prioritizr

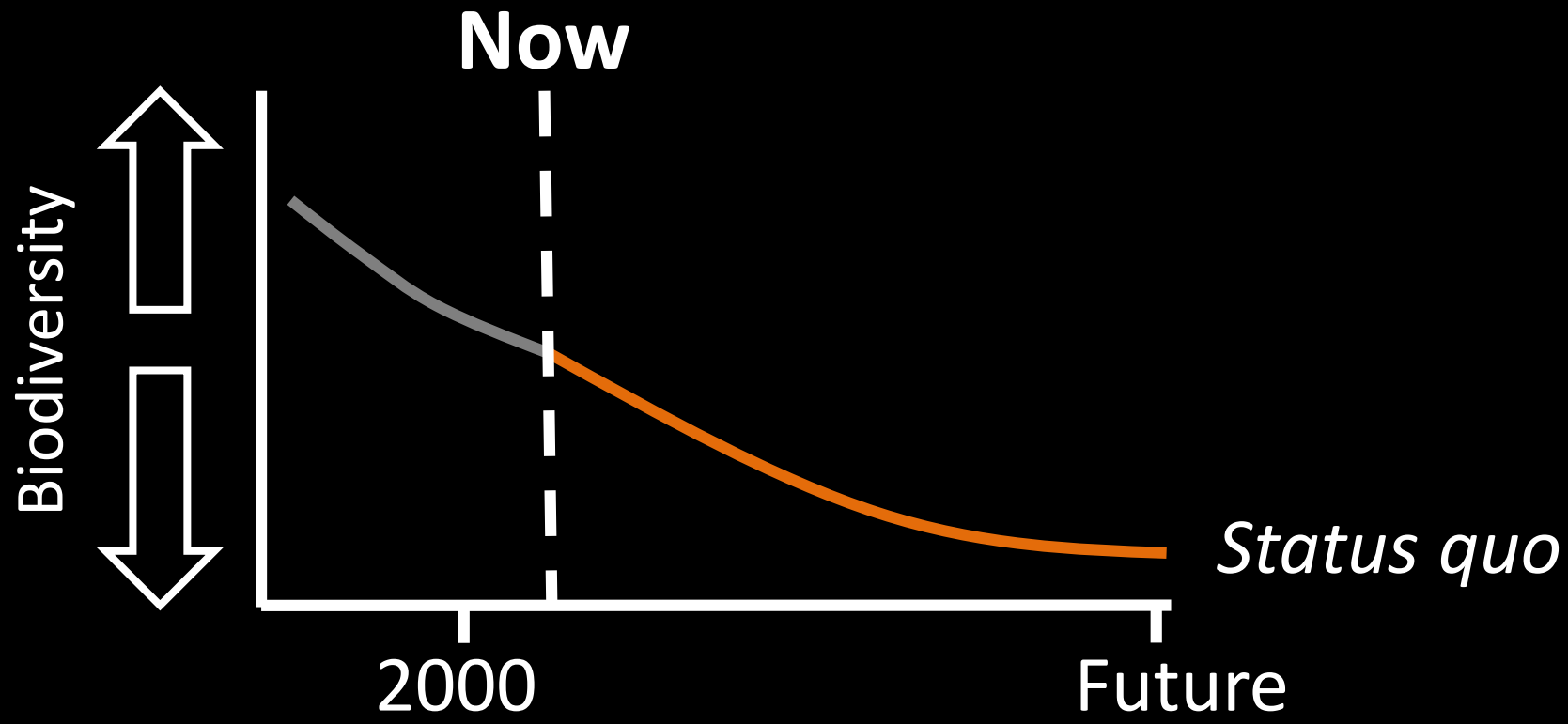
Systematic conservation planning in R

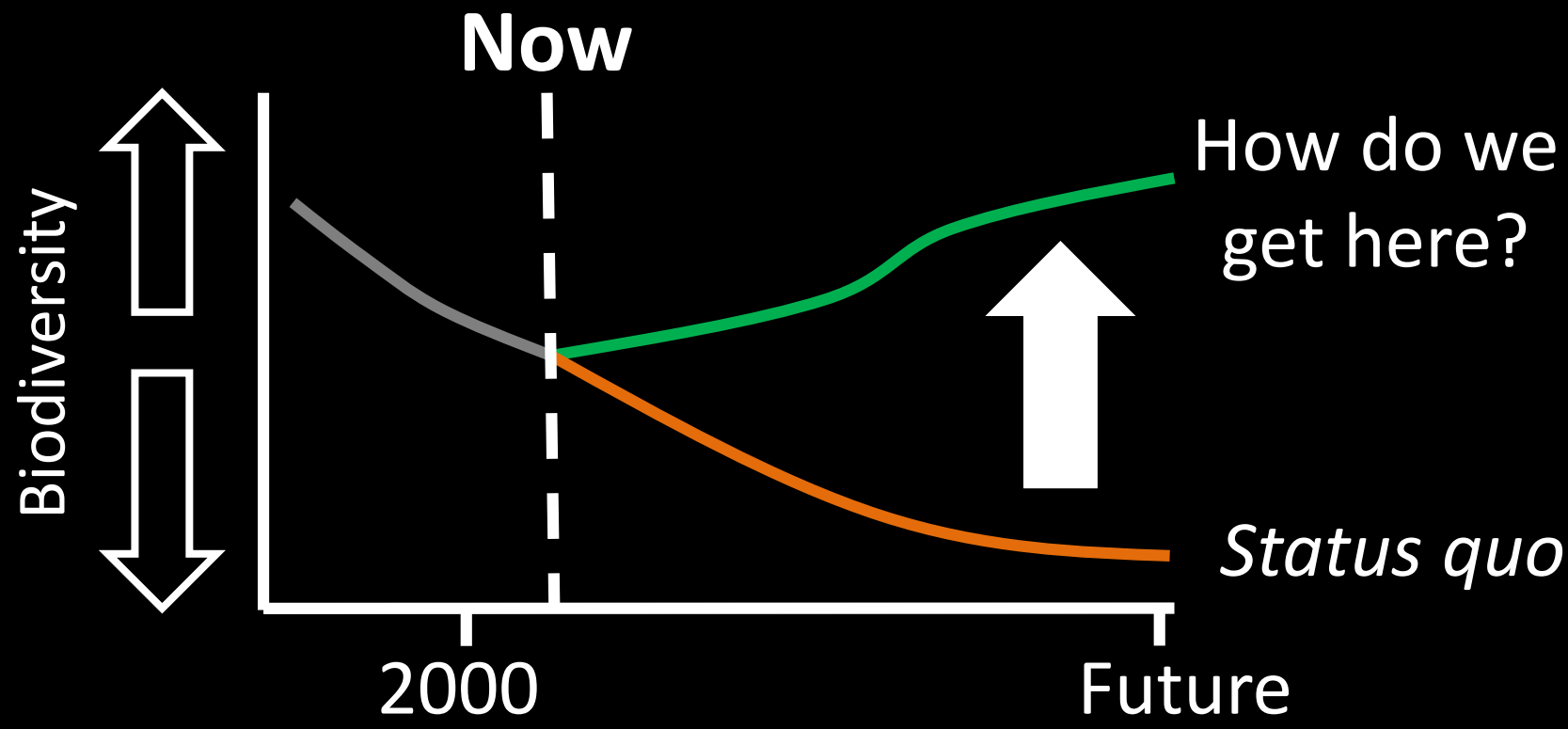
Session 1

Jeffrey Hanson

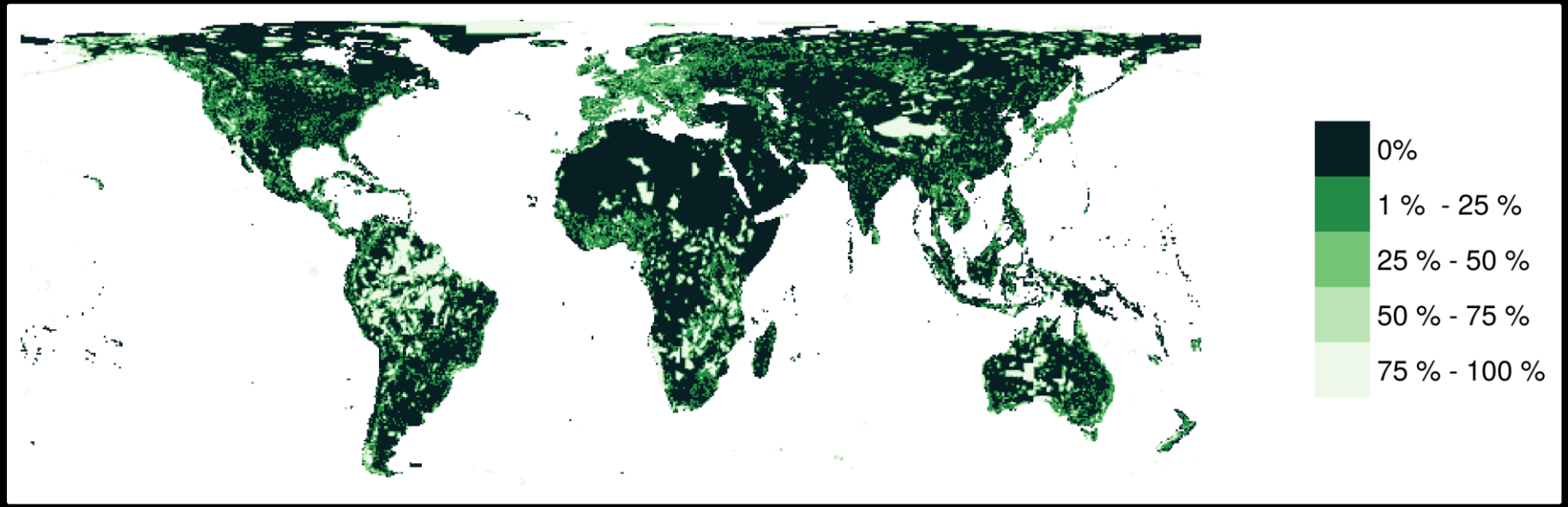
jeffrey.hanson@uqconnect.edu.au

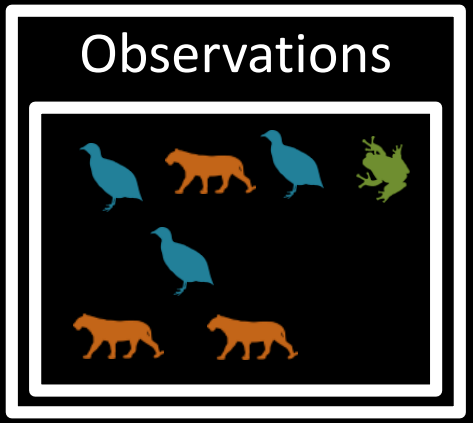
prioritizr.net

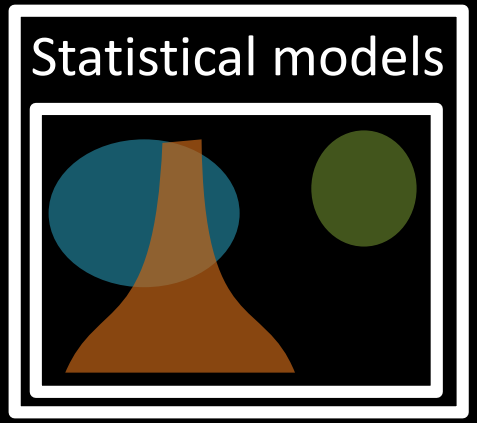

Now
Biodiversity
Status quo
2000
Future

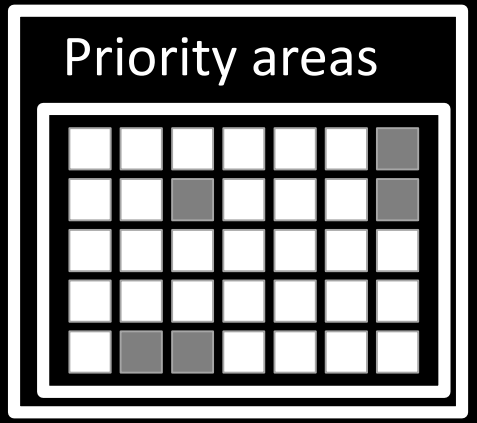

Now
Biodiversity
How do we get here?
Status quo
2000
Future

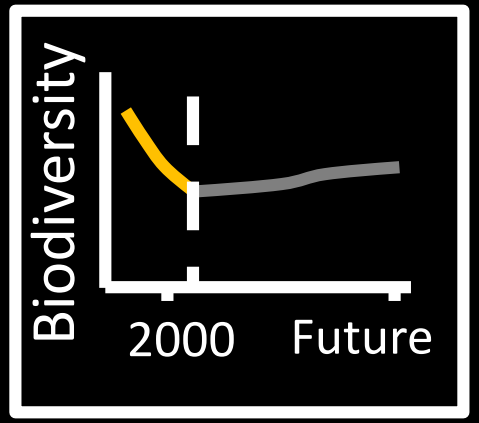
Protected areas





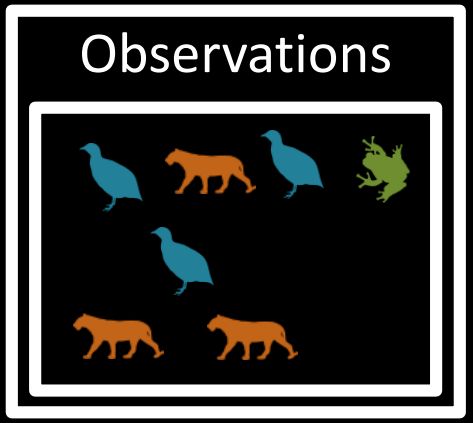


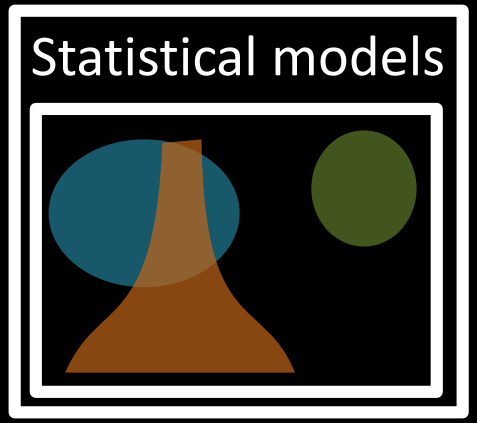


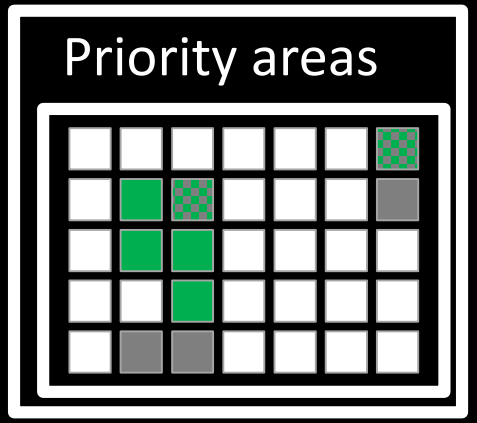


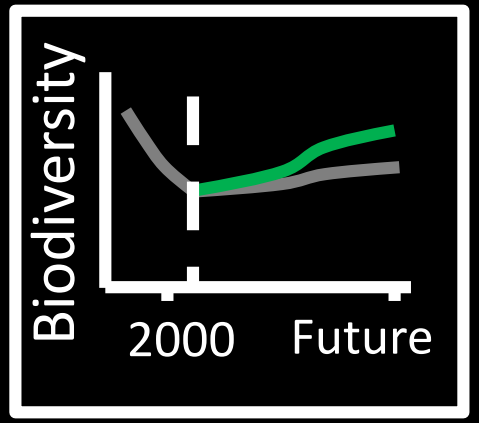
Data → Information → Plan → Outcome

