation feature in the solution.

PU cost = 1
BLM = 1.5
SPF = 10 (all features)

Target: represent each feature at least once.

Example: Conservation Project

Score =

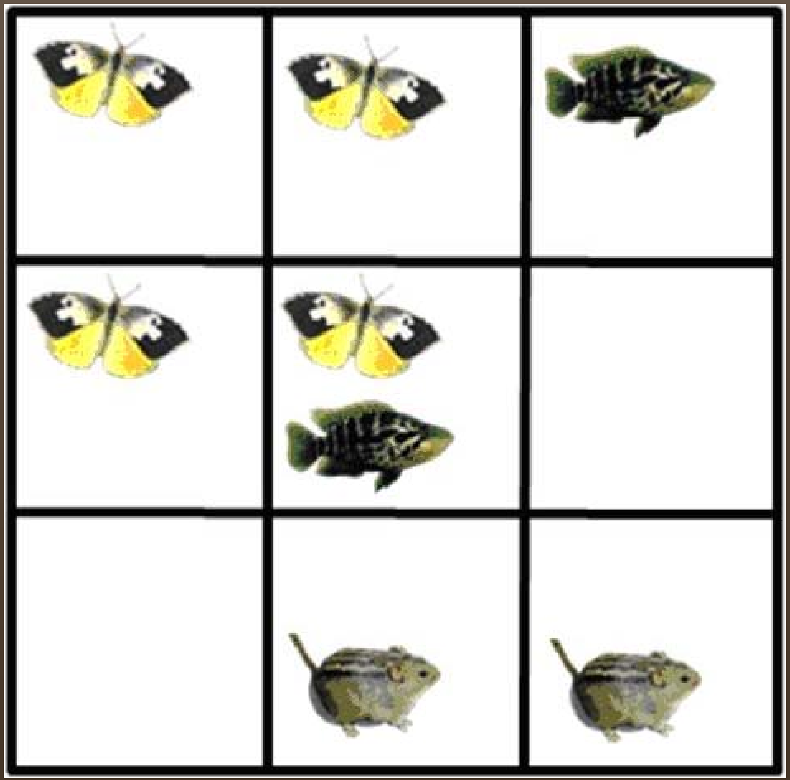
Cost of the reserve system

+

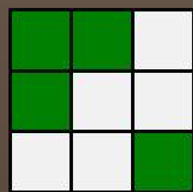
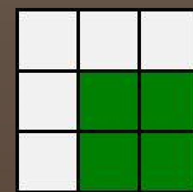
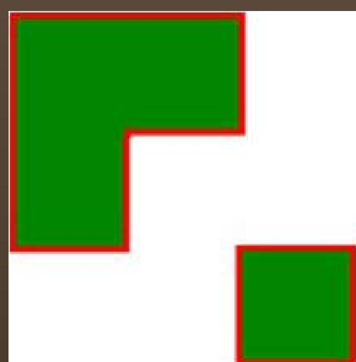
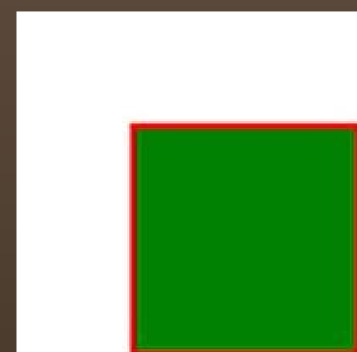
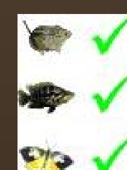
Boundary length of the reserve system

