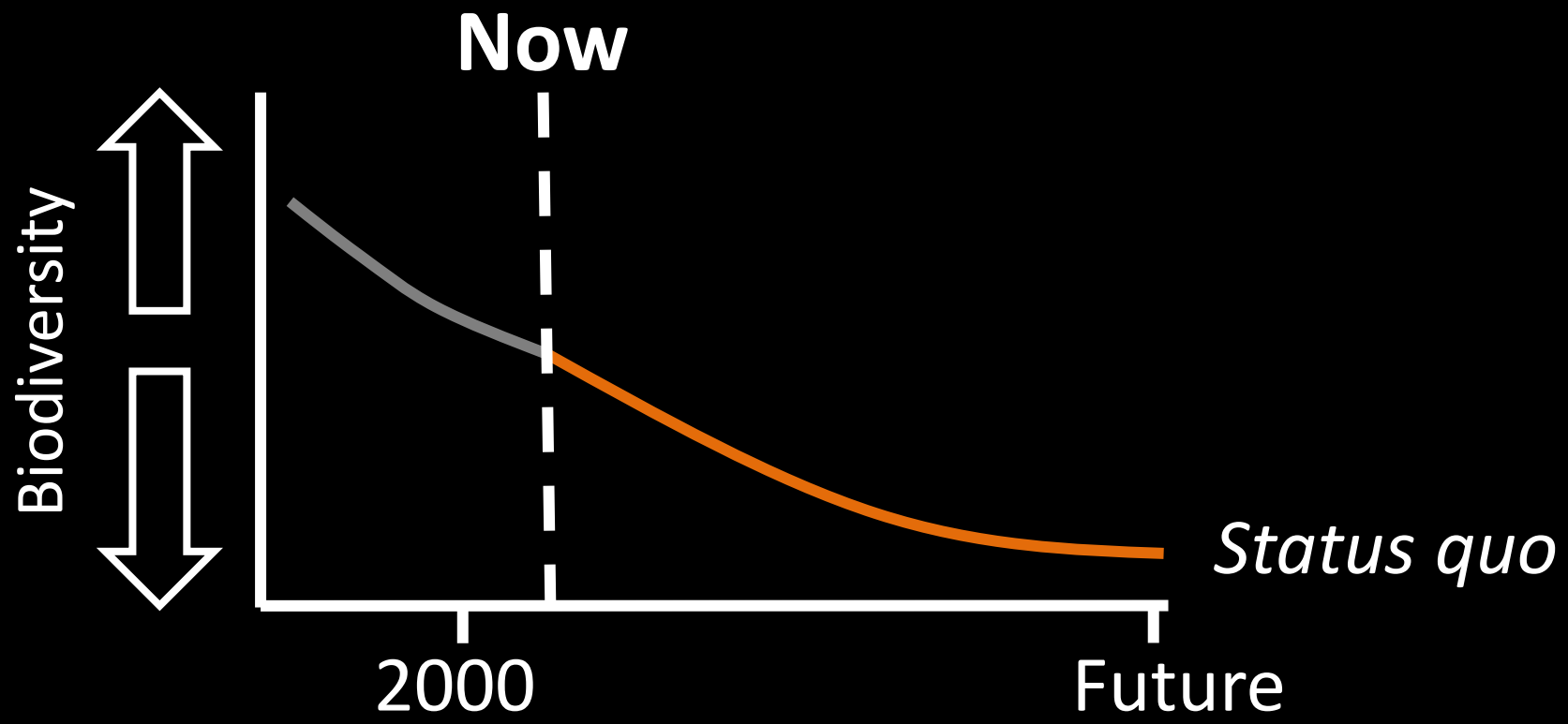
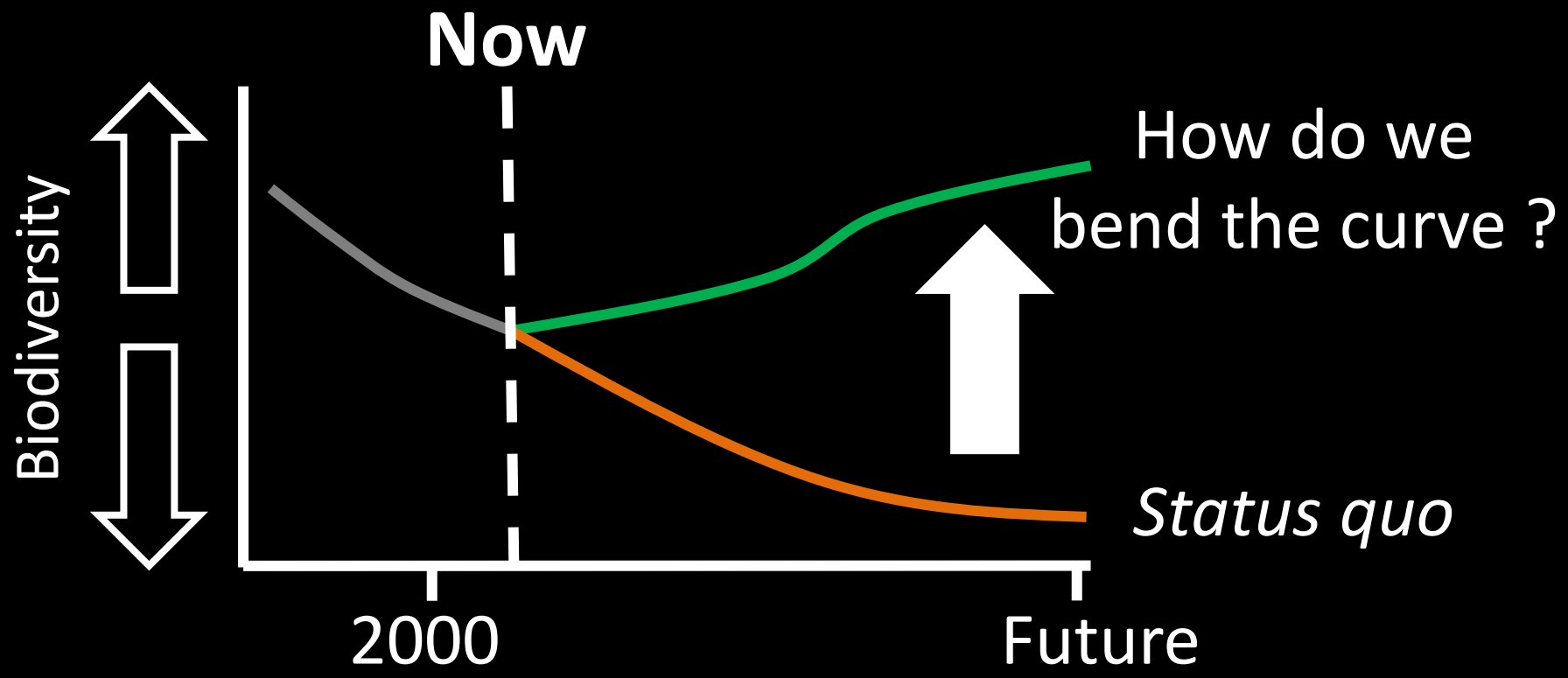
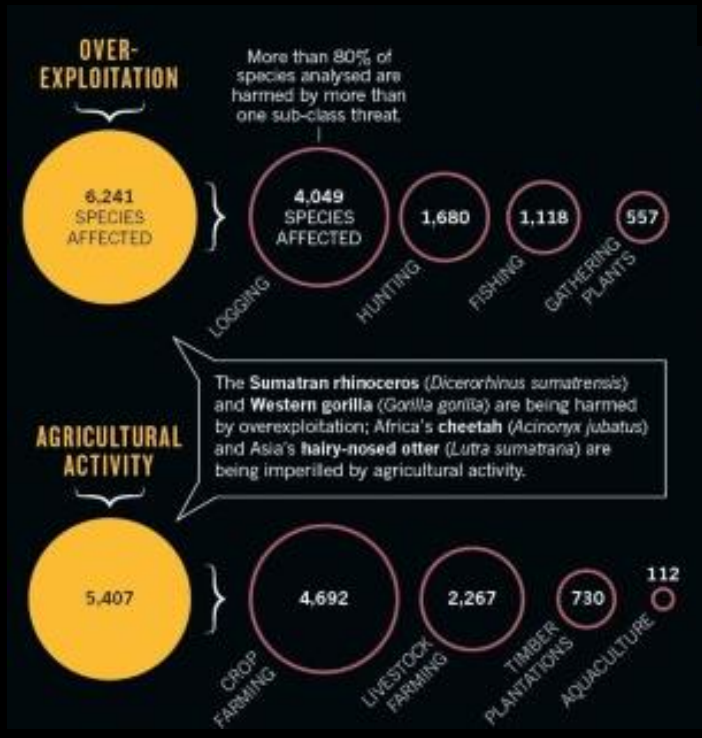
Conservation science (196.315)
Reserve selection