Objectives Constraints









Data → Information → **Plan** → Outcome

Better plan

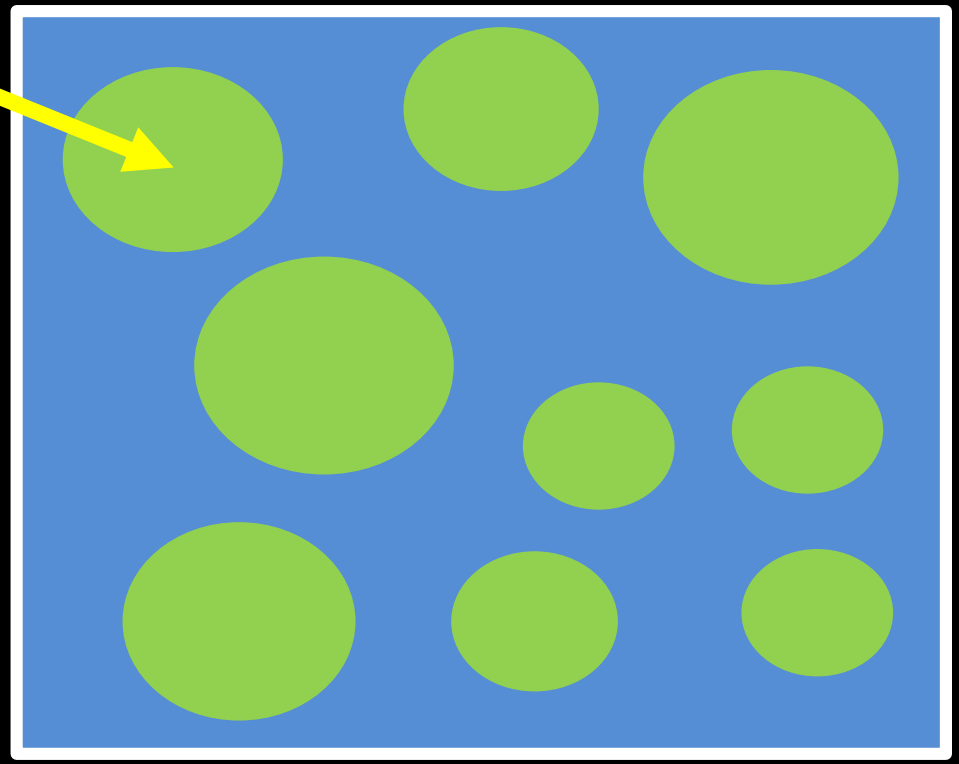
Better outcome

Objectives Constraints

Reserve selection

Planning units

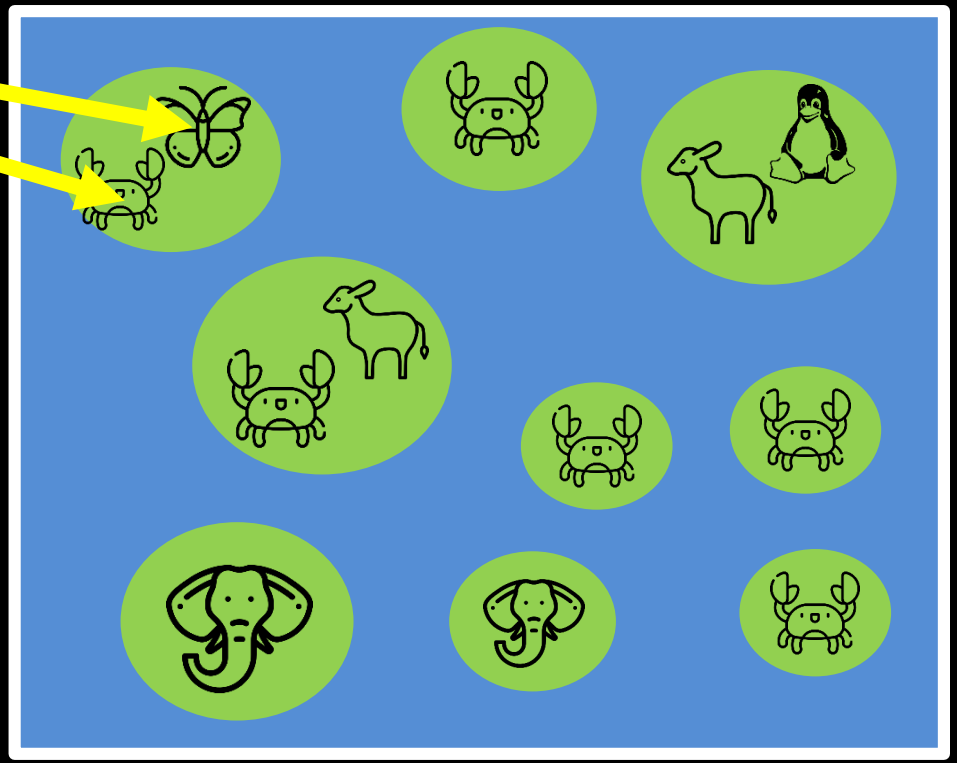
- Discrete places for conservation management
- Each planning unit is managed separately
- Commonly include land parcels, islands, spatial grid cells



Reserve selection

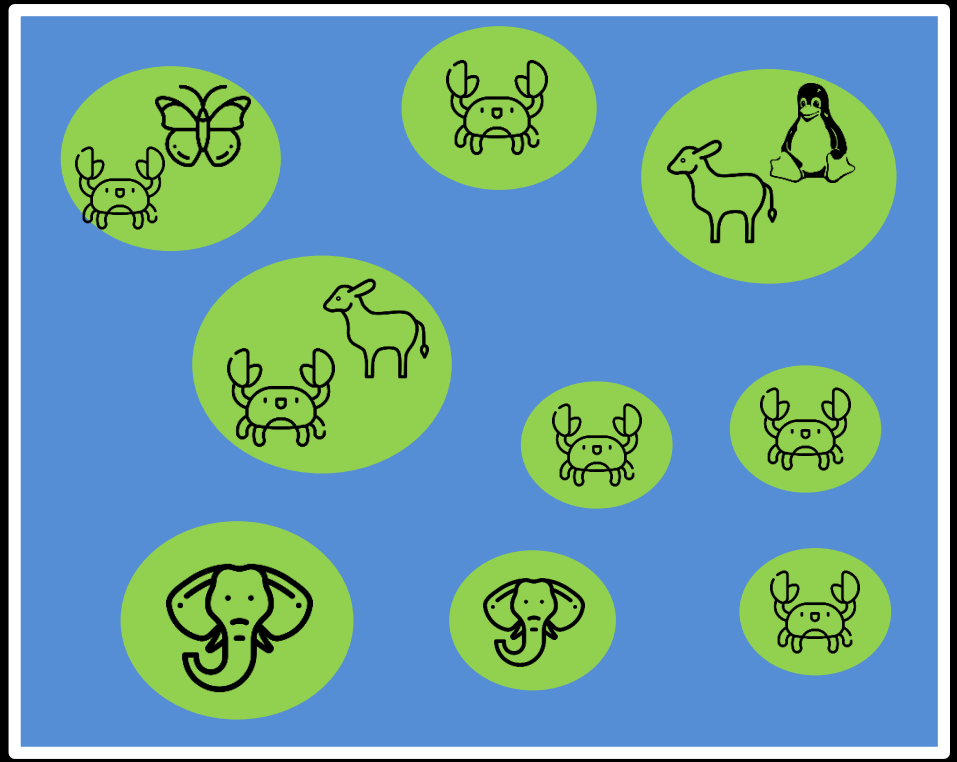
Features

- Stuff that we care about
- Each feature is relatively independent
- Commonly include species, ecosystem types, ecosystem services (e.g., water provisioning, carbon sequestration)



Reserve selection

Which planning units should we manage for conservation?