+

Penalty incurred for unmet targets



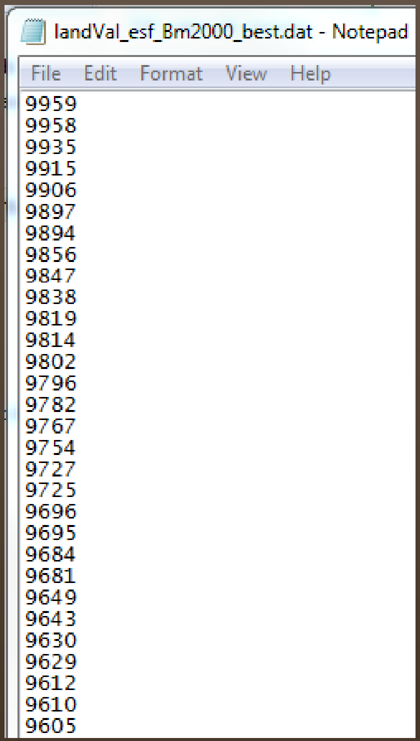
Example: Conservation Project

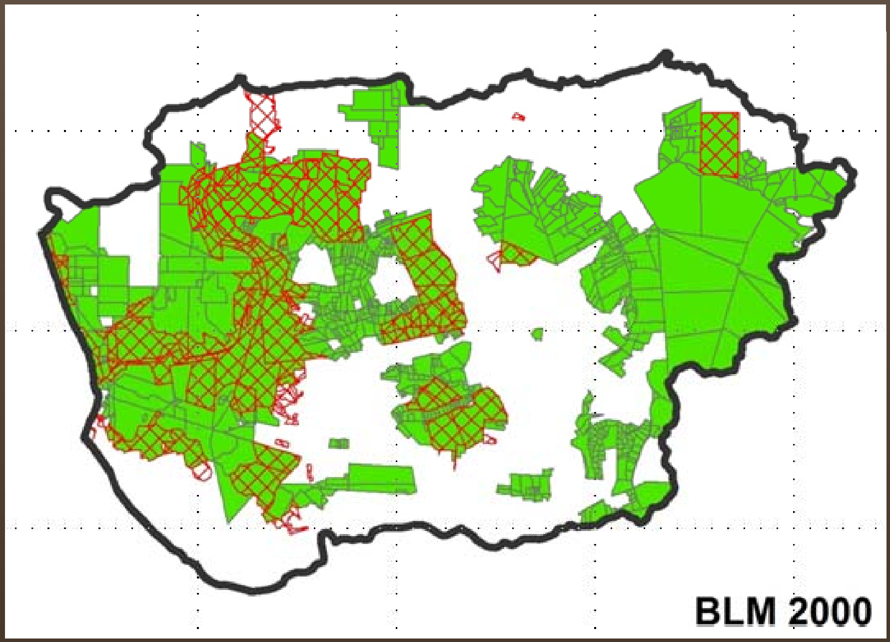
Solution 1				Solution 2
4		Total PU Cost		4
12*1.5		BLM		8*1.5
10		SPF		0

Total = 4+(12*1.5)+10 = 32

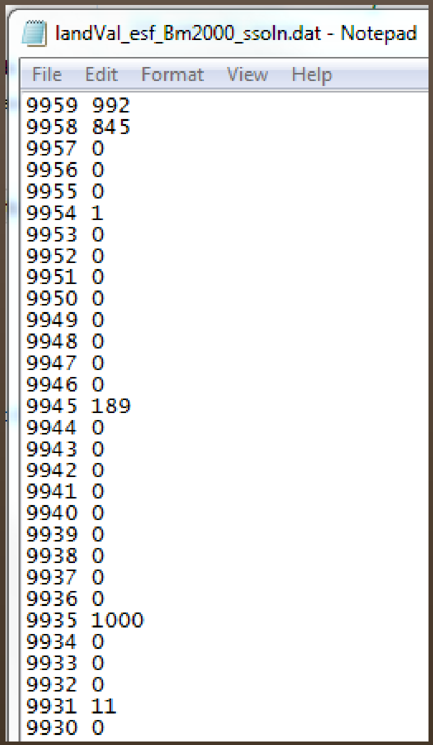
Total = 4+(8*1.5)+0 = 16

Outputs – best solution (output_best.txt)