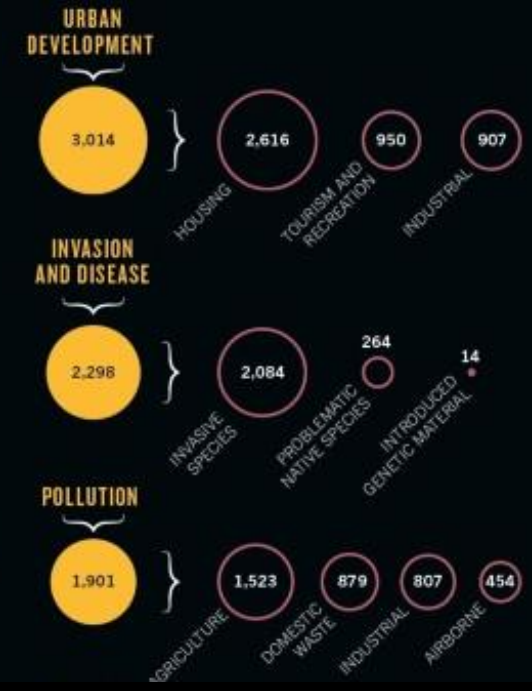
Jeffrey Hanson

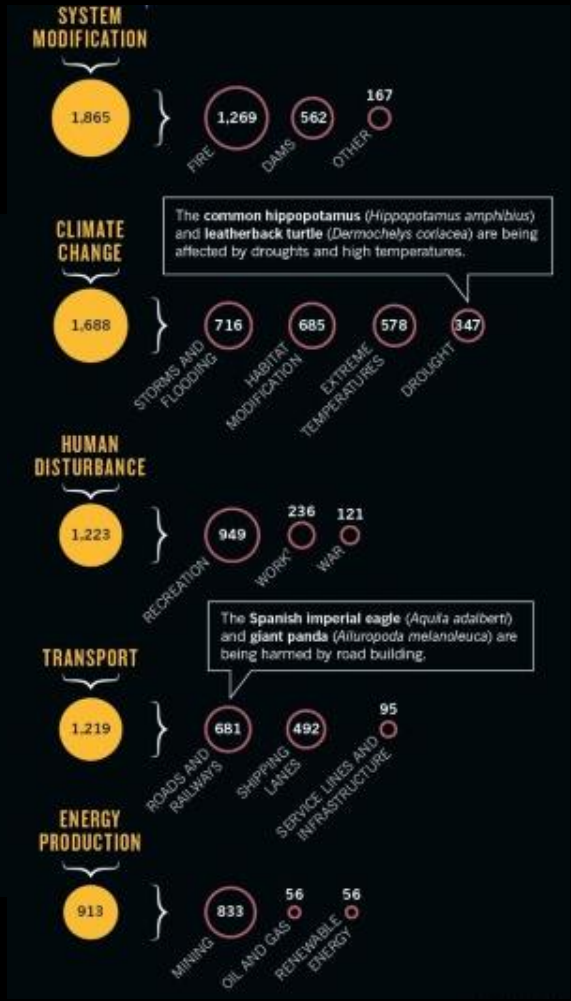

Now
Biodiversity
Status quo
2000
Future


Now
Biodiversity
How do we
bend the curve ?
Status quo
2000
Future

Global drivers of biodiversity loss

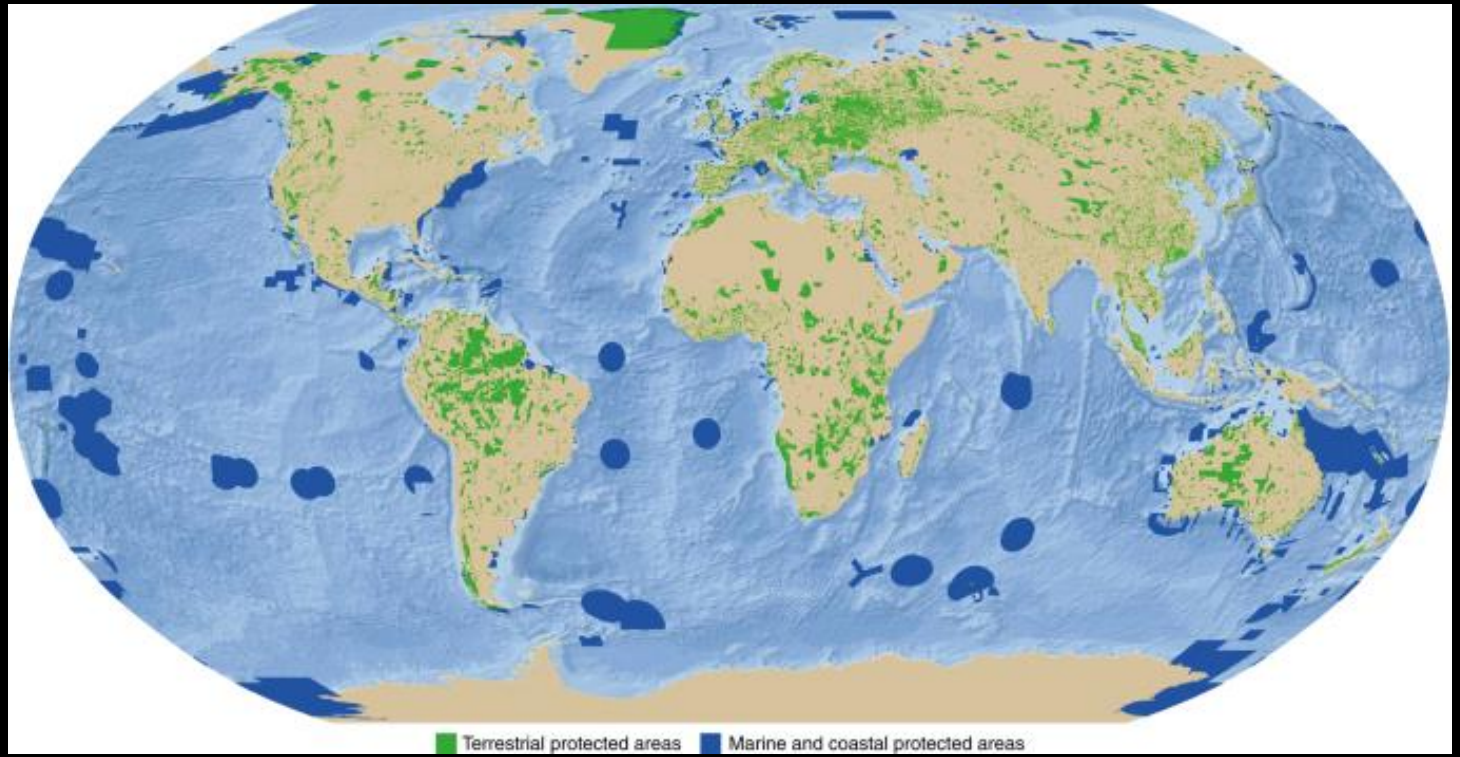




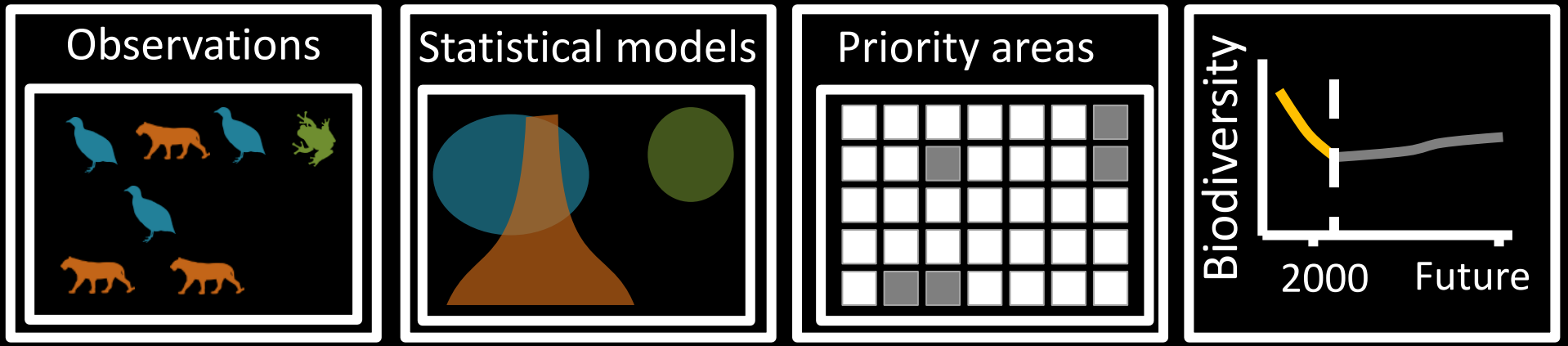


Maxwell et al. (2016) Nature, DOI:10.1038/536143a

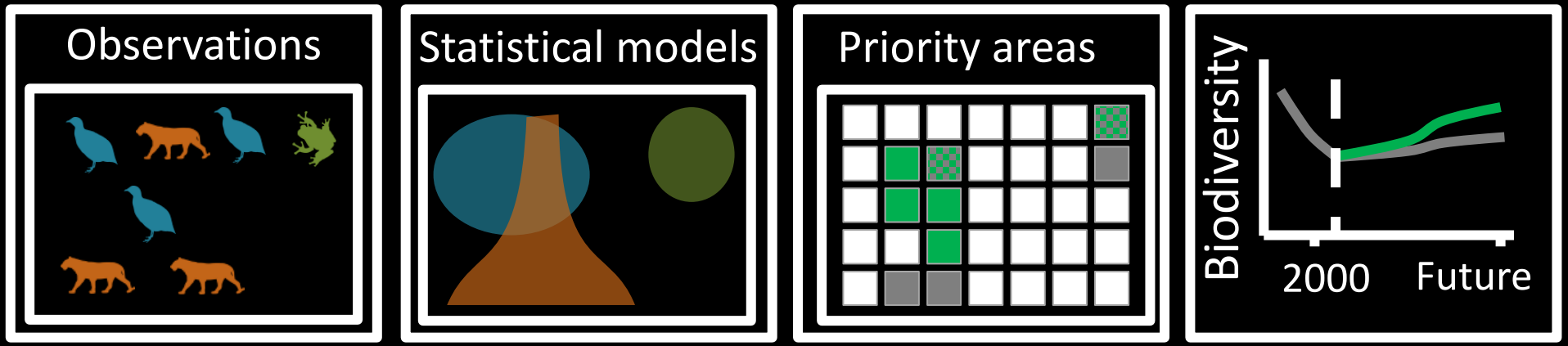
Protected areas



Bingham et al. (2019) Nature Ecology and Evolution, DOI: 10.1038/s41559-019-0869-3



Data → Information → Plan → Outcome



Data → Information → **Plan** → Outcome

Better plan

Better outcome

Prioritization

Systematic conservation planning

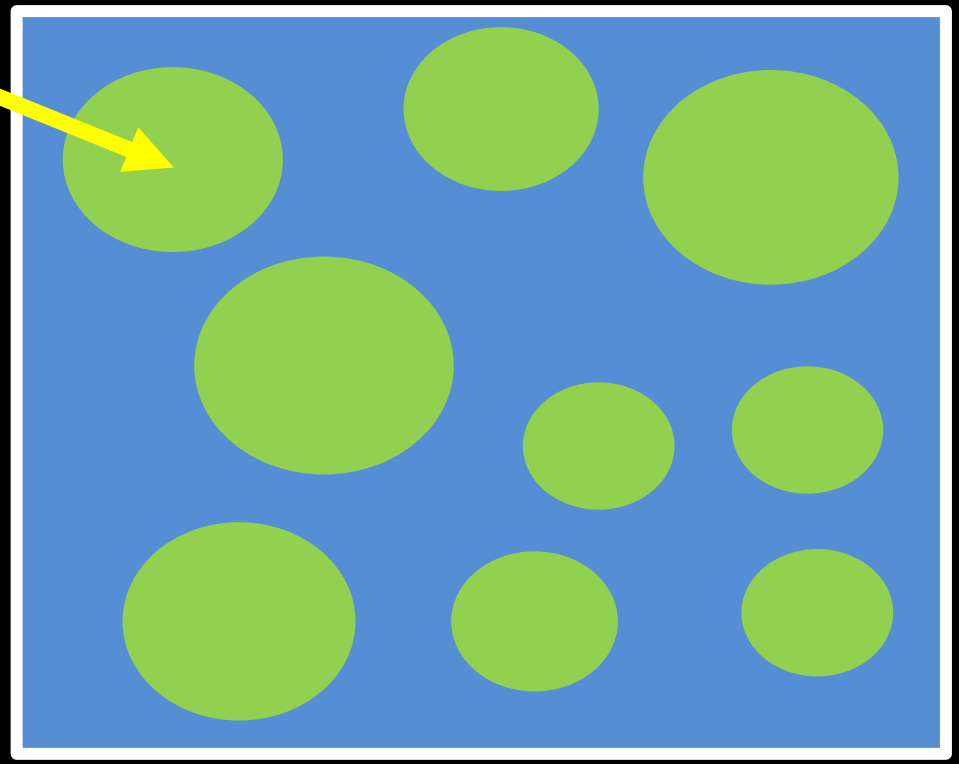
"Systematic conservation planning aims to provide a rigorous, repeatable, and structured approach for designing new protected areas that efficiently meet conservation objectives"