CARE Principles

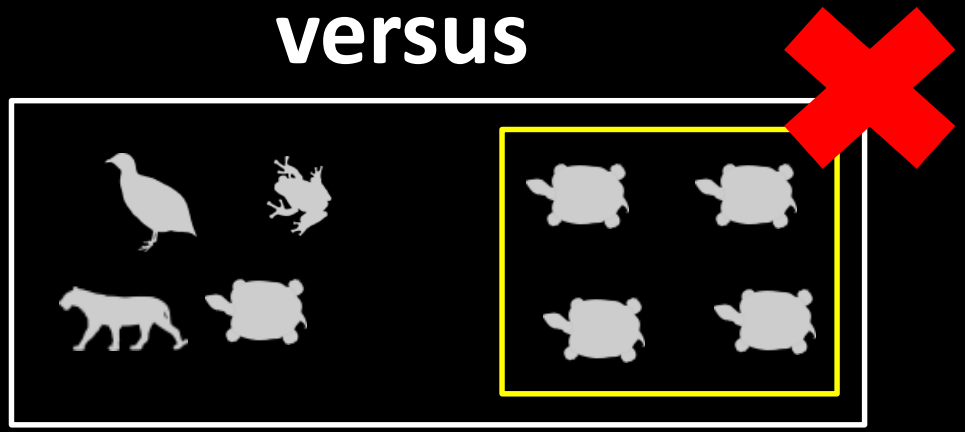
- Comprehensive
- Adequate
- Representative
- Efficient

Kukkala & Moilanen (2013) DOI:10.1111/brv.12008

CARE Principles

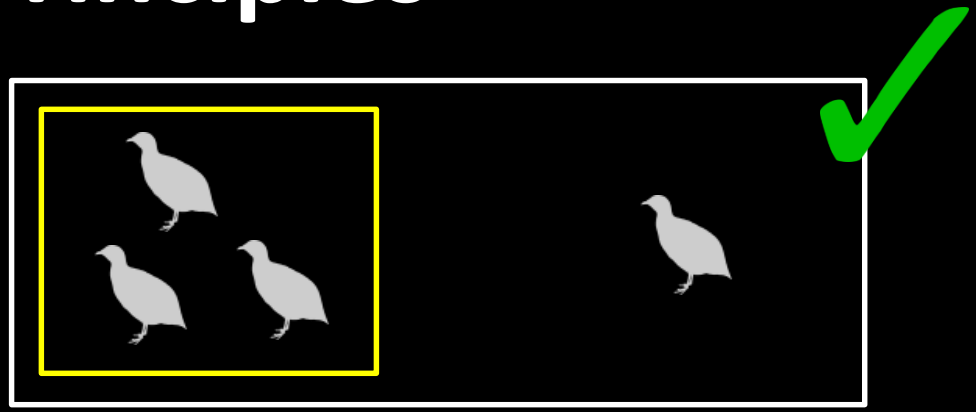
- **Comprehensive**
- Adequate
- Representative
- Efficient

versus

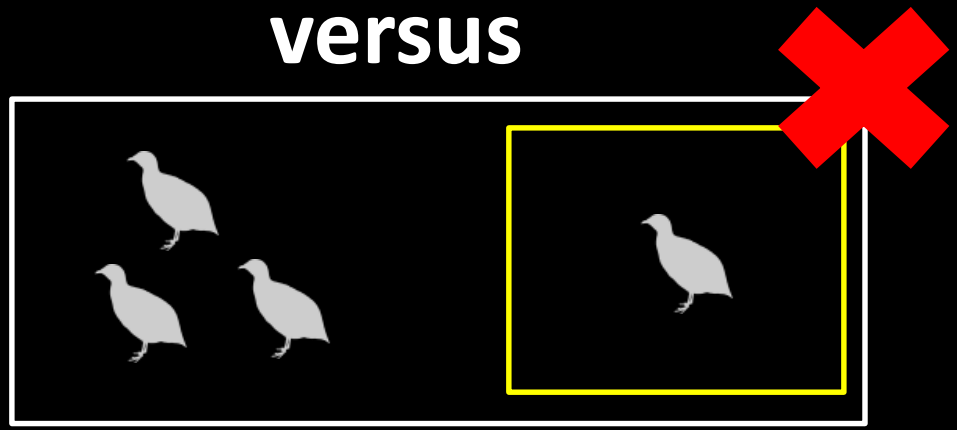


CARE Principles

- Comprehensive
- **Adequate**
- Representative
- Efficient



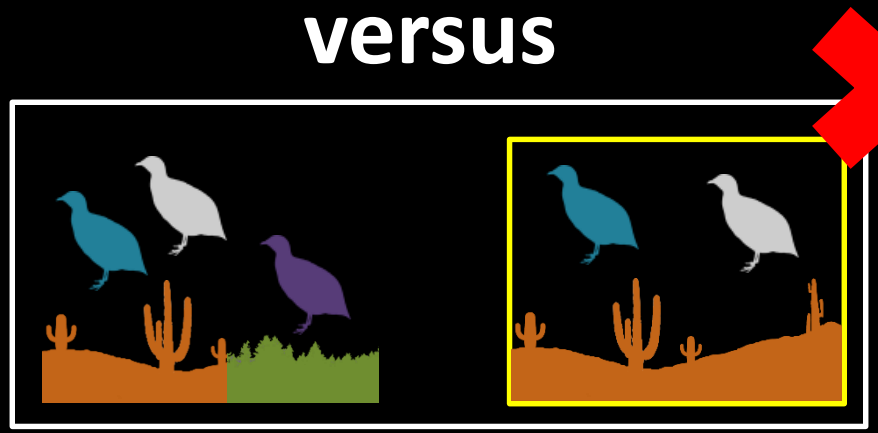
versus



CARE Principles

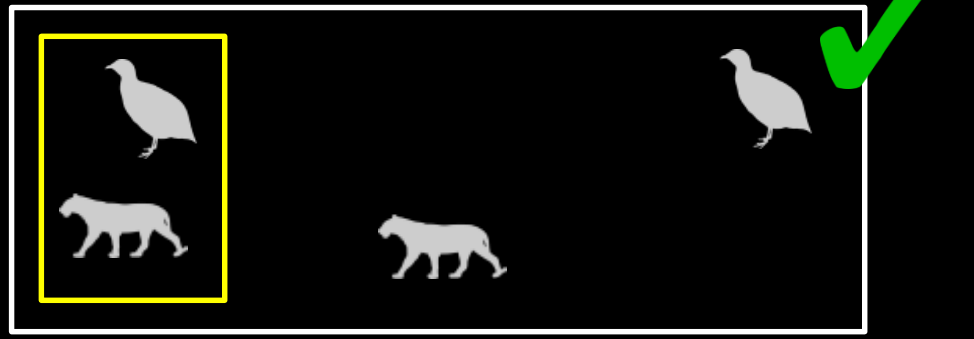
- Comprehensive
- Adequate
- **Representative**
- Efficient

versus

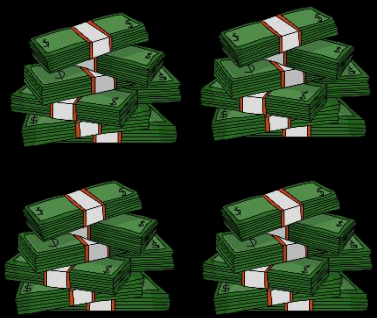


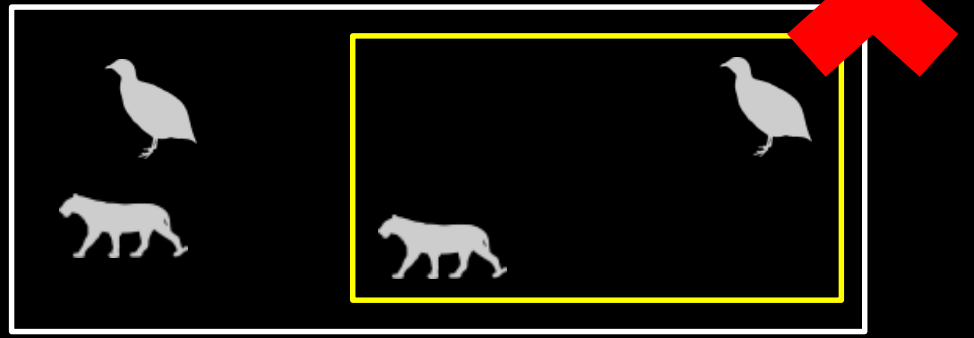
CARE Principles

- Comprehensive
- Adequate
- Representative
- **Efficient**



versus

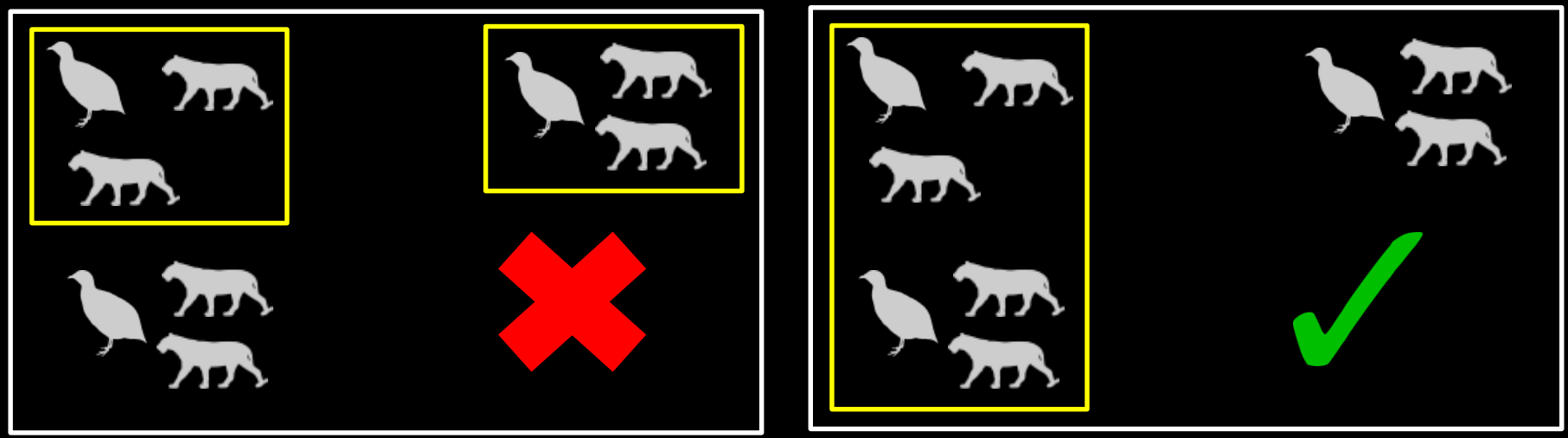




Connectivity

"improve population resilience to disturbance, increase metapopulation viability, promote genetic diversity and maintain energetic pathways among ecosystems"