Outputs – summed solution (output_ssoln.txt)


landVal_esf_Bm2000_ssoln.dat - Notepad

File Edit Format View Help

9959 992
9958 845
9957 0
9956 0
9955 0
9954 1
9953 0
9952 0
9951 0
9950 0
9949 0
9948 0
9947 0
9946 0
9945 189
9944 0
9943 0
9942 0
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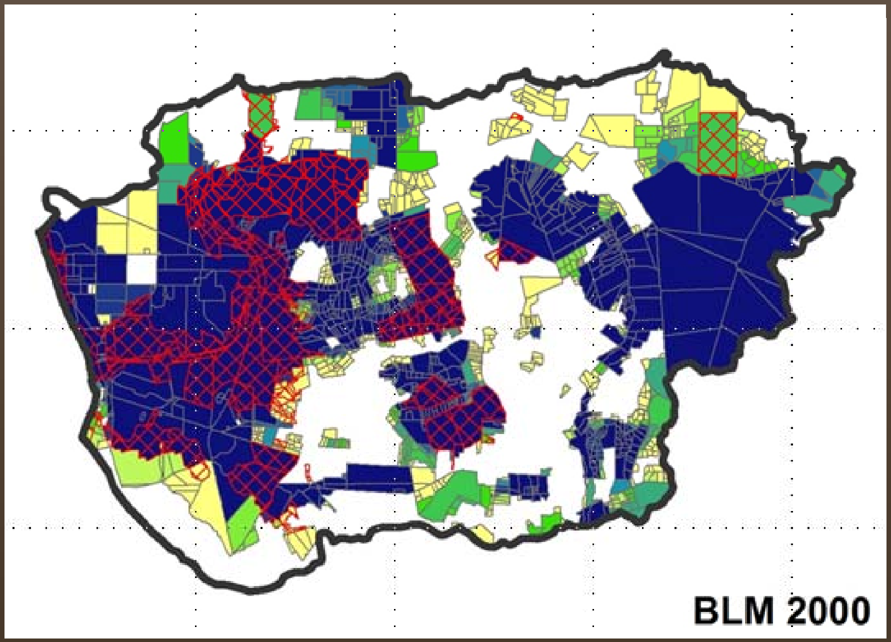
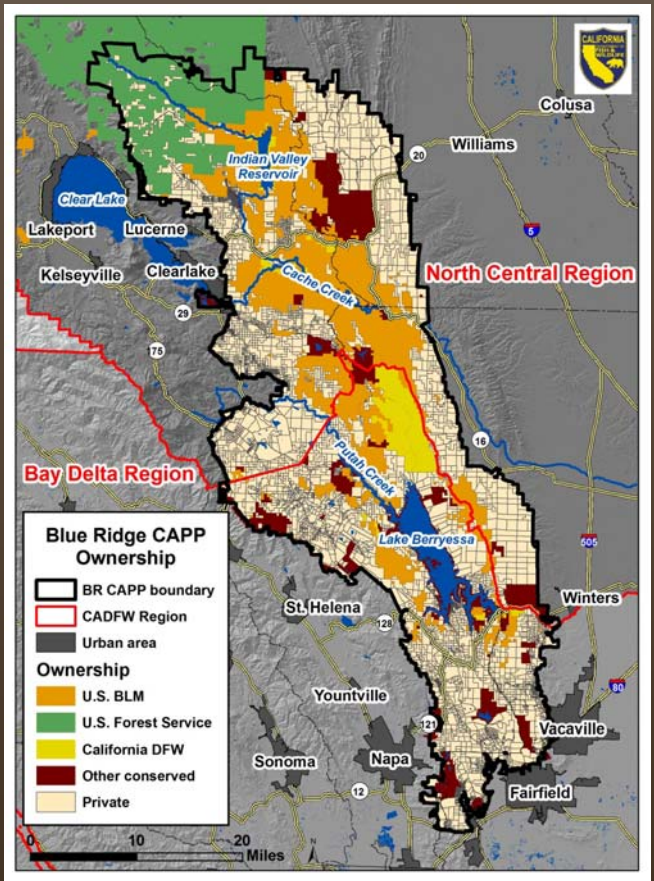
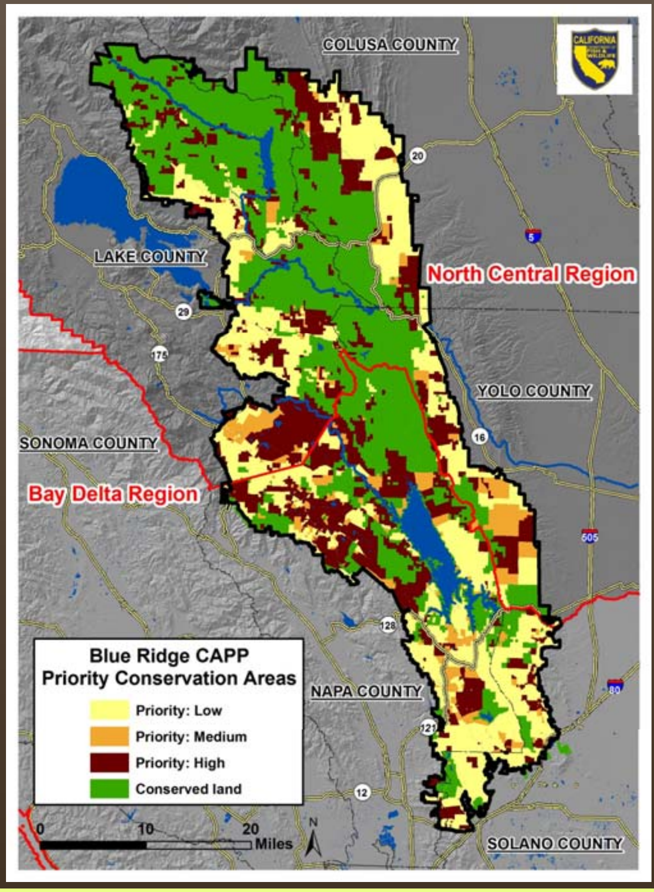
9933 0
9932 0
9931 11
9930 0