Schuster et al. (2020) PeerJ, DOI:10.7717/peerj.9258

Reserve selection

Planning units

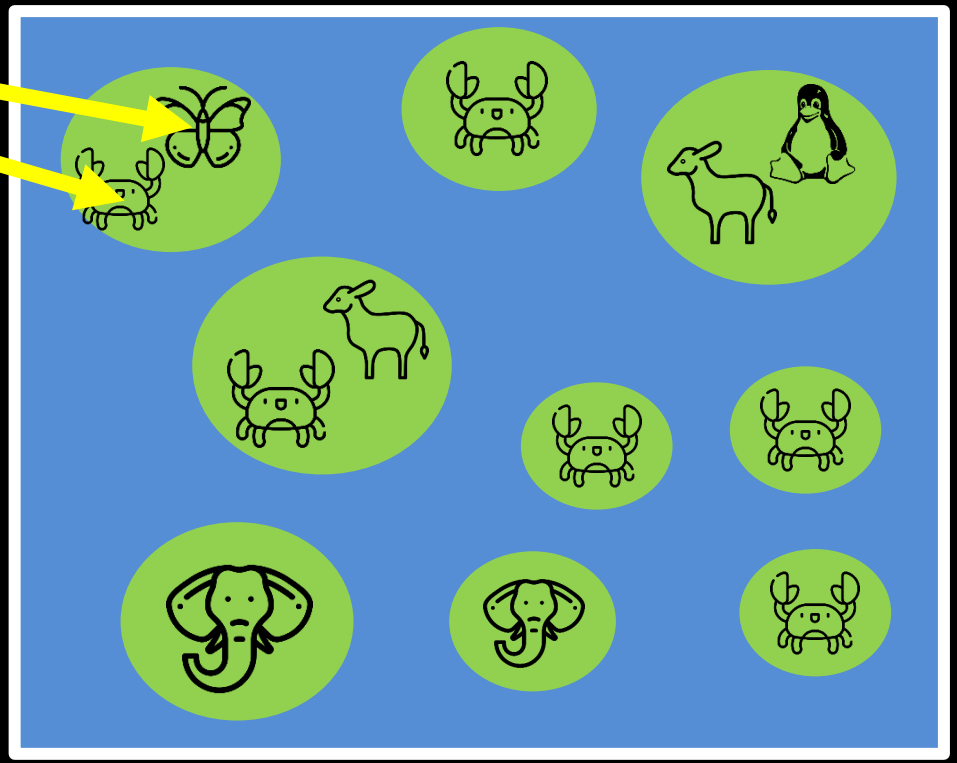
- Discrete places for conservation management
- Each planning unit is managed separately
- Commonly include land parcels, islands, spatial grid cells



Reserve selection

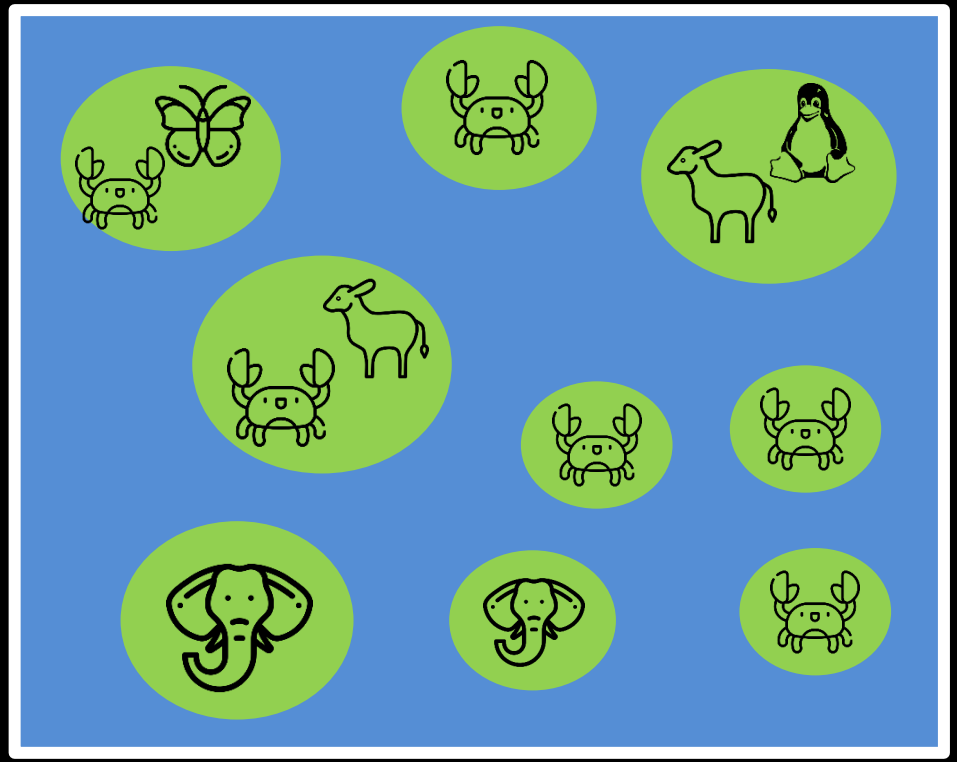
Features

- 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-C Principles

- Comprehensive
- Adequate
- Representative
- Efficient
- Connectivity

Nielsen et al. (2023) Trends Ecol Evol, doi:10.1016/j.tree.2022.09.006

CARE-C Principles

- **Comprehensive**
- Adequate
- Representative
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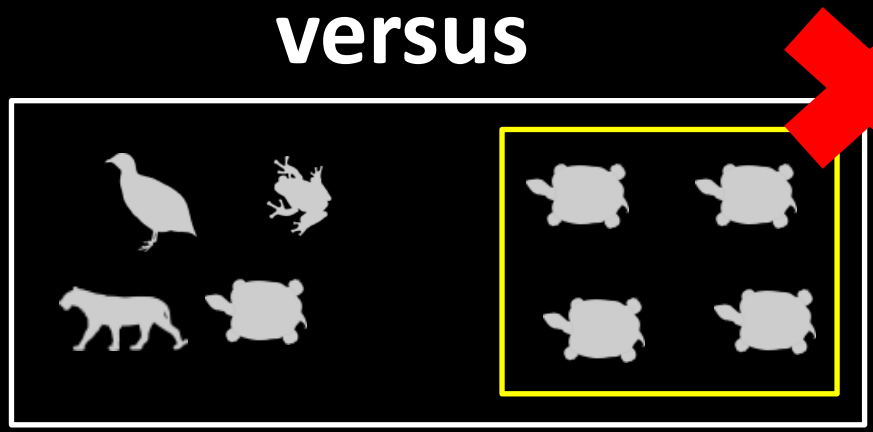
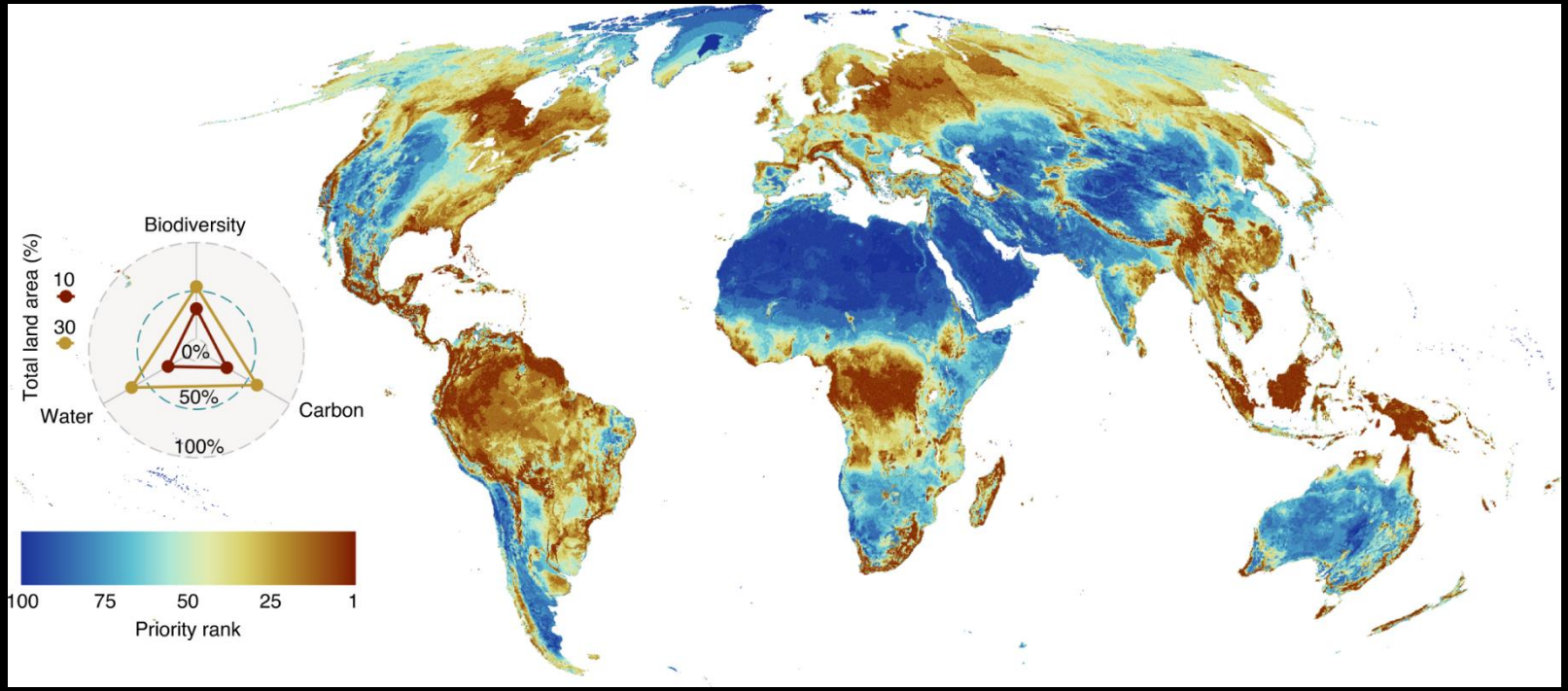
- Connectivity