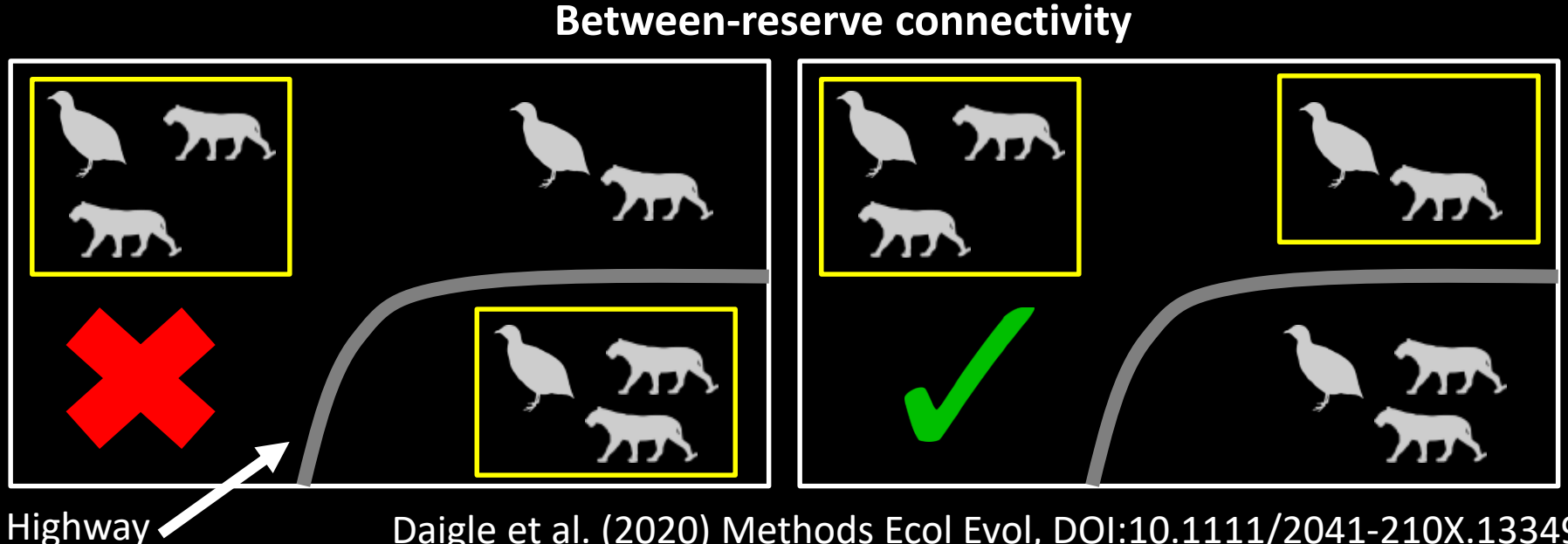
Within-reserve connectivity



Daigle et al. (2020) Methods Ecol Evol, DOI:10.1111/2041-210X.13349

Connectivity

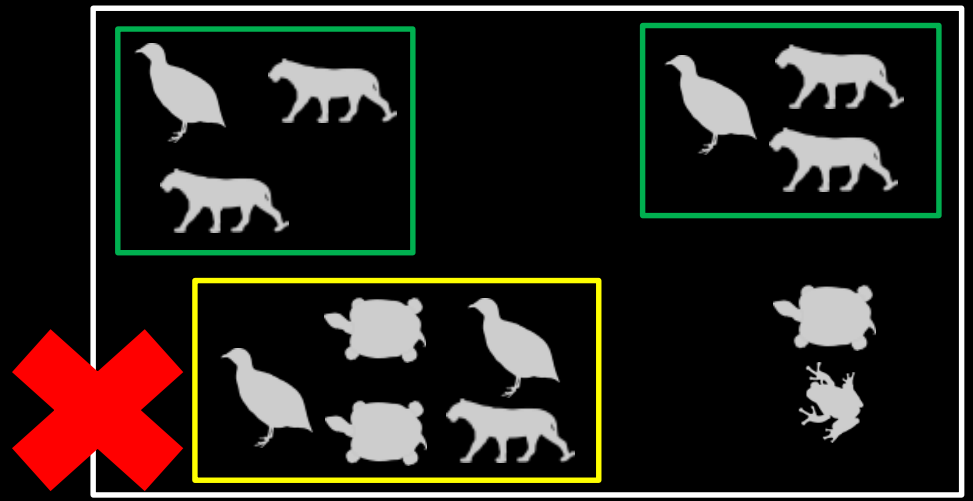
"improve population resilience to disturbance, increase metapopulation viability, promote genetic diversity and maintain energetic pathways among ecosystems"

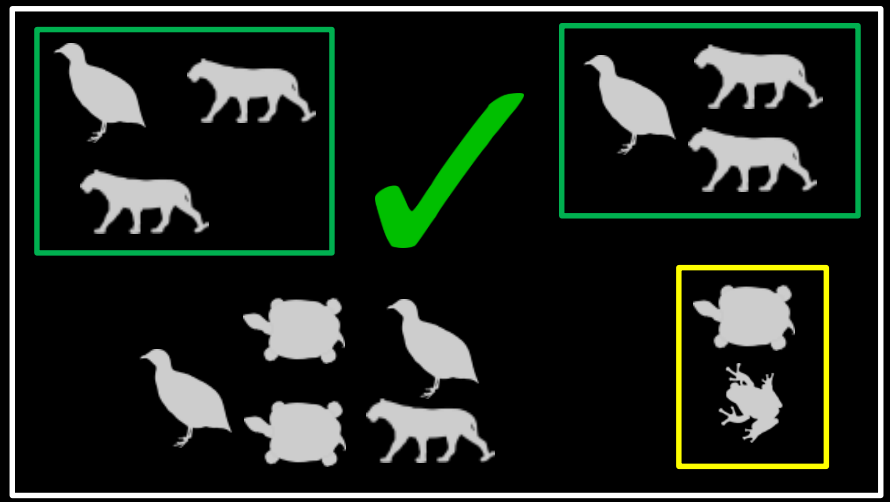


Daigle et al. (2020) Methods Ecol Evol, DOI:10.1111/2041-210X.13349

Principle complementarity

Protected areas should “complement” each other to maximize the performance of the overall protected area network (including. existing protected areas)

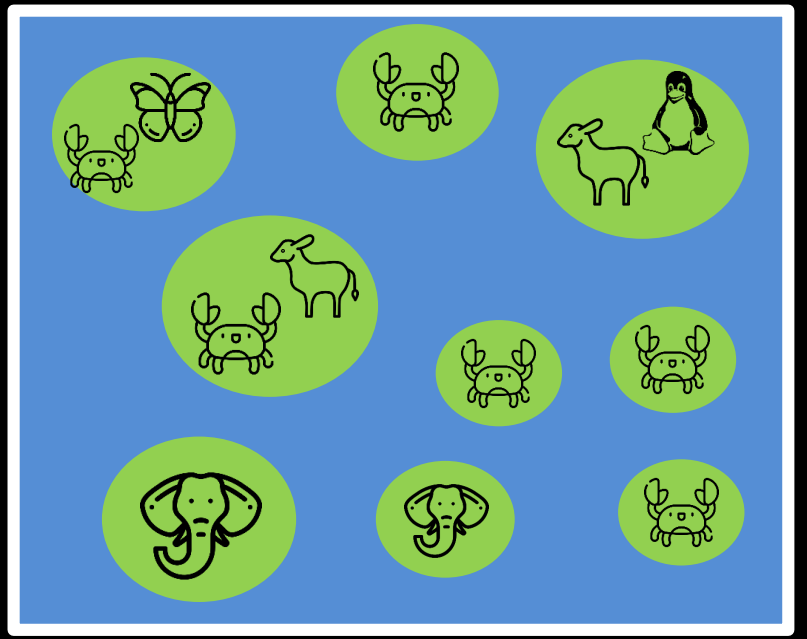




Vane-Wright, et al (1991) Biol Cons, DOI: 10.1016/0006-3207(91)90030-D

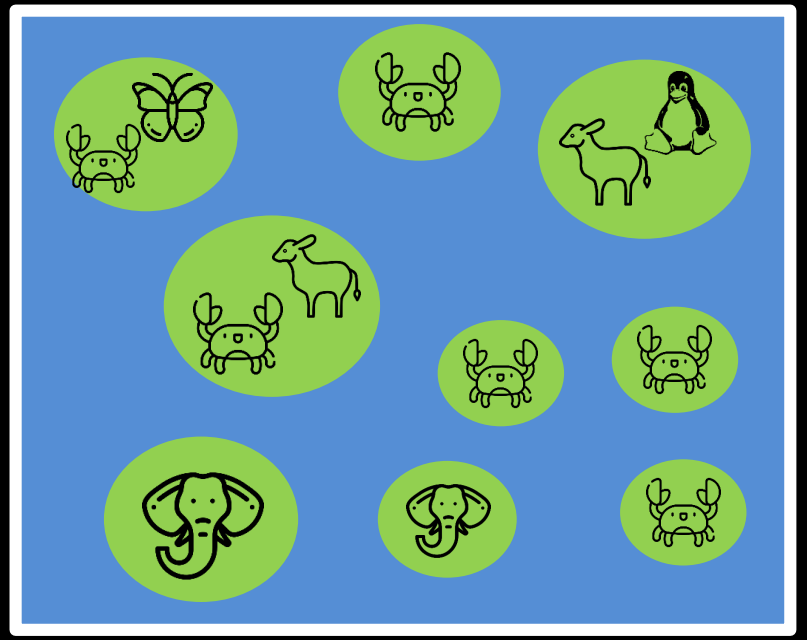
Reserve selection as optimization

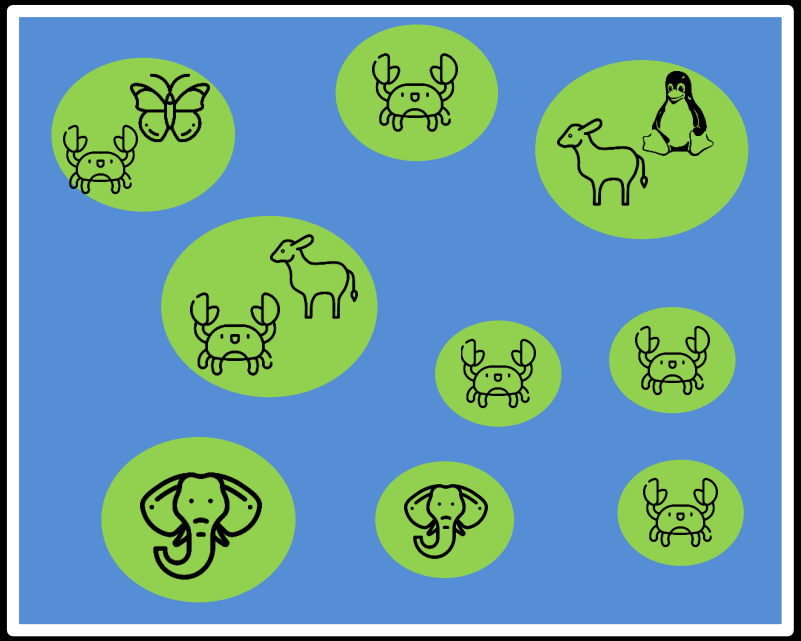
- Objective: what do we want to maximize or minimize?
- Constraints: what does the prioritization have to do?
- Decisions: what will we do to each planning unit?