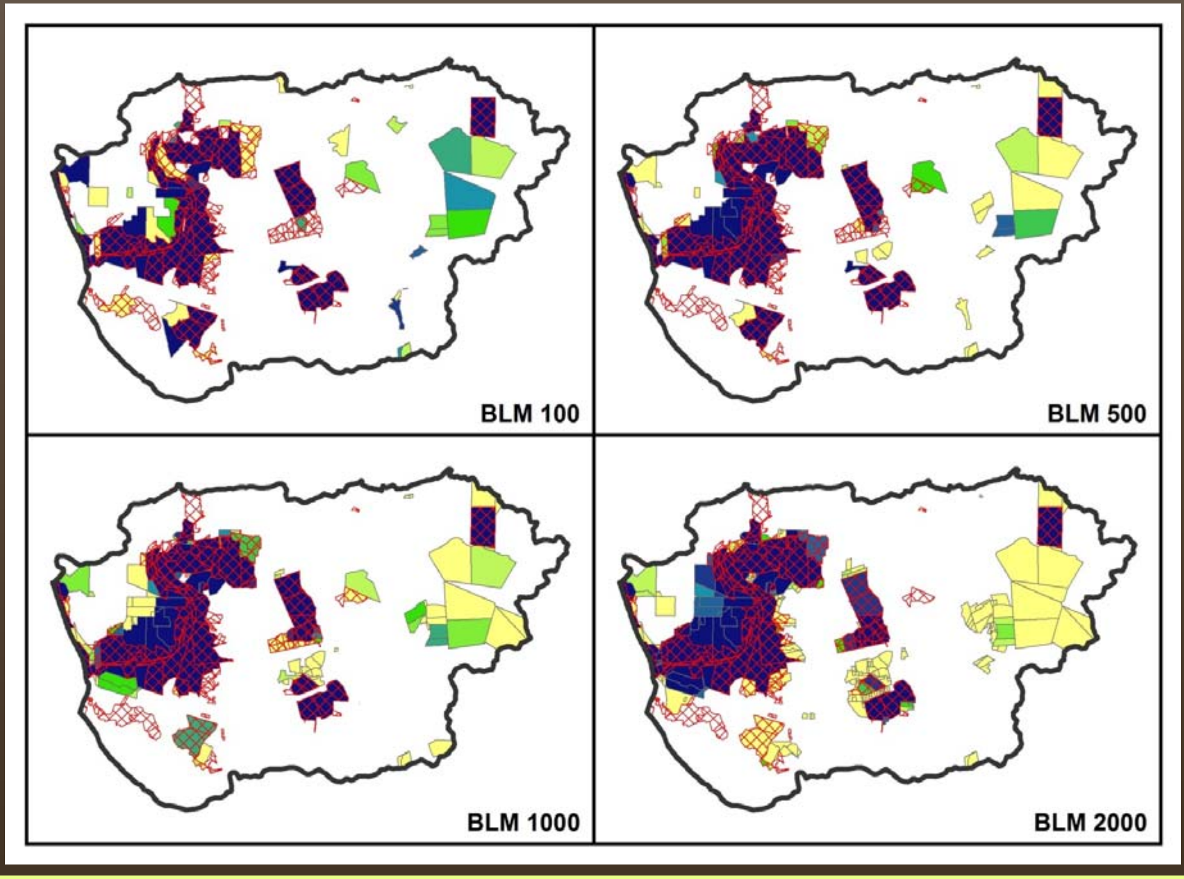
Marxan uses – select new reserves



- •BRBNA Conservation Partnership
- Consortium of land trusts, agencies, other organizations
- 5 counties
- Establish a CAPP
- Address multiple conservation objectives

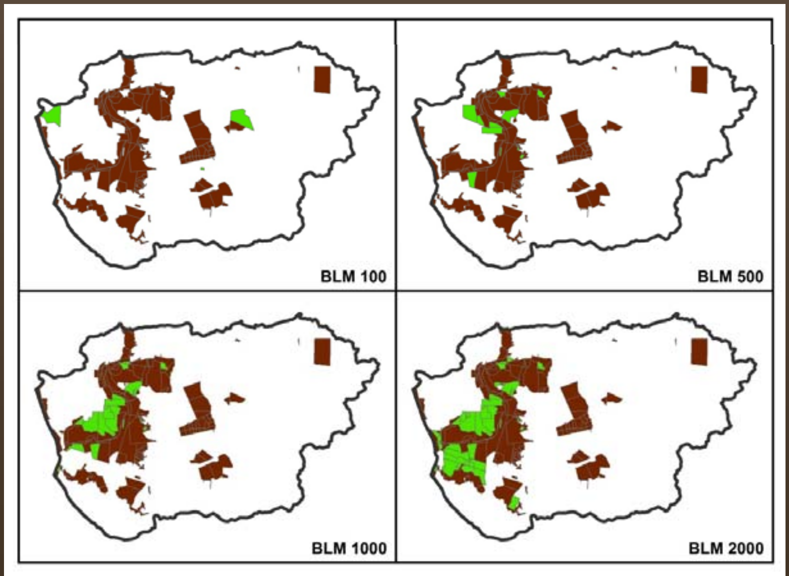


Marxan uses – current reserve assessment



Marxan uses – compensatory mitigation

Habitat	Ratio	San Juan	Hwy. 156	Scenic Trail	Artichoke Ave.	G12	Total (acres)
		Projects					
Freshwater	3:1	1.139	0.406	*2.084 (mit)*		0.21	7.349
Wetlands	3:1	0.164	1.824		*4.0 (mit)*	0.83	12.454
Riparian	3:1	0.905	3.23			1.97	18.315
Maritime Chaparral	5:1		0.16			0.77	4.65
Oak Woodland	5:1	0.204	17.348			6.52	120.36
Grasslands	1:1	14.528	18.824			20.08	53.432
Agriculture	1:1	0.205	165.0		9.0	6.12	180.325
Eucalyptus	1:1			1.08			1.08