versus



Accounting for comprehensiveness



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

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

CARE-C Principles

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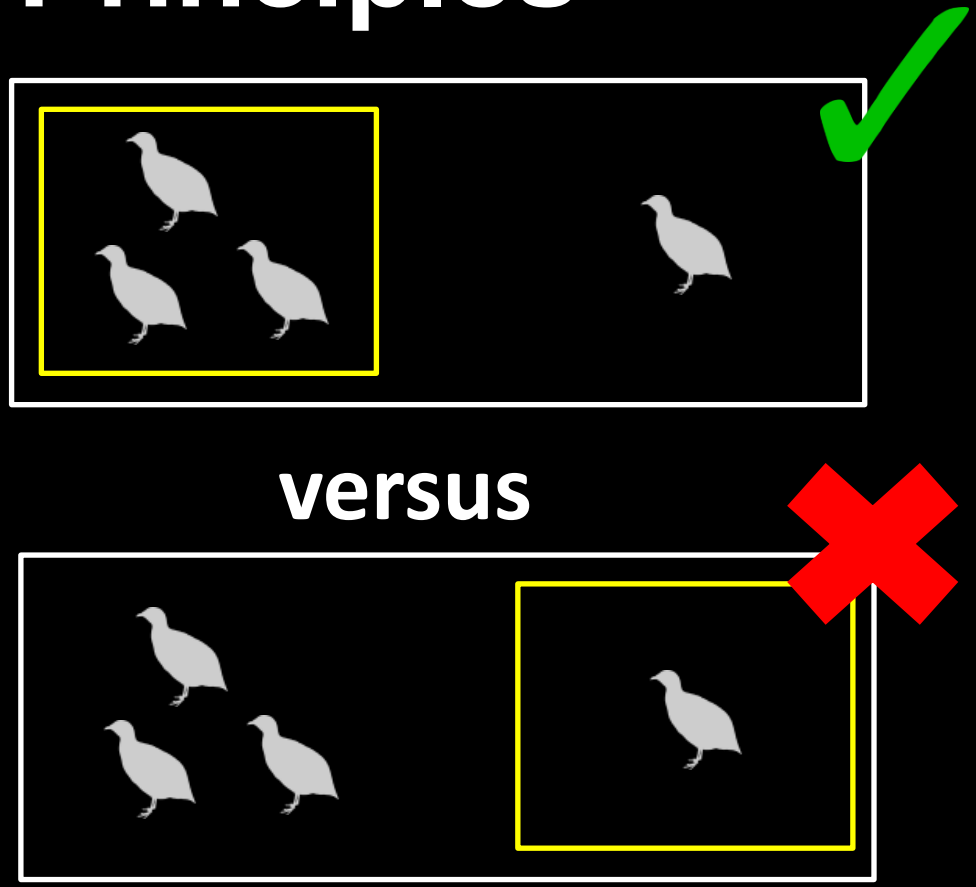
- **Adequate**
- Representative
- Efficient
- Connectivity

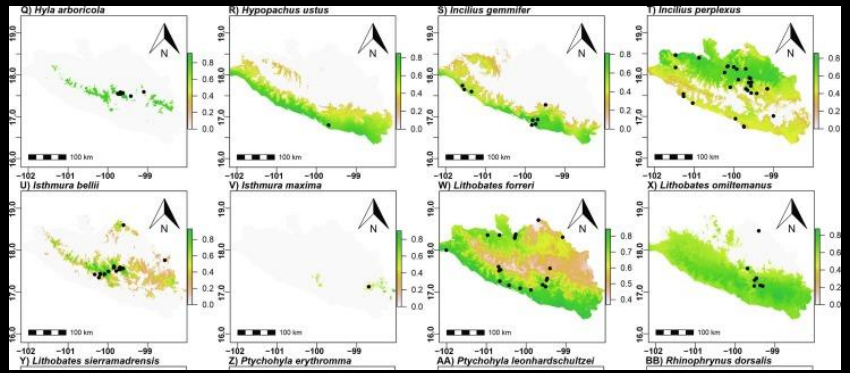


Accounting for adequacy

Get good data…

High resolution estimates of habitat suitability

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



Species distribution models

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

Species range maps

(IUCN Red List, https://www.iucnredlist.org/)

… and set good targets!

Representation targets

- Policy

Policy

"In 1992, the Fourth World Congress on National Parks and Protected Areas [recommended] "that protected areas cover at least 10 percent of each biome by the year 2000" (McNeely 1993)."

"[Aichi target 11] […] targets mandate that 17% of terrestrial areas, and 10% of coastal and marine areas should be covered by nature conservation networks […]"

Targets

"We set as a fixed target the conservation of at least 10% of grid cells occupied by a species, with a minimum of one."

"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
Jetz et al. (2014) Current Biol, DOI:10.1016/j.cub.2014.03.011
Brooks et al. (2004) BioScience, DOI:10.1641/0006-3568(2004)054[1081:CPBTGP]2.0.CO;2

Representation targets

- Statistical estimates/models

"We aimed to include 30% of each biodiversity feature [e.g. vegetation types, environmental domains, species distributions] while minimizing the economic cost of the system of selected areas. We set conservation targets for each feature at 30% of their pre-clearing (year 1770) extent to be consistent with international recommendations (IUCN, 2003) and to ensure that biodiversity features are represented in proportion to their natural extent"

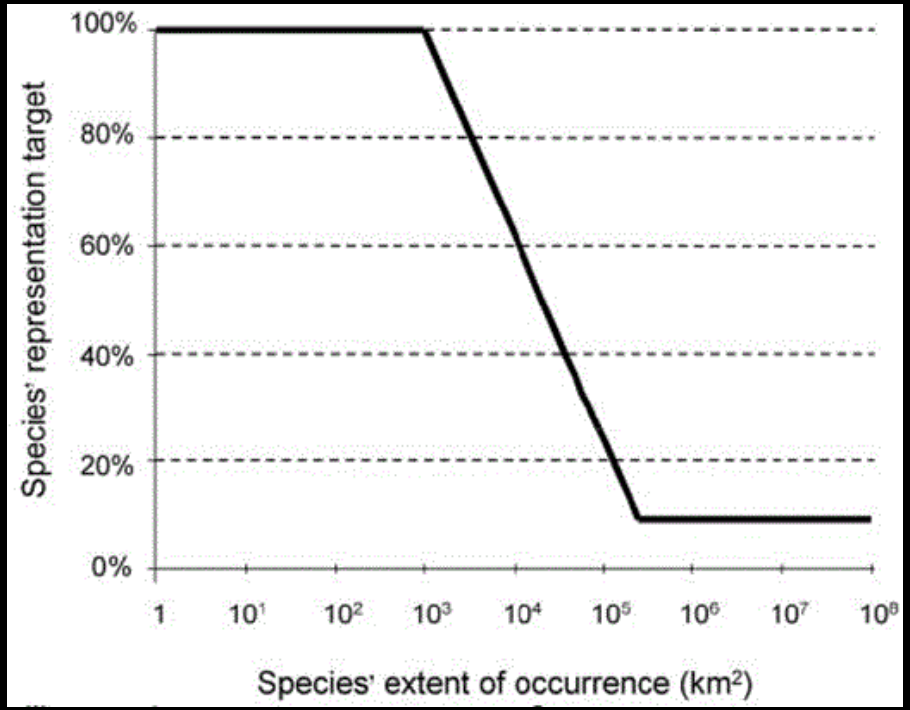
Klein *et al.* (2009) Biol Cons, DOI:10.1016/j.biocon.2009.01.035
Taylor *et al.* (2017) Plos ONE, DOI:10.1371/journal.pone.0169629

"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 […]. [The worst case scenario] required the Leadbeater's Possum reserve to be expanded to 171,345 ha."

Representation targets

- Expert thresholds

"Species into as many biodiversity features as the biomes in which the species occurs. 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"



Jung *et al.* (2021) Nat Ecol Evol DO:10.1038/s41559-021-01528-7

Rodrigues *et al.* (2004), BioSicence, DOI: 10.1641/0006-568(2004)054[1092:GGAPRF]2.0.CO;2

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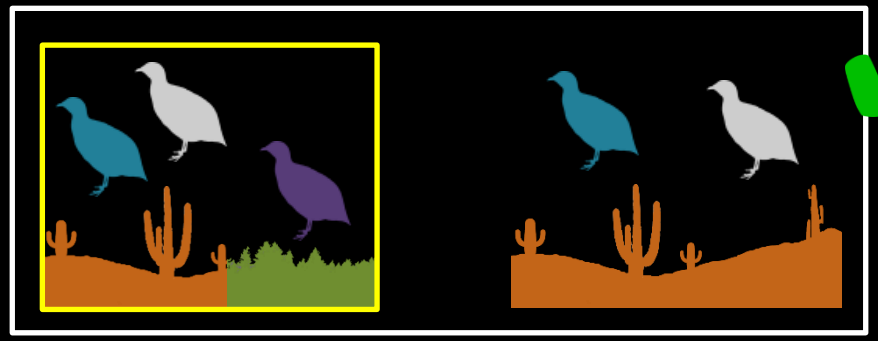
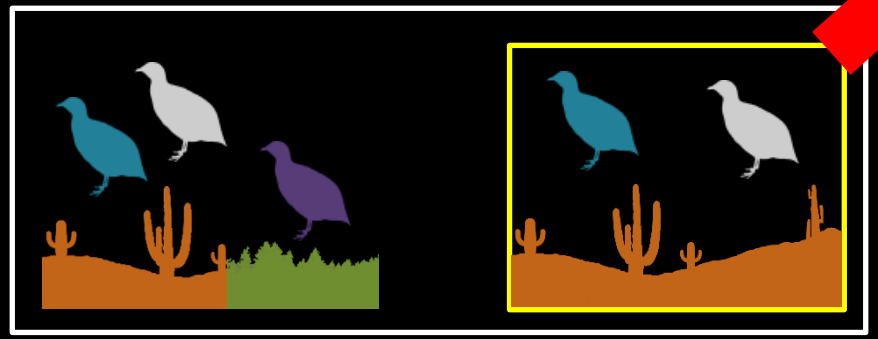
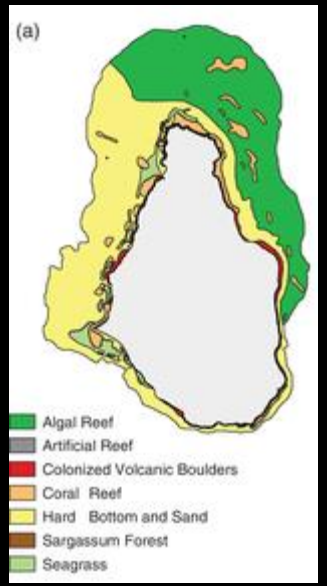