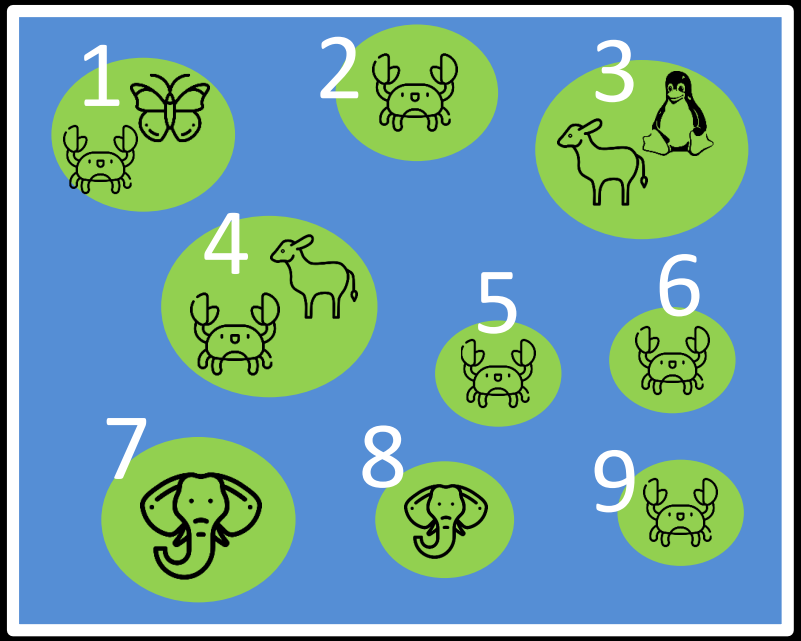


Minimum set formulation

- Objective: min. # of islands
- Constraints: ensure adequate coverage of each and every species
- Decisions: create a reserve on an island or not?



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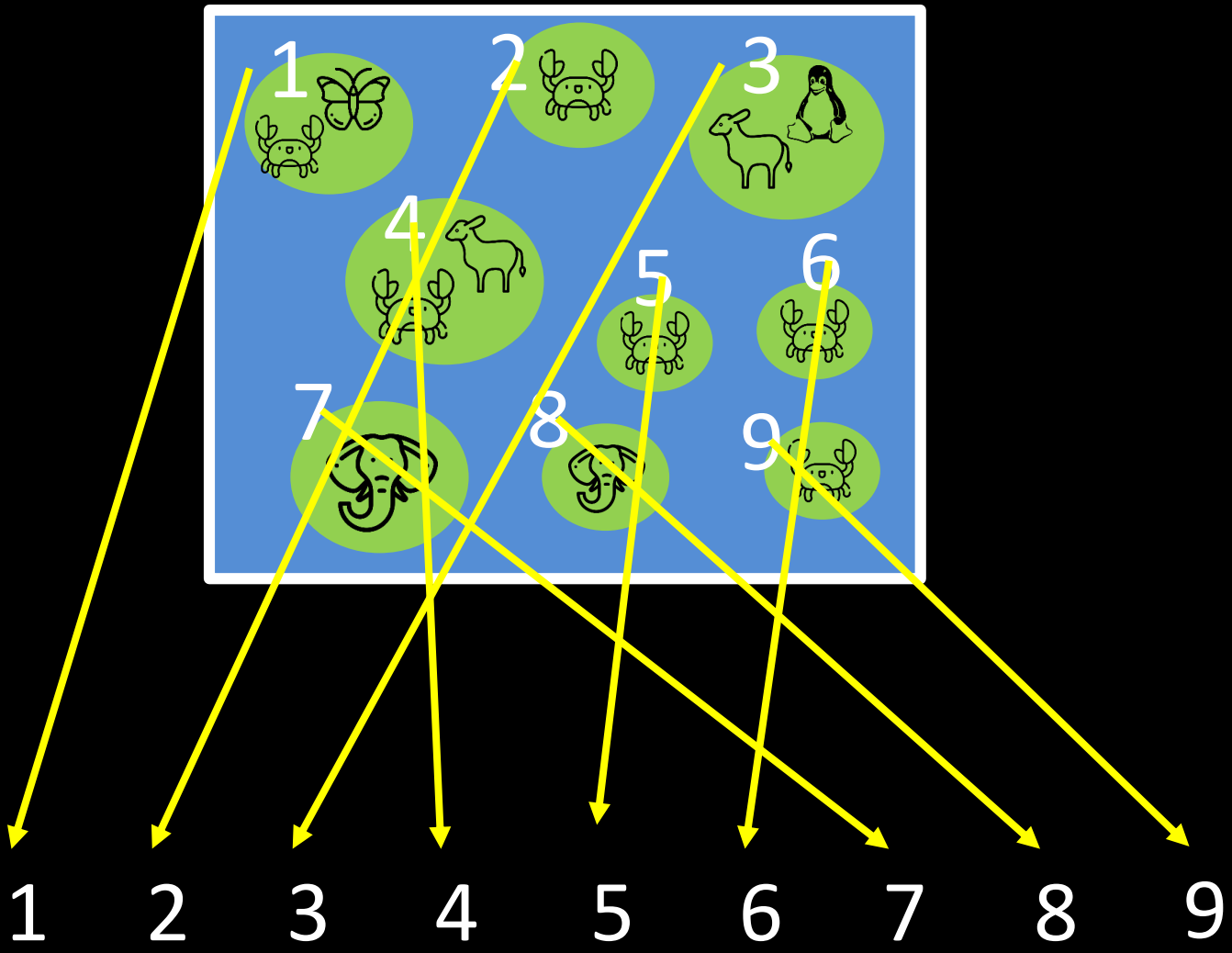
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1 2 3 4 5 6 7 8 9

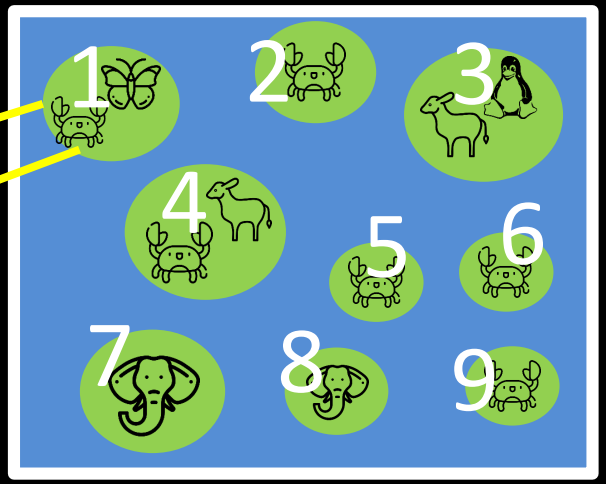
1 2 3 4 5 6 7 8 9

Upper	1	1	1	1	1	1	1	1	1
Lower	0	0	0	0	0	0	0	0	0
V. type	B	B	B	B	B	B	B	B	B
	1	2	3	4	5	6	7	8	9

Min $: +1 +1 +1 +1 +1 +1 +1 +1 +1

Upper	1	1	1	1	1	1	1	1	1
Lower	0	0	0	0	0	0	0	0	0
V. type	B	B	B	B	B	B	B	B	B
	1	2	3	4	5	6	7	8	9

Min $: +1 +1 +1 +1 +1 +1 +1 +1 +1



Upper	1	1	1	1	1	1	1	1	1
Lower	0	0	0	0	0	0	0	0	0
V. type	B	B	B	B	B	B	B	B	B
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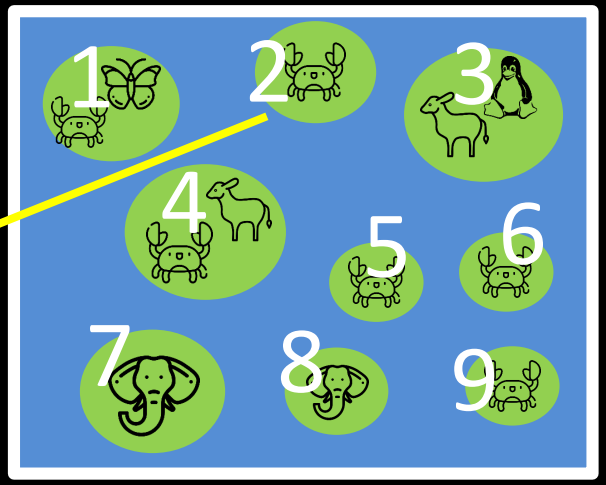
Min $: +1 +1 +1 +1 +1 +1 +1 +1 +1

+1

+1 +1



Upper	1	1	1	1	1	1	1	1	1
Lower	0	0	0	0	0	0	0	0	0
V. type	B	B	B	B	B	B	B	B	B
	1	2	3	4	5	6	7	8	9

Min $: +1 +1 +1 +1 +1 +1 +1 +1 +1

+1

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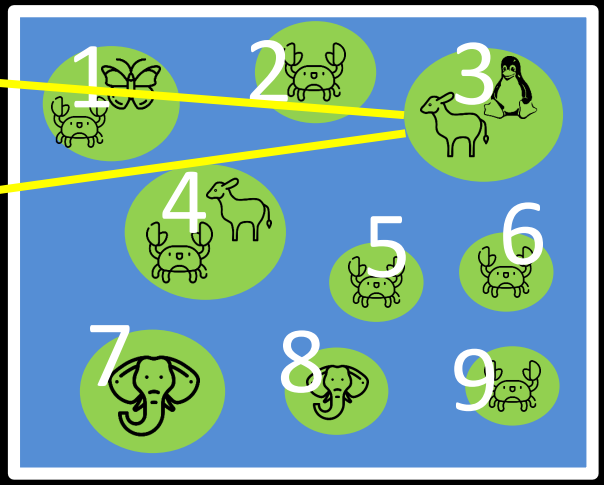

Upper	1	1	1	1	1	1	1	1	1
Lower	0	0	0	0	0	0	0	0	0
V. type	B	B	B	B	B	B	B	B	B
	1	2	3	4	5	6	7	8	9

Min $:	+1	+1	+1	+1	+1	+1	+1	+1	+1
			+1						
							+1	+1	
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	+1	+1		+1	+1	+1			+1
Upper	1	1	1	1	1	1	1	1	1
Lower	0	0	0	0	0	0	0	0	0
V. type	B	B	B	B	B	B	B	B	B
	1	2	3	4	5	6	7	8	9

Min $:	+1	+1	+1	+1	+1	+1	+1	+1	+1	
			+1							≥ 1
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			+1	+1						≥ 1
	+1									≥ 1
	+1	+1		+1	+1	+1			+1	≥ 1
Upper	1	1	1	1	1	1	1	1	1	
Lower	0	0	0	0	0	0	0	0	0	
V. type	B	B	B	B	B	B	B	B	B	
	1	2	3	4	5	6	7	8	9	