Marxan uses – non-spatial examples

Sustainability indicator selection

- Planning units = indicators
- Species = sustainability issues
- No boundary

```
"id","type","target","spf","target2","targetocc","name"
1,0,1,1,0,0,"Land &amp; Soil",0,0
2,0,1,1,0,0,"Agricultural Productivity",0,0
3,0,1,1,0,0,"Agrobiodiversity",0,0
4,0,1,1,0,0,"Carbon Sequestration",0,0
5,0,1,1,0,0,"Cropping Systems",0,0
6,0,1,1,0,0,"Crop Yield",0,0
7,0,1,1,0,0,"Desertification",0,0
8,0,1,1,0,0,"Disasters - Environmental Impact",0,0
9,0,1,1,0,0,"Ecosystem Health",0,0
```

Plant palette selection

- Planning units = plant species
- Species = plant characteristics
- No boundary

```
id,type,target,spf,target2,sepdistance
260,0,13,1,0,0,0,"natbeepoll",0
270,0,3,1,0,0,0,"natbeenest",0
280,0,6,1,0,0,0,"bumble",0
290,0,4,1,0,0,0,"honey",0
300,0,5,1,0,0,0,"predatory",0
310,0,15,1,0,0,0,"butterfly",0
320,0,1,1,0,0,0,"AdeBre_host",0
325,0,1,1,0,0,0,"AtaCam_host",0
328,0,1,1,0,0,0,"AtaCam_nectar",0
330,0,1,1,0,0,0,"AtlHal_nectar",0
340,0,1,1,0,0,0,"BatPhi_host",0
345,0,1,1,0,0,0,"BatPhi_nectar",0
```

Marxan and climate change – examples

Approach #1

- Time as additional dimension
- Multiple planning units in each location
- Adjacency through time and space

Approach #2

- Land facets
- Physical characteristics (topography, etc.)
- "Preserving the stage"
- Ensure representation of physical types

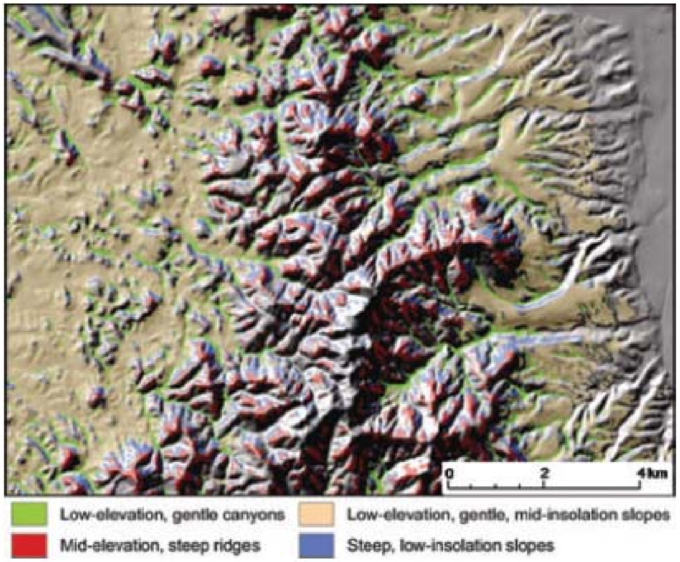


Figure 2. Illustration of the geographic distribution of land facets, defined on the basis of elevation, slope, insolation, and topographic position, draped over a hillshade map. For clarity, not all land facets in the landscape are shown.

(Beier & Brost 2010)