versus



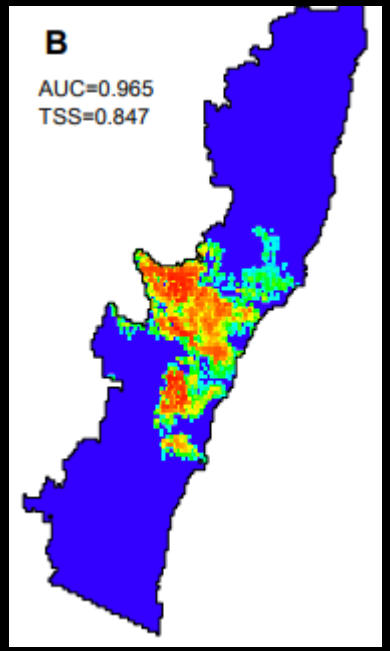
Accounting for representativeness

Ecosystems



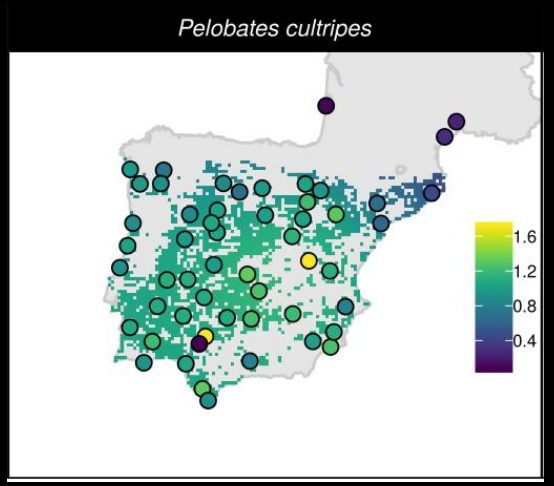
Flower et al. (2010)
DOI: 10.1111/csp2.158

Species



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

Genes



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

CARE-C Principles

- Comprehensive
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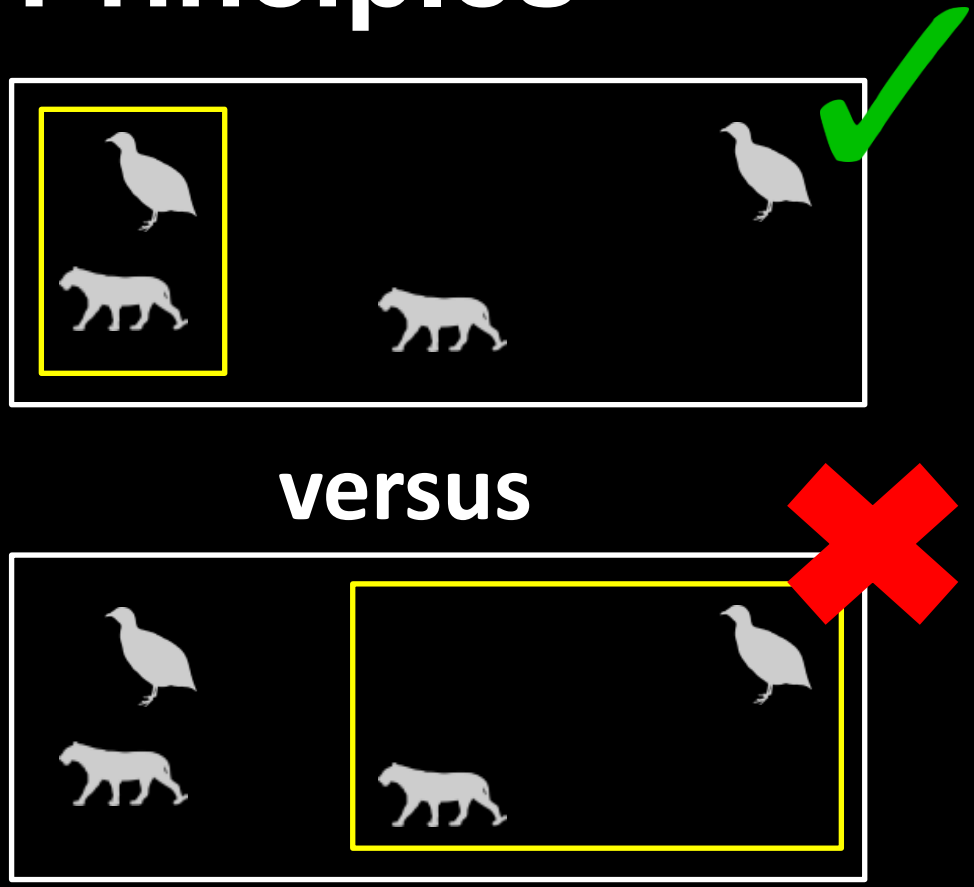
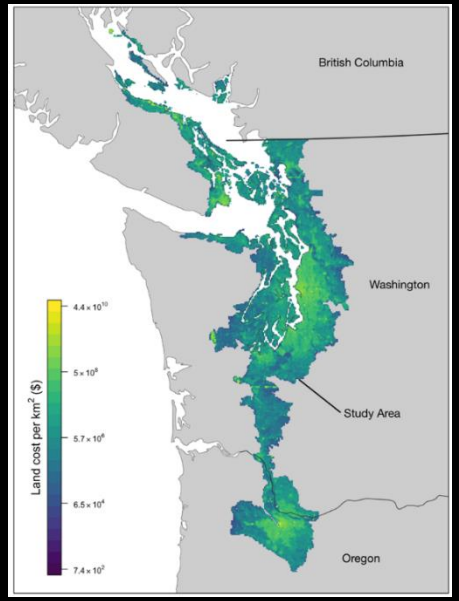
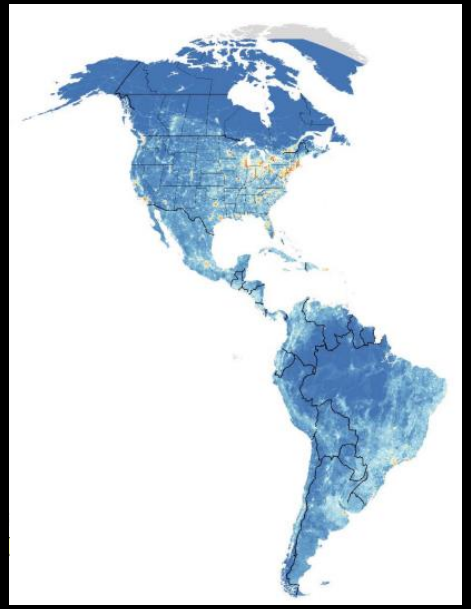


Accounting for efficiency



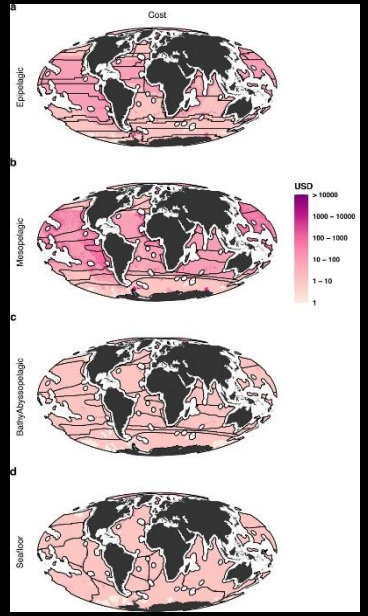
Land value assessments

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



Human pressure

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



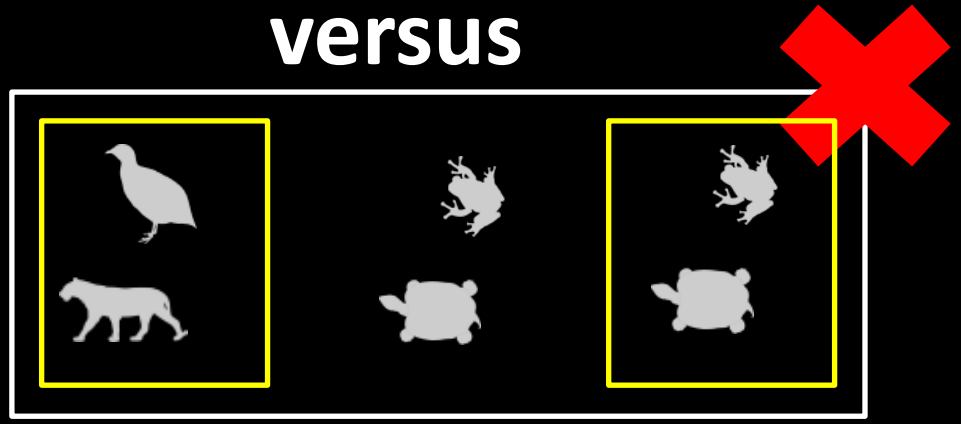
Opportunity cost to commercial fisheries