Min $: +1 +1 +1 +1 +1 +1 +1 +1 +1

+
+

GUROBI OPTIMIZATION

COMPUTATIONAL INFRASTRUCTURE FOR OPERATIONS RESEARCH
COIN|OR

IBM CPLEX

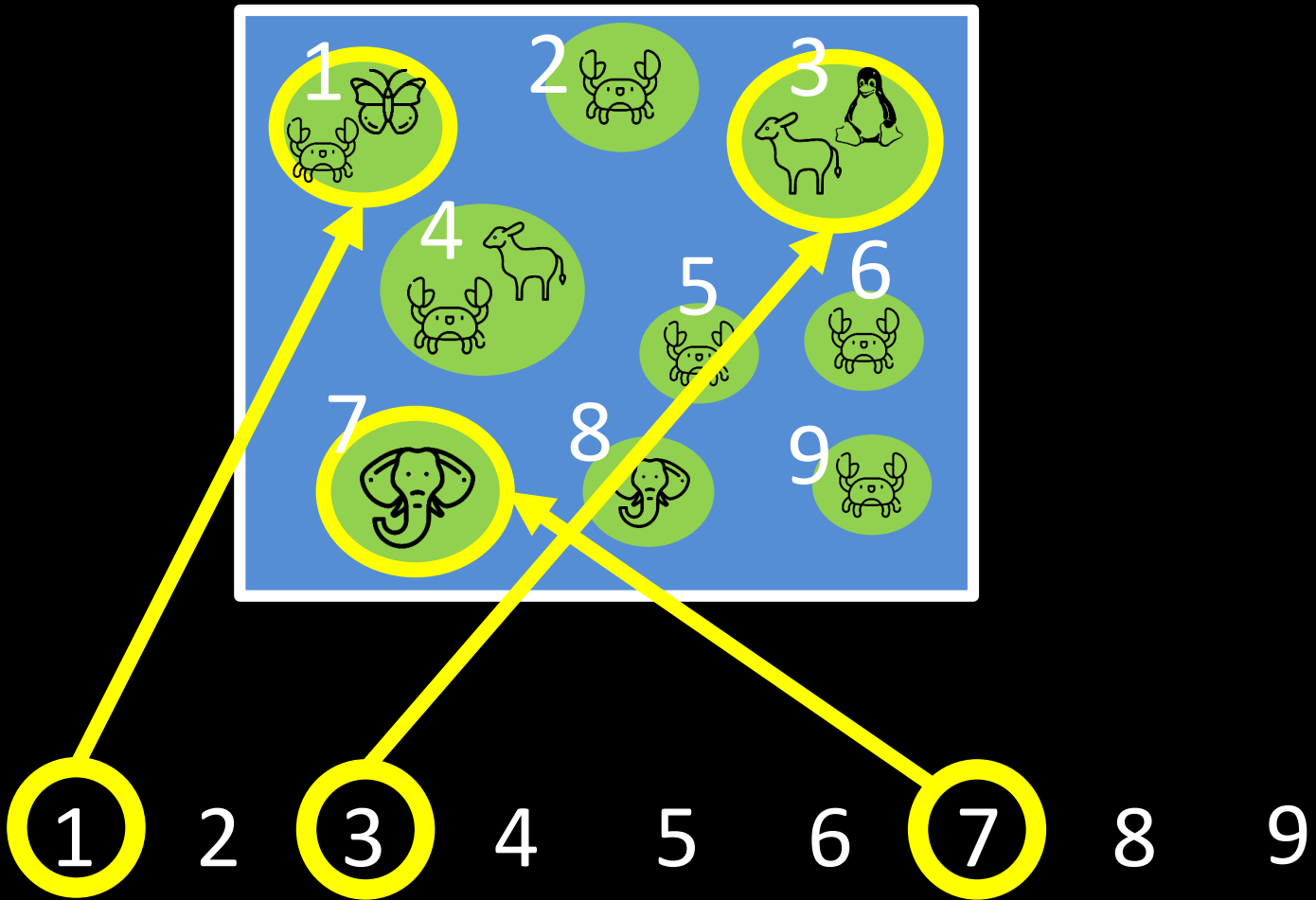
≥ 1
≥ 1
≥ 1
≥ 1
≥ 1

Upper

Lower

V. type	B	B	B	B	B	B	B	B	B
	1	2	3	4	5	6	7	8	9

Min $:	+1	+1	+1	+1	+1	+1	+1	+1	+1	
			+1							≥ 1
							+1	+1		≥ 1
			+1	+1						≥ 1
	+1									≥ 1
	+1	+1		+1	+1	+1			+1	≥ 1
Upper	1	1	1	1	1	1	1	1	1	
Lower	0	0	0	0	0	0	0	0	0	
V. type	B	B	B	B	B	B	B	B	B	
	1	2	3	4	5	6	7	8	9	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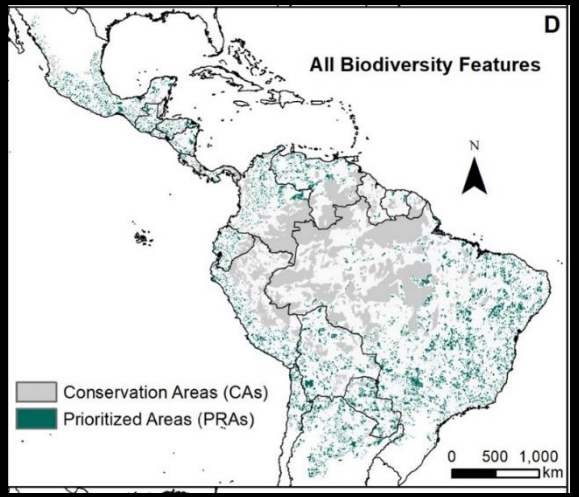
But reality is more complex…

Accounting for existing conservation areas

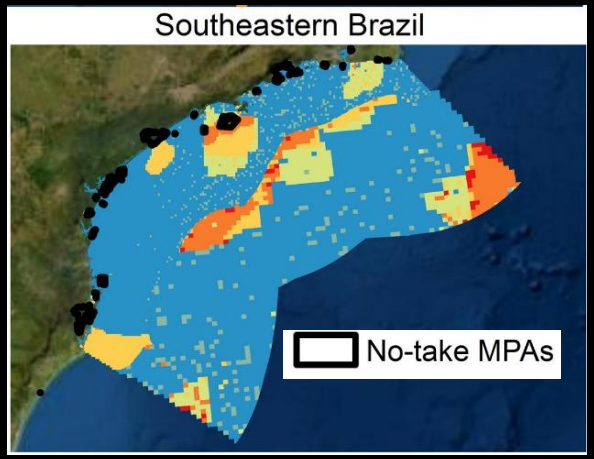
Min $:	+1	+1	+1	+1	+1	+1	+1	+1	+1	
			+1							≥ 1
							+1	+1		≥ 1
			+1	+1						≥ 1
	+1									≥ 1
	+1	+1		+1	+1	+1			+1	≥ 1
Upper	1	1	1	1	1	1	1	1	1	
Lower	0	1	0	0	0	0	1	0	0	
V. type	B	B	B	B	B	B	B	B	B	
	1	2	3	4	5	6	7	8	9	

Accounting for existing conservation areas



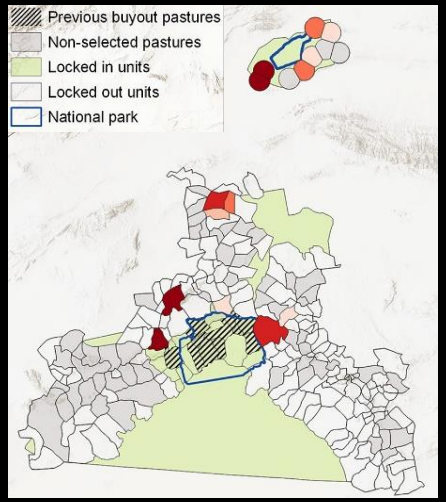
Protected areas + Indigenous Lands

Burbano-Girón et al. (2022)
DOI:10.1016/j.biocon.2021.109421



No-take marine reserves

Magris et al. (2020)
DOI:10.1111/ddi.13183



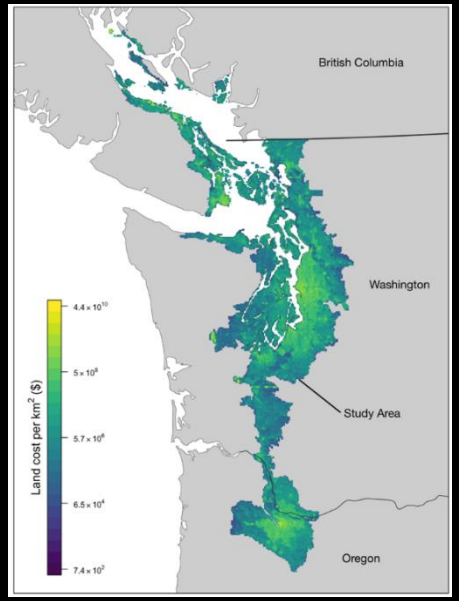
Areas with existing habitat + pastures where grazing rights have already been bought

Daberger et al. (2022)
10.1111/csp2.12832

Accounting for efficiency

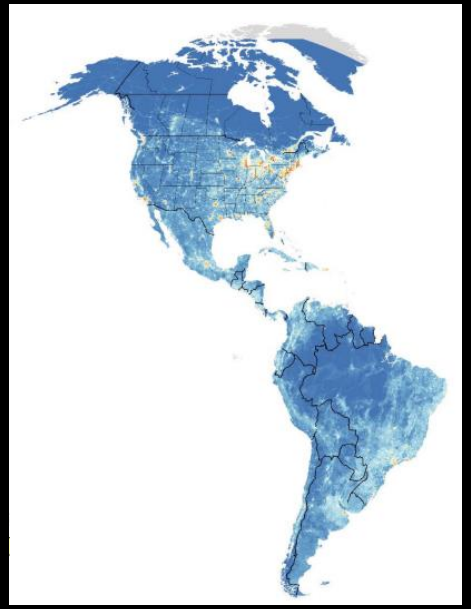
Min $:	+9	+2	+5	+1	+5	+8	+3	+6	+8	
			+1							≥ 1
							+1	+1		≥ 1
			+1	+1						≥ 1
	+1									≥ 1
	+1	+1		+1	+1	+1			+1	≥ 1
Upper	1	1	1	1	1	1	1	1	1	
Lower	0	1	0	0	0	0	1	0	0	
V. type	B	B	B	B	B	B	B	B	B	
	1	2	3	4	5	6	7	8	9	

Accounting for efficiency



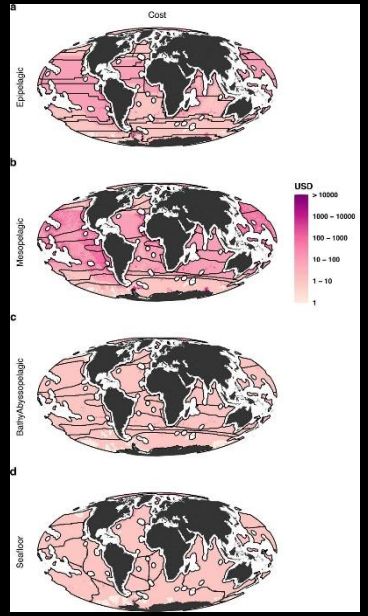
Land value assessments

Rodewald et al. (2019)
DOI:10.1038/s41598-019-52241-2



Human pressure

Schuster et al. (2019)
DOI:10.1038/s41467-019-09723-8



Opportunity cost to commercial fisheries

Brito-Morales et al. (2022)
DOI:10.1038/s41558-022-01323-7

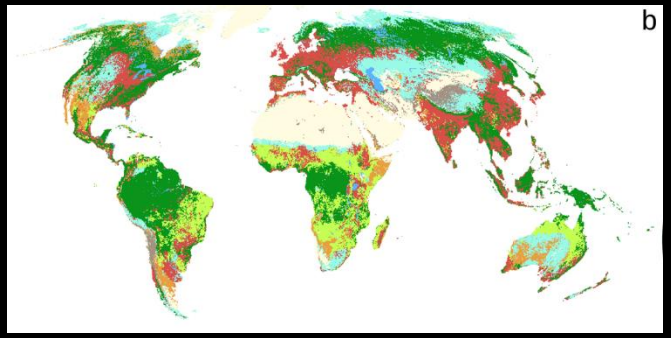
Accounting for adequacy, comprehensiveness, and representativeness

Min $:	+9	+2	+5	+1	+5	+8	+3	+6	+8	
			+10							≥ 10
							+2	+5		≥ 7
			+3	+7						≥ 3
	+1									≥ 1
	+9	+8		+9	+8	+4			+3	≥ 12
Upper	1	1	1	1	1	1	1	1	1	
Lower	0	1	0	0	0	0	1	0	0	
V. type	B	B	B	B	B	B	B	B	B	
	1	2	3	4	5	6	7	8	9	

Accounting for adequacy – get good data!

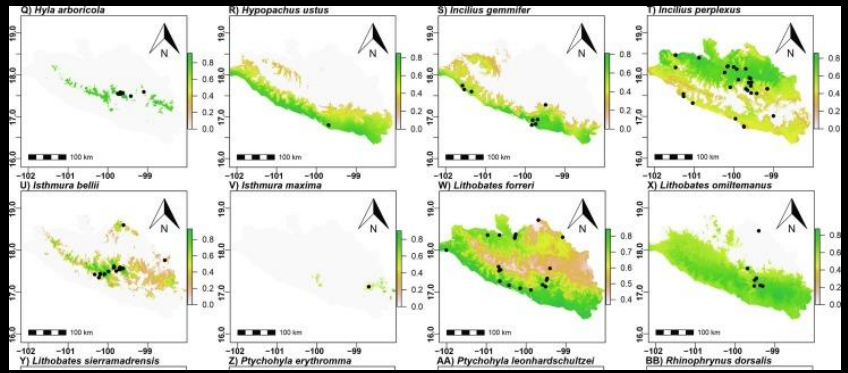
Area of habitat data

Hanson et al. (2022) DOI:10.1038/s41586-020-2138-7



Habitat classification

Jung et al. (2020) DOI: 10.1038/s41597-020-00599-8



Species distribution models

González-Fernández (2022) DOI:10.1016/j.jnc.2022.126235

Modelled abundance

Fink (2020) DOI:10.1002/eap.2056

Accounting for adequacy – set good targets!

Minimum coverage of features by the prioritization

- **Policy** “As a habitat-specific target, we used 17% of the total number of PUs where the respective habitat occurs, adopting Aichi target 11”

Friedrichs et al. (2018) Plos ONE, DOI:10.1371/journal.pone.0208264 Taylor *et al.* (2017) Plos ONE, DOI:10.1371/journal.pone.0169629 Jung *et al.* (2021) Nat Ecol Evol DO:10.1038/s41559-021-01528-7

Representation targets

Minimum coverage of features by the prioritization

- **Policy** “As a habitat-specific target, we used 17% of the total number of PUs where the respective habitat occurs, adopting Aichi target 11”
- **Statistical models** “We modelled […] scenarios based on […] the [population viability analysis] by Todd *et al*. (2016). The reserve scenarios were based on the protected area required to achieve a less than 5% chance of the Leadbeater’s Possum population falling to (or below) 500 or fewer adult females in 40 generations ”

Friedrichs et al. (2018) Plos ONE, DOI:10.1371/journal.pone.0208264 Taylor *et al.* (2017) Plos ONE, DOI:10.1371/journal.pone.0169629 Jung *et al.* (2021) Nat Ecol Evol DO:10.1038/s41559-021-01528-7

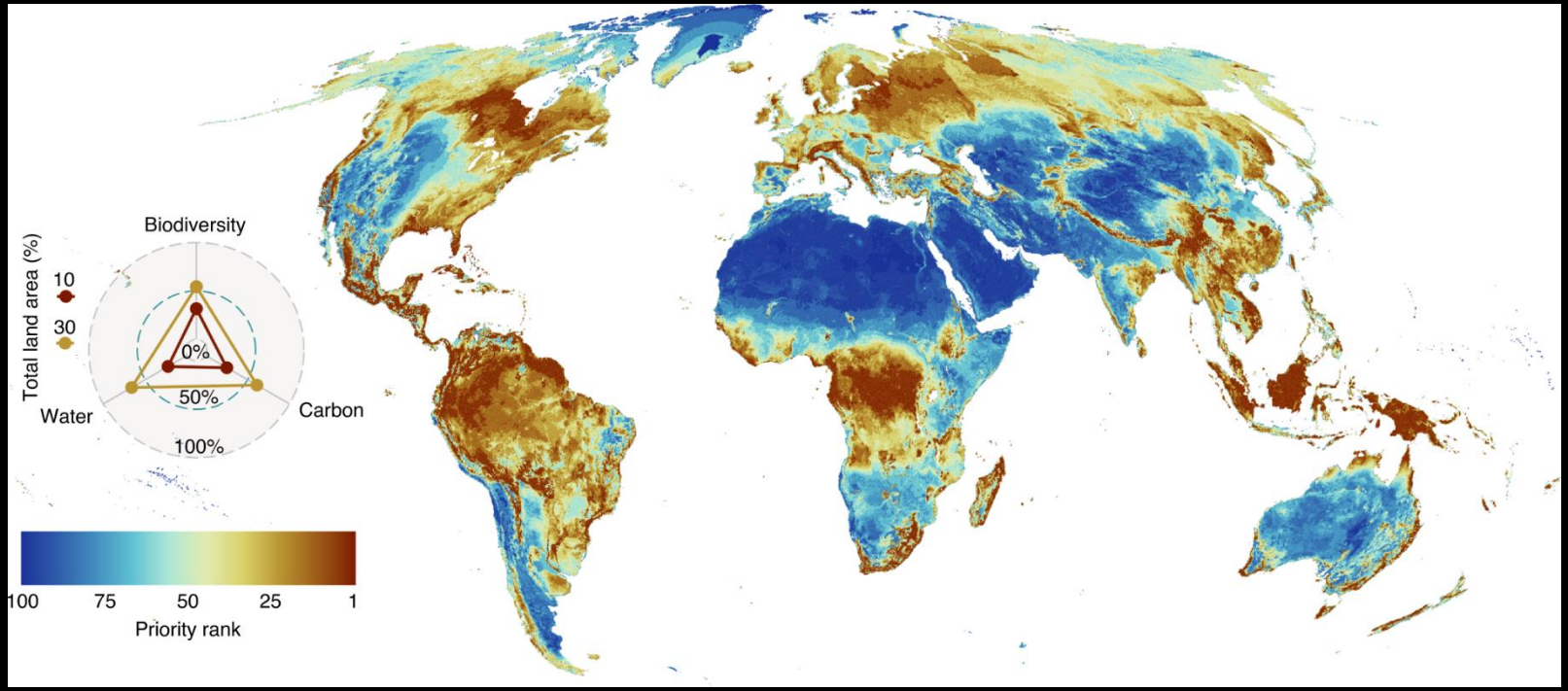
Representation targets

Minimum coverage of features by the prioritization

- **Policy** “As a habitat-specific target, we used 17% of the total number of PUs where the respective habitat occurs, adopting Aichi target 11”
- **Statistical models** “We modelled […] scenarios based on […] the [population viability analysis] by Todd *et al*. (2016). The reserve scenarios were based on the protected area required to achieve a less than 5% chance of the Leadbeater’s Possum population falling to (or below) 500 or fewer adult females in 40 generations ”
- **Export thresholds** “We set species targets to conserving the minimum amount of species’ habitat necessary to qualify it for the conservation status ‘Least Concern’ following IUCN Red List criteria”

Friedrichs et al. (2018) Plos ONE, DOI:10.1371/journal.pone.0208264 Taylor *et al.* (2017) Plos ONE, DOI:10.1371/journal.pone.0169629 Jung *et al.* (2021) Nat Ecol Evol DO:10.1038/s41559-021-01528-7

Accounting for comprehensiveness

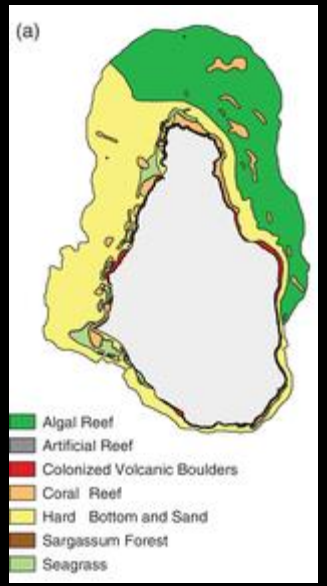


Amphibians, mammals, birds, reptiles, plants, water provisioning, carbon sequestration

Jung et al. 2021 DOI:10.1038/s41559-021-01528-7

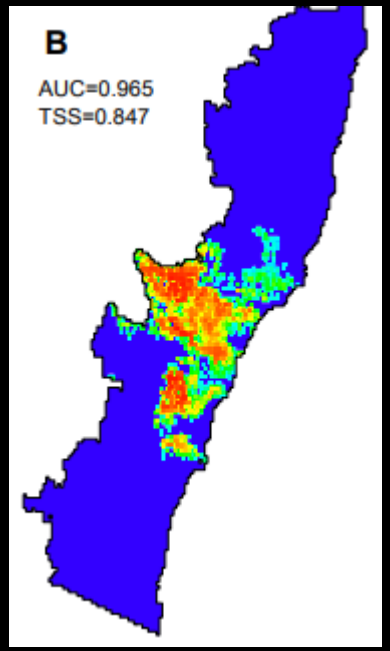
Accounting for representativeness

Ecosystems



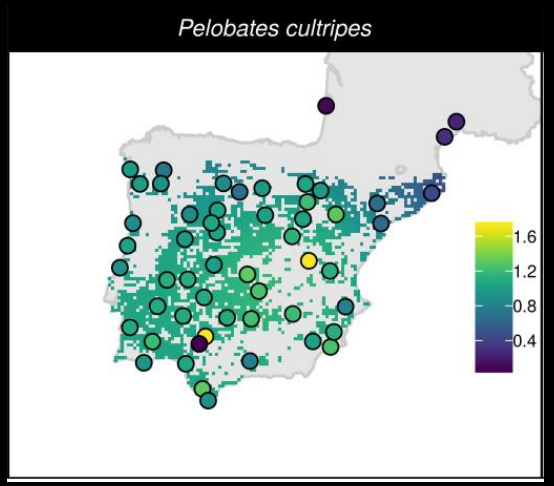
Flower et al. (2010)
DOI: 10.1111/csp2.158