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

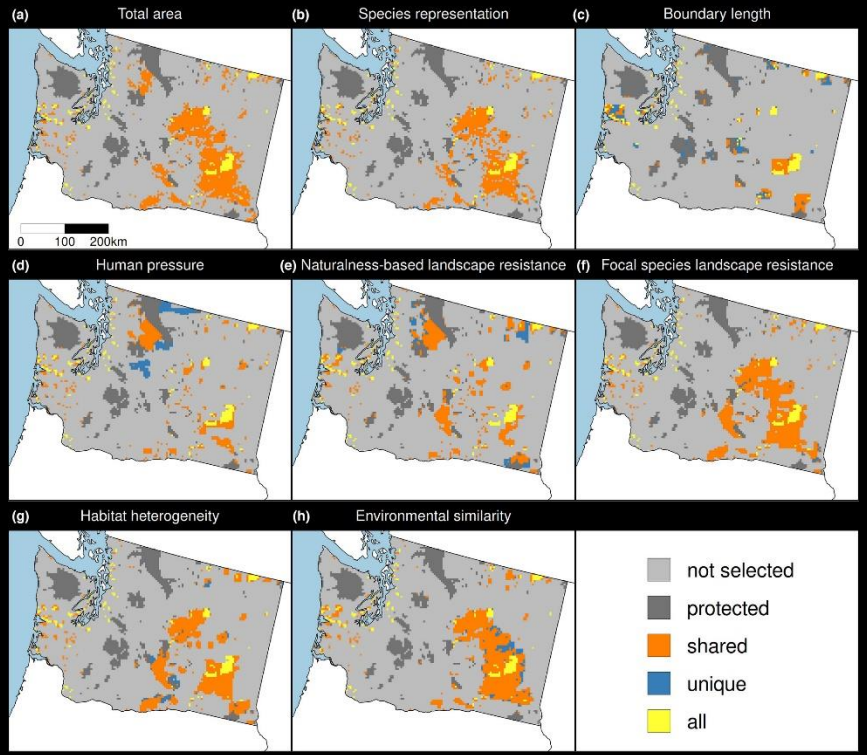
CARE-C Principles

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

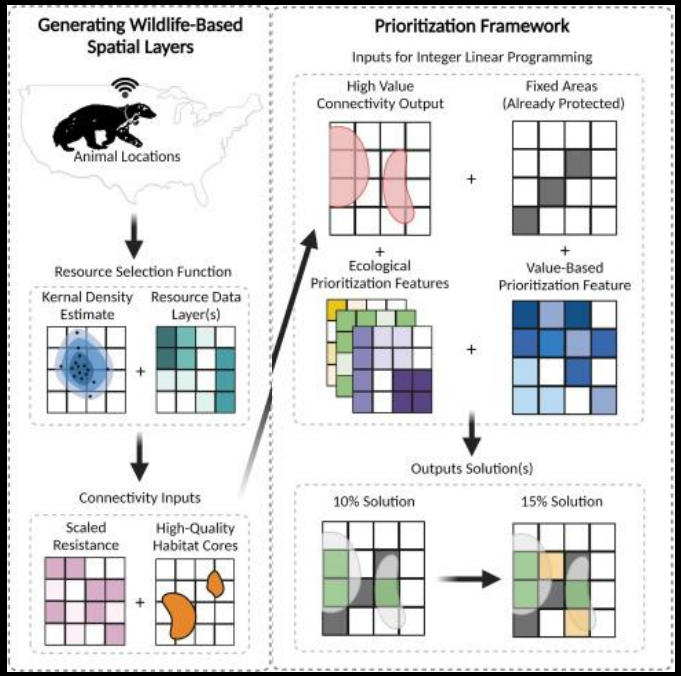
versus



Accounting for connectivity



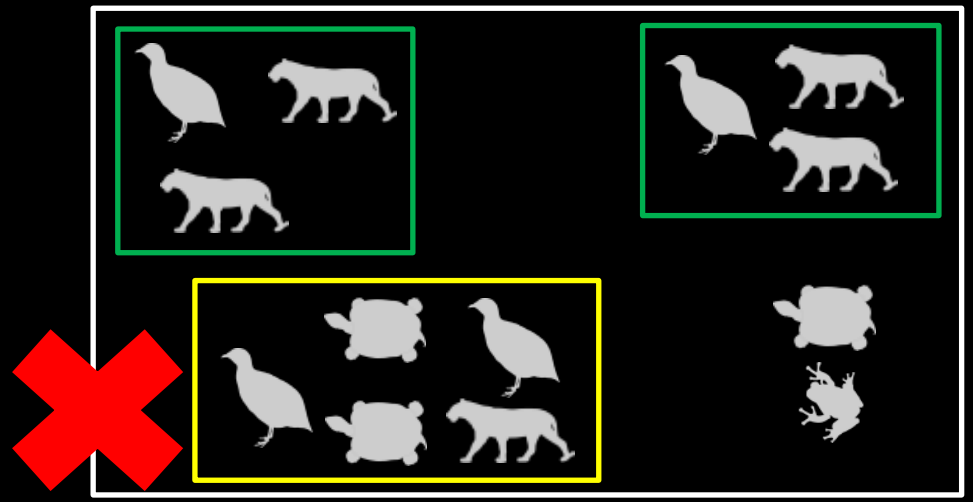
Hanson et al. (2022) DOI:10.1111/1365-2664.14251

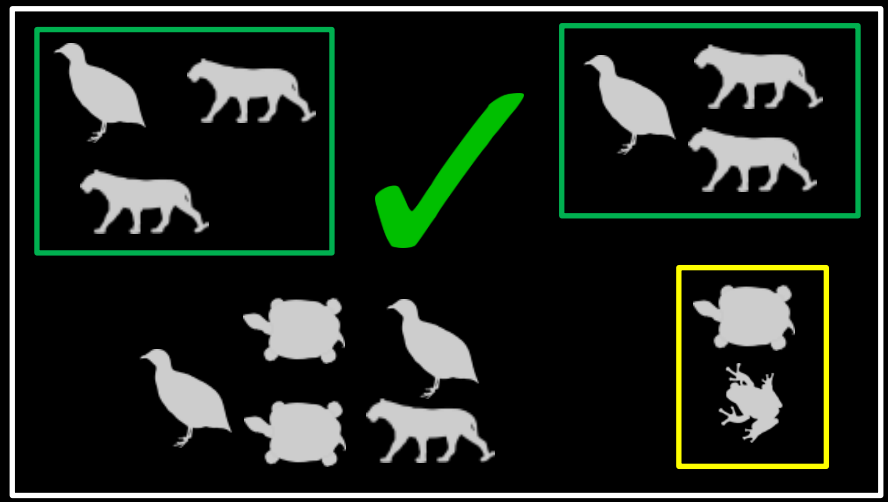


Carroll (2021)
DOI:10.1016/j.xpro.2021.100882

Principle complementarity

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



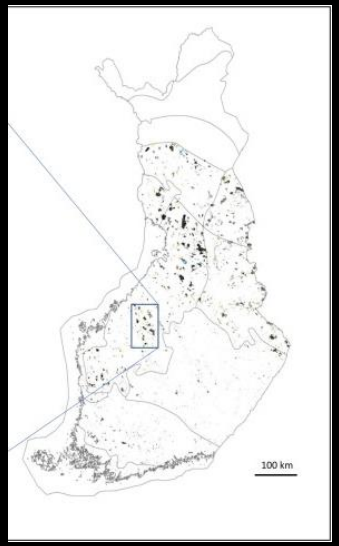


Vane-Wright, et al (1991) Biol Cons, DOI: 10.1016/0006-3207(91)90030-D

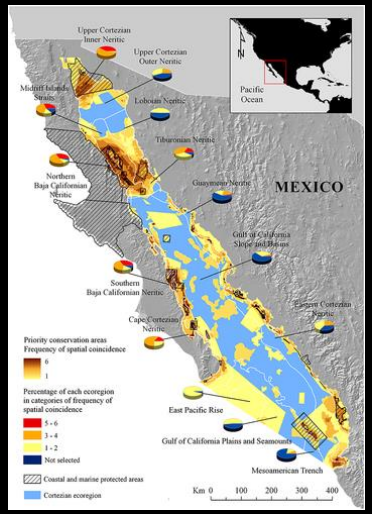
But does all this stuff actually matter?

Systematic conservation planning has helped create protected areas

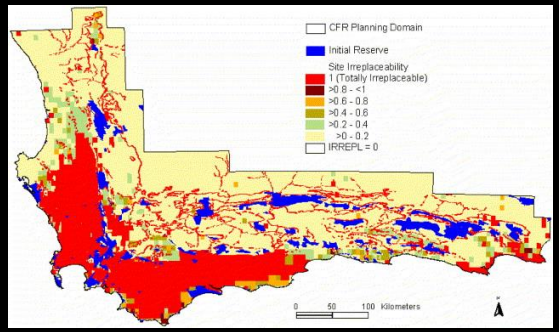
Australia [1]



Finland [2]



Mexico [3]

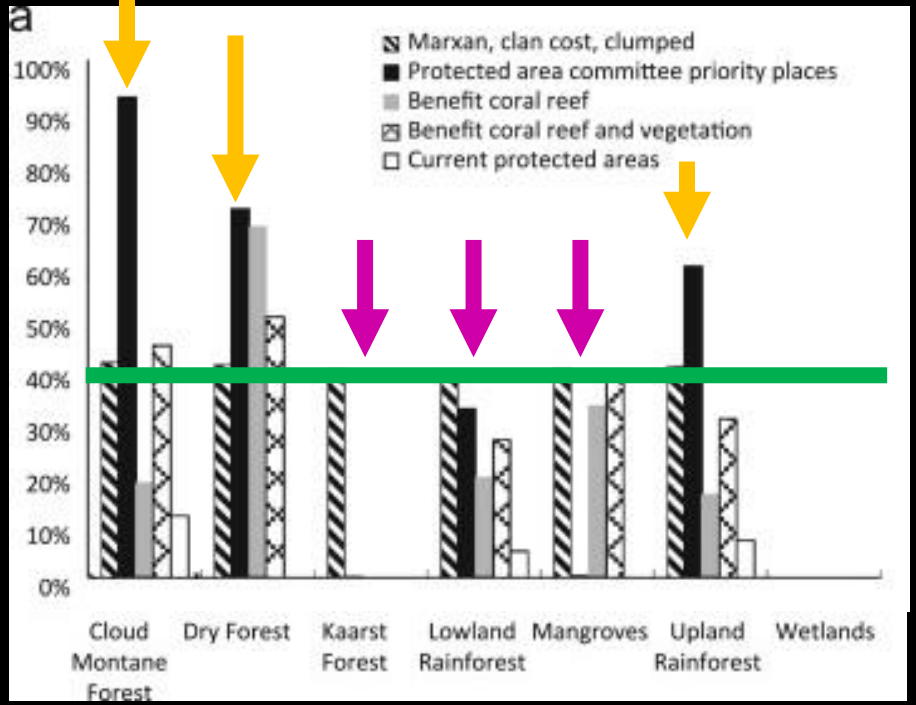


South Africa [4]

[1] Fernandes et al. (2005) Cons Biol, DOI:10.1111/j.1523-1739.2005.00302.x
[2] Kareksela et al. (2020) Biol Conser, DOI:10.1016/j.biocon.2019.108324
[3] Álvarez-Romero et al. (2013) Aquatic Conservation: Marine & Freshwater Ecosystems, DOI :10.1002/aqc.2334
[4] Cowling et al. (2003) Biol Conserv, DOI:10.1016/S0006-3207(02)00425-1

Why not have experts pick priority areas?

Viti Levu island in Fiji



- Klein et al. conducted study to compare approaches for identifying priority areas
- Targets were to represent >= 40% of each habitat type
- SCP (striped bars) selected priority areas that met all targets in cost-effectively
- Experts (solid black bars) selected priority areas that were very inefficient, with some habitat types massively over-represented
- Experts (solid black bars) selected priority areas that failed to meet the targets for some habitat types

Klein et al. (2014) Marine Policy, DOI: 10.1016/j.marpol.2013.10.001

Framing conservation as a decision science problem

- Goal: what is our vision for the future?
- Objective: what quantity are we maximizing/minimizing to achieve the goal?
- Constraints: what must things must we account for when implementing different actions?
- Decisions: what actions can we implement to achieve our objective?