Species



Domisch et al. (2019)
DOI: 10.1111/ddi.12891

Genes



Hanson et al. (2022)
DOI: 10.1111/1365-2664.13718

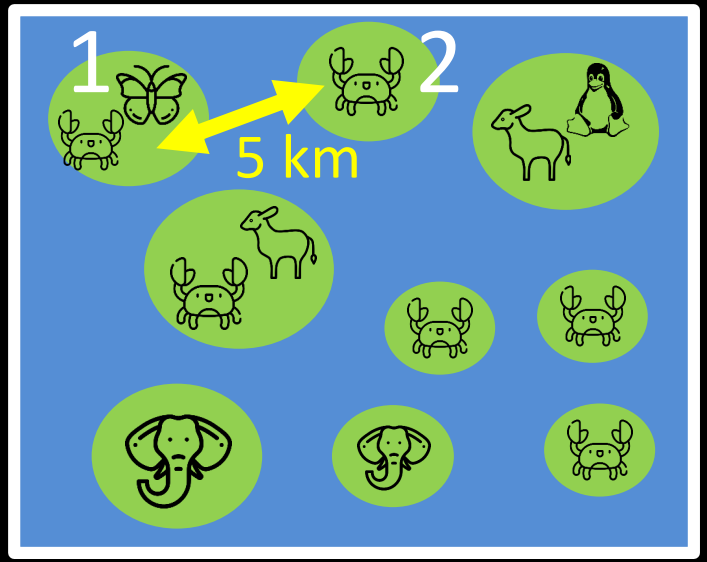
Accounting for connectivity

Min $:	+9	+2	+5	+1	+5	+8	+3	+6	+8	
			+10							≥ 10
							+2	+5		≥ 7
			+3	+7						≥ 3
	+1									≥ 1
	+9	+8		+9	+8	+4			+3	≥ 12
Upper	1	1	1	0	1	1	1	1	0	
Lower	0	1	0	0	0	0	1	0	0	
V. type	B	B	B	B	B	B	B	B	B	
	1	2	3	4	5	6	7	8	9	

What if connectivity = 1/distance?

Min $:	+9	+2	-3*1/5	
	-1		+1	≤ 0
		+1	-1	≤ 0
	-1	-1	+1	≥ -1
Upper	1	1	1	
Lower	0	1	0	
V. type	B	B	B	
	1	2	1&2	

Let's just consider islands 1 and 2



Scaling factor: 3 connectivity units = 1 cost unit

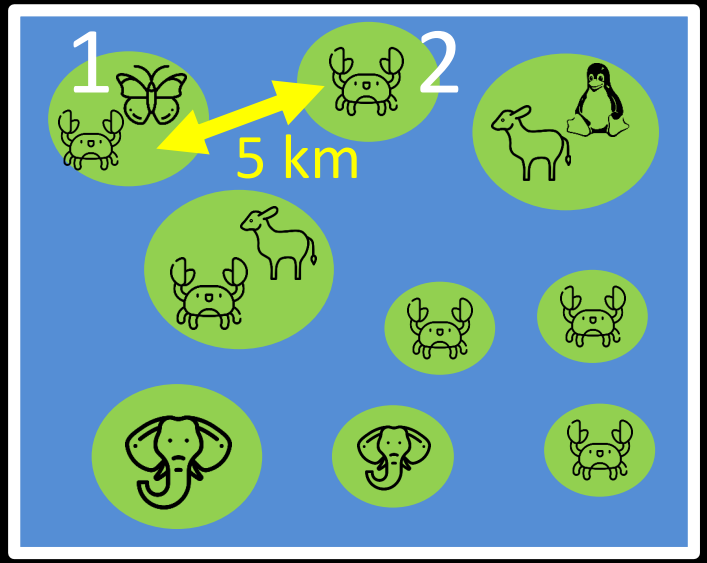
Beyer et al. (2016)
DOI:10.1016/j.ecolmodel.2016.02.005

What if connectivity = 1/distance?

Min $:	+9	+2	-3*1/5	
(1)	-1		+1	≤ 0
(2)		+1	-1	≤ 0
	-1	-1	+1	≥ -1
Upper	1	1	1	
Lower	0	1	0	
V. type	B	B	B	
	1	2	1&2	

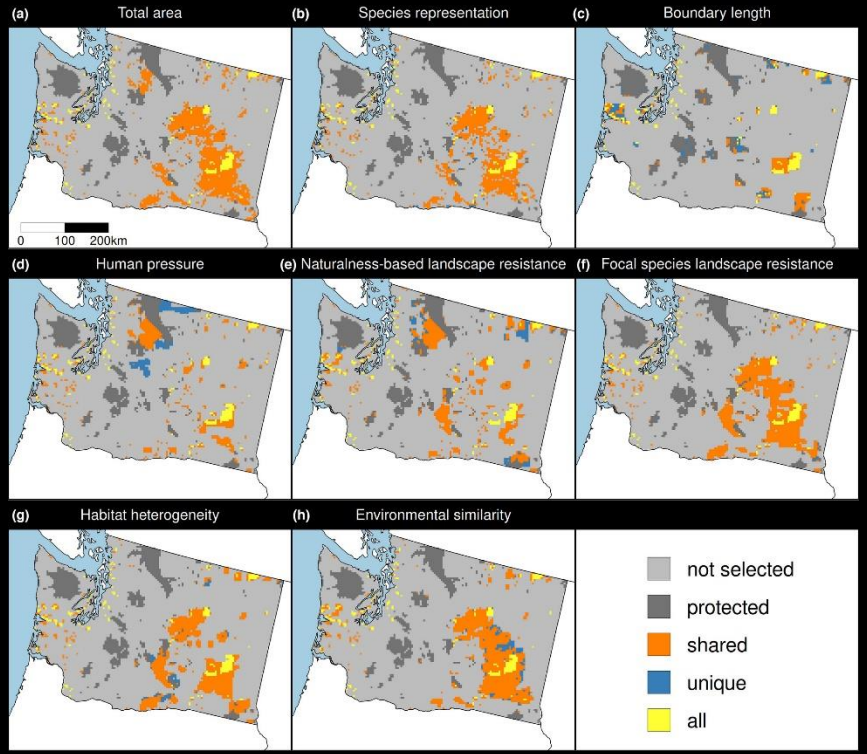
So, +1 variable and +2 constraints per pair of planning units.. increases problem size a lot!

Let's just consider islands 1 and 2

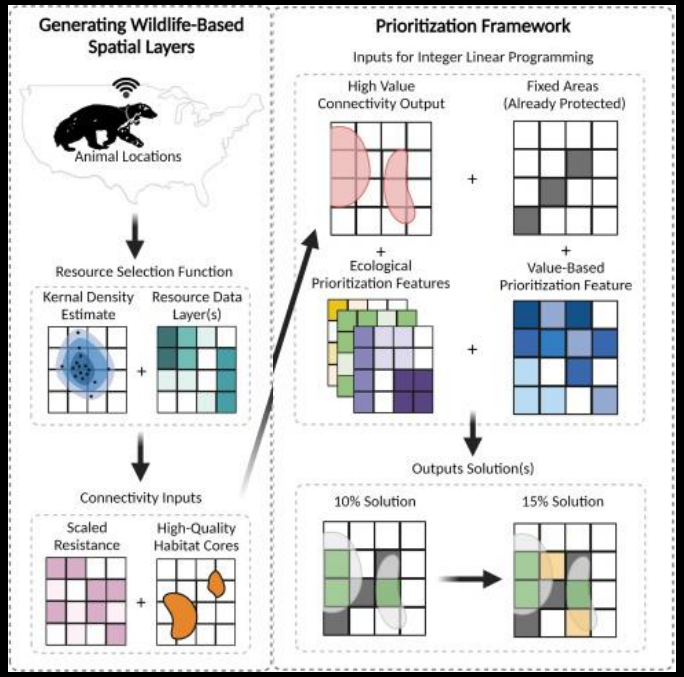


E.g., 1k planning = ~500k extra constraints

Accounting for connectivity

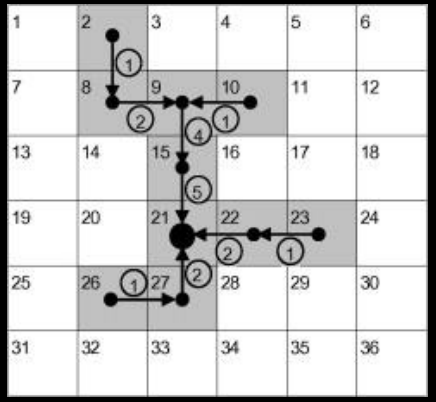


Hanson et al. (2022) DOI:10.1111/1365-2664.14251



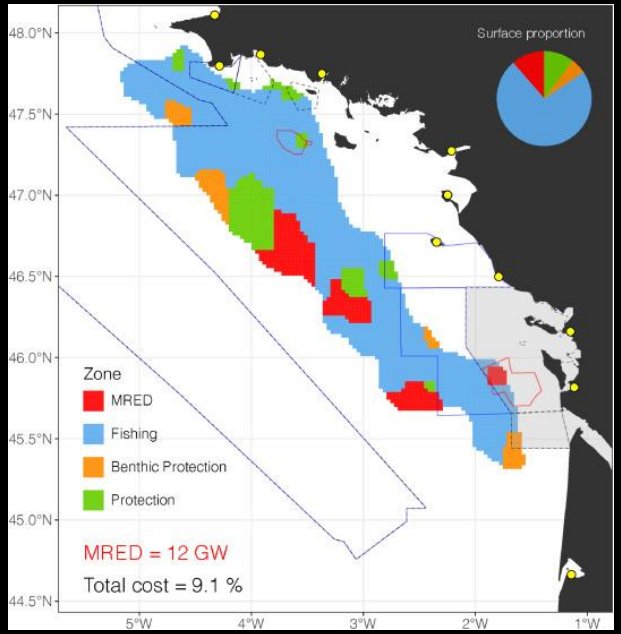
Carroll (2021)
DOI:10.1016/j.xpro.2021.100882

Other stuff too!



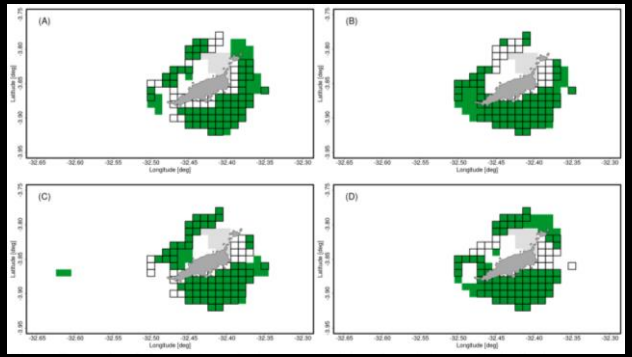
Spatially contiguity

Wang and Önal (2013)
DOI: 10.1016/j.chnaes.2013.07.004



Multiple management zones

Boussarie et al. (2023)
DOI: 10.1016/j.jenvman.2023.117857



Solution portfolios

Brunel et al. (2022)
DOI: 10.1007/s10666-022-09862-1

What you will do today

- Workshop manual sections 1—4.
  - Learn how to work with spatial data in R
  - Perform a gap analysis
  - Answer questions in the manual

https://prioritizr.github.io/workshop

Getting help

- prioritizr website
  - https://prioritizr.net
- RDocumentation
  - https://www.rdocumentation.org
- Geocompr
  - https://geocompr.robinlovelace.net/

jeffrey.hanson@uqconnect.edu.au

github.com/prioritizr/prioritizr

prioritizr.net