Framing conservation as a decision science problem

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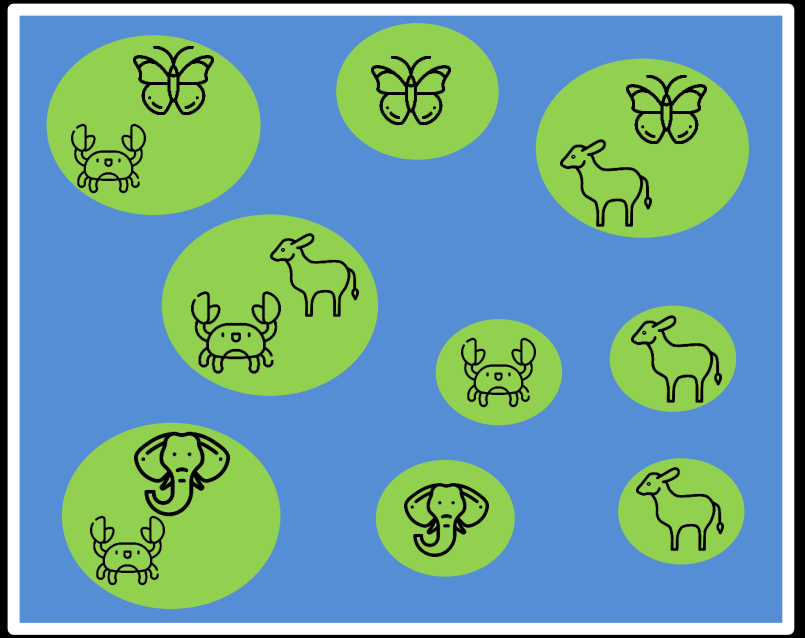
Reserve selection as optimization

- Goal: conserve biodiversity
- Objective: min. # of islands
- Constraints: sufficient habitat for each species (≥ 1 island per species)
- Decisions: create a reserve on an island or not?



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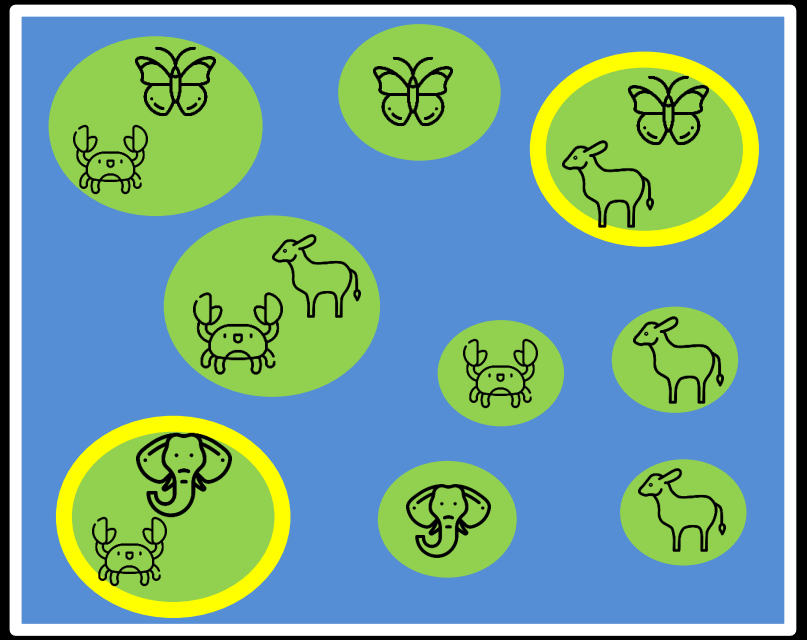
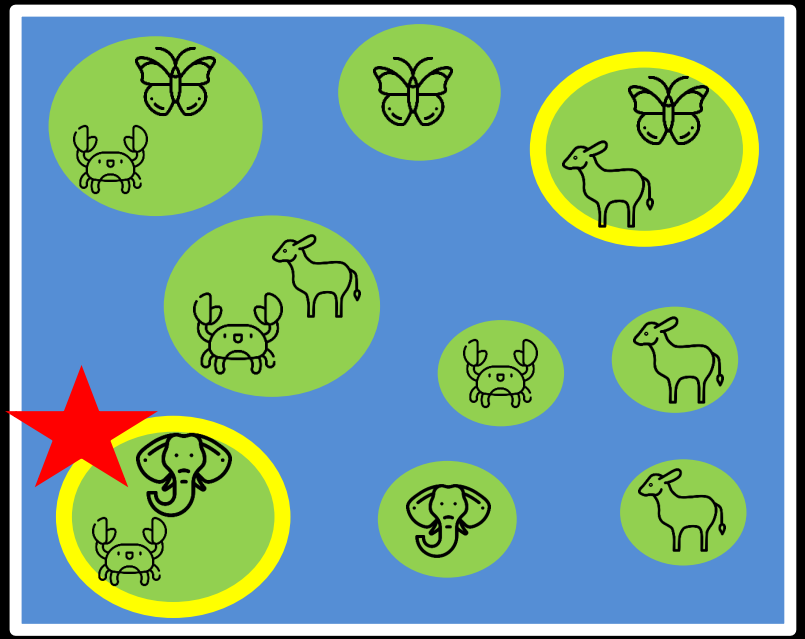


But what are the top priorities?

- Irreplaceability

"[…] continuum of values between 0 and 1, where sites with values of 1 are essential for achieving one or more targets and are therefore irreplaceable."

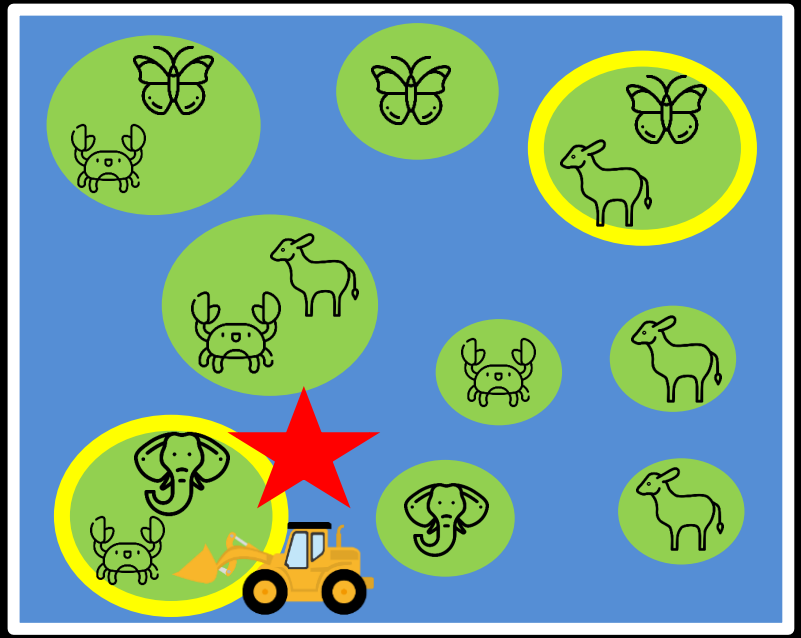


Carwardine etl al. (2007) Biodivers Conserv, DOI:10.1007/s10531-006-9055-4

But where do we start?

- Vulnerability

"[…] measure of the likelihood of the biodiversity in an area being lost to current or threatening processes"

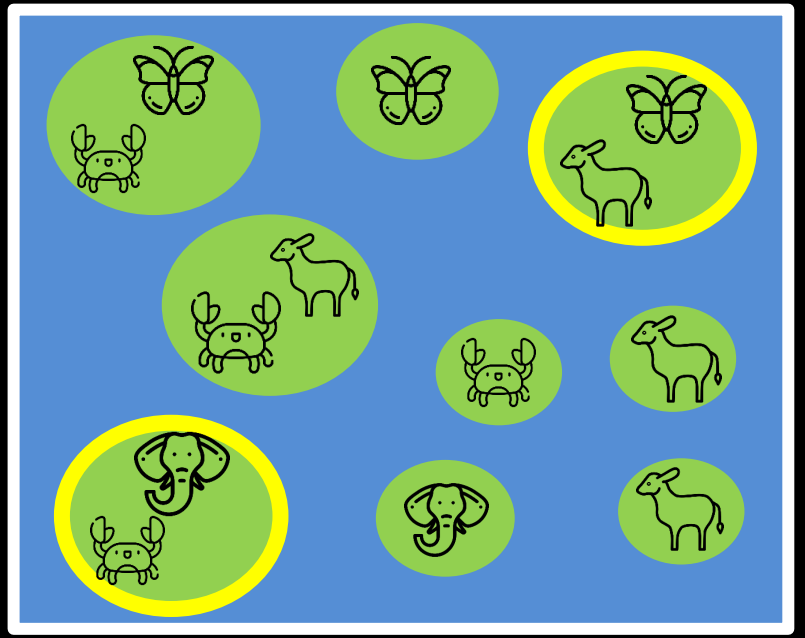


Kukkala & Moilanen (2013) Biol Rev, doi:10.1111/brv.12008

But what are the top priorities?

- Replacement cost

"[…] loss in solution value given that the optimal cost-efficient solution cannot be protected and alternative solutions, with particular sites forcibly included or excluded, are needed"



Carbeza & Moilanen (2006) Biol Cons, DOI:10.1016/j.biocon.2006.04.025

But what are the top priorities?

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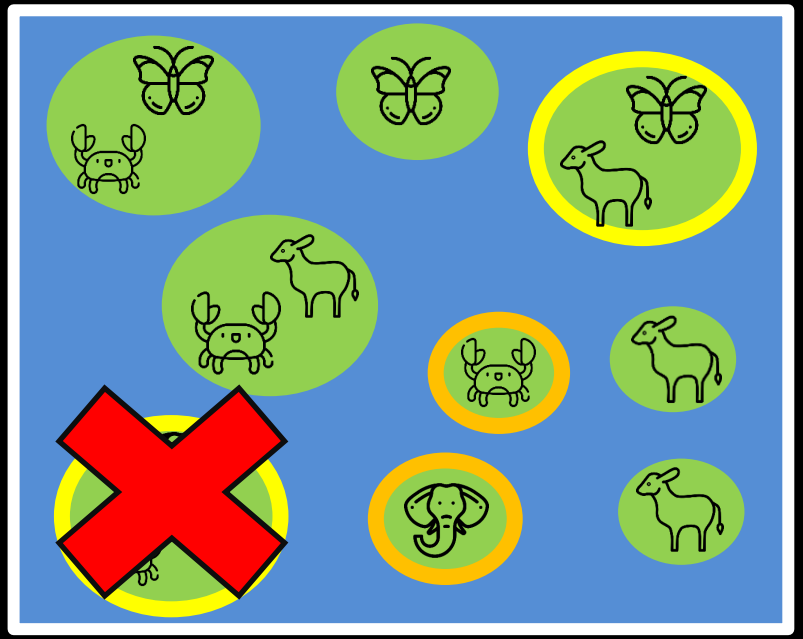
"[…] loss in solution value given that the optimal cost-efficient solution cannot be protected and alternative solutions, with particular sites forcibly included or excluded, are needed"

Alternate solution 1:
1 extra island needed



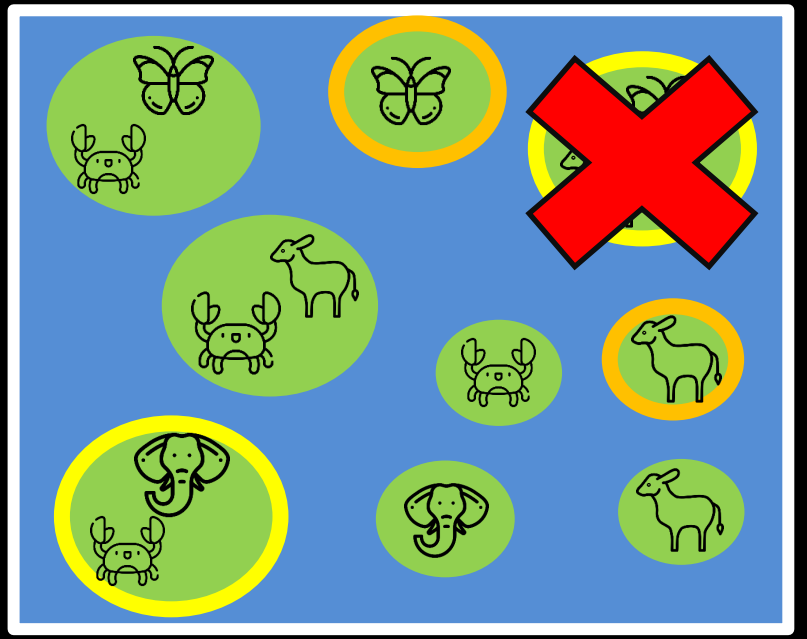
Carbeza & Moilanen (2006) Biol Cons, DOI:10.1016/j.biocon.2006.04.025

But what are the top priorities?

- Replacement cost

"[…] loss in solution value given that the optimal cost-efficient solution cannot be protected and alternative solutions, with particular sites forcibly included or excluded, are needed"

Alternate solution 2:
1 extra island needed



Carbeza & Moilanen (2006) Biol Cons, DOI:10.1016/j.biocon.2006.04.025

But what are the top priorities?

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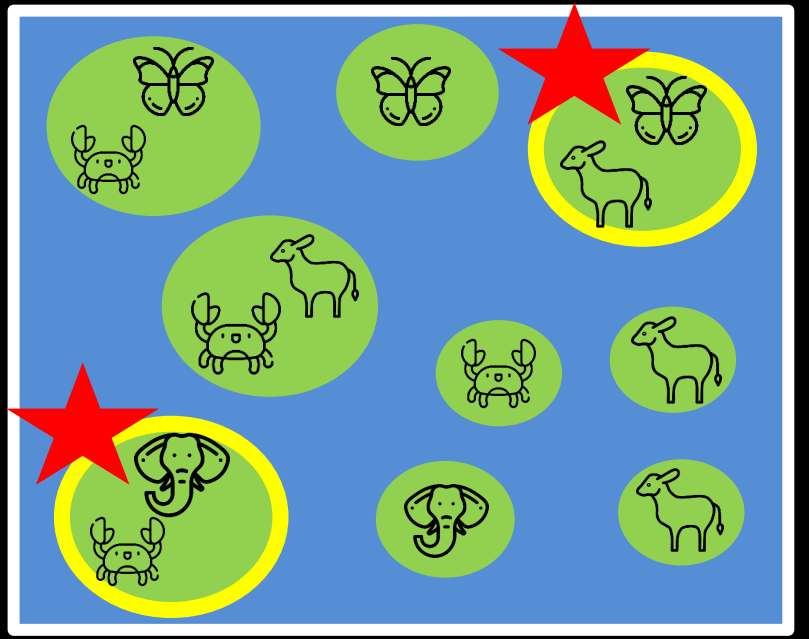
"[…] loss in solution value given that the optimal cost-efficient solution cannot be protected and alternative solutions, with particular sites forcibly included or excluded, are needed"

It's a tie?

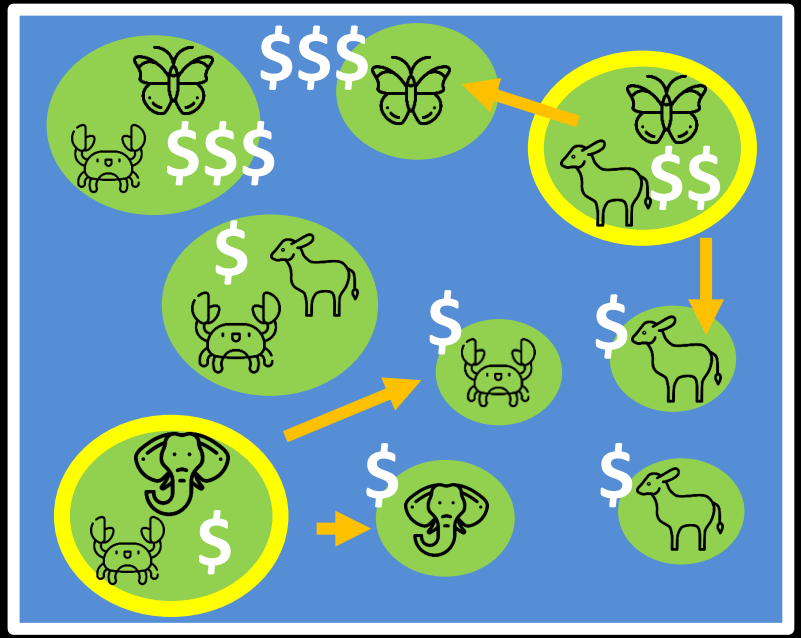


Carbeza & Moilanen (2006) Biol Cons, DOI:10.1016/j.biocon.2006.04.025

But what are the top priorities?

- Replacement cost

Different from irreplaceability because it accounts for lost efficiency, so priorities change if we wanted to minimize total cost (instead of just number of islands)



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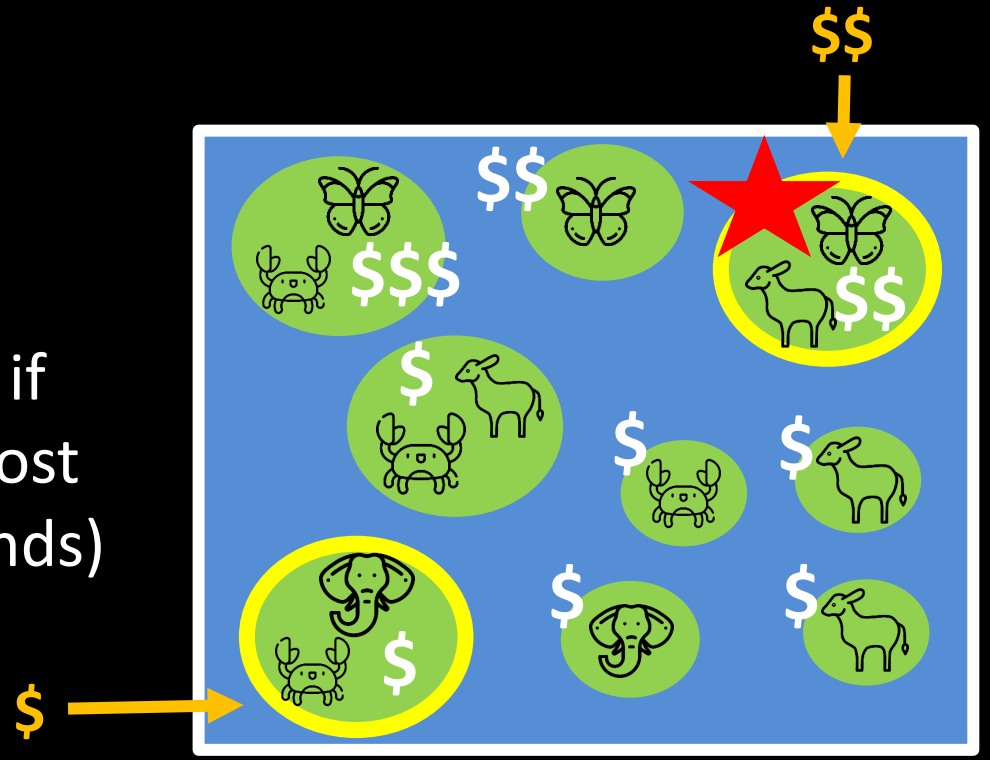


Carbeza & Moilanen (2006) Biol Cons, DOI:10.1016/j.biocon.2006.04.025

Decision support tools

Zonation

- Best suited for budget-limited problems
- Heuristic algorithm
- Trade-off curves for different species
- Lots of built-in ways to handle connectivity
- www.github.com/cbig/zonation-core/releases

Marxan

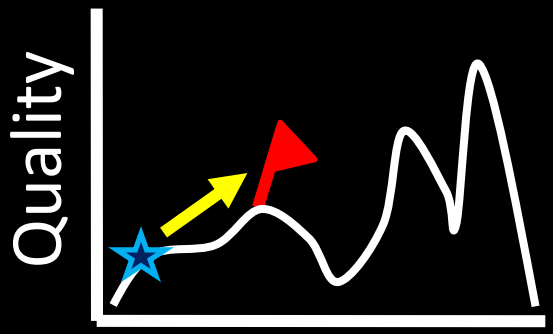
- Best suited for minimum set problems
- Simulated annealing algorithm
- Representation targets for different species
- Generates portfolios of solutions
- www.marxansolutions.org

Prioritizr

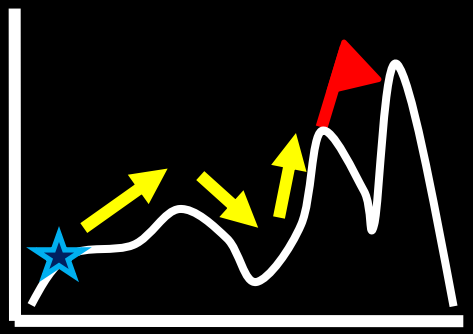
- Best suited for both problem types
- Exact algorithms
- Representation targets for different species
- Extremely customizable
- R package
- www.prioritizr.net
- I'm one of the developers of this tool

Guaranteed quality

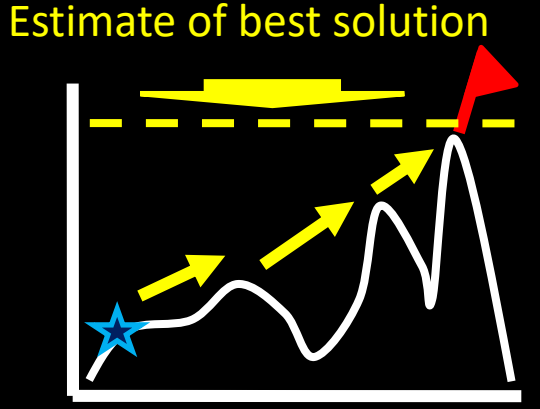
Heuristic algorithms



Meta-heuristic algorithms



Exact algorithms



MARXAN
conservation solutions

GUROBI OPTIMIZATION
IBM CPLEX
COIN|OR

Thanks for listening!

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