# DSWG ICCB Workshop
# prioritizr session

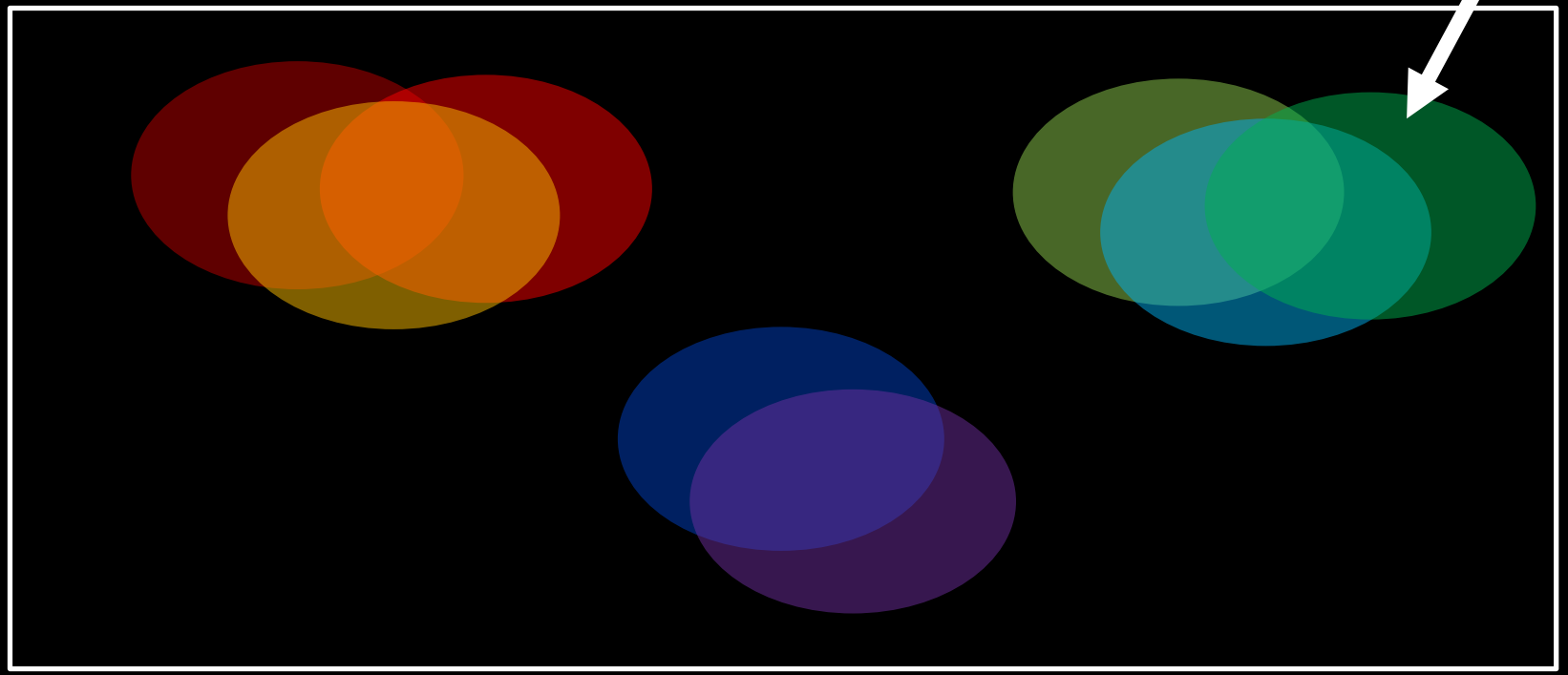
Jeffrey Hanson and Richard Schuster

# 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"

Margules & Pressey (2000) Nature, DOI:10.1038/35012251 Schuster et al. (2020) PeerJ, DOI:10.7717/peerj.9258

# Reserve selection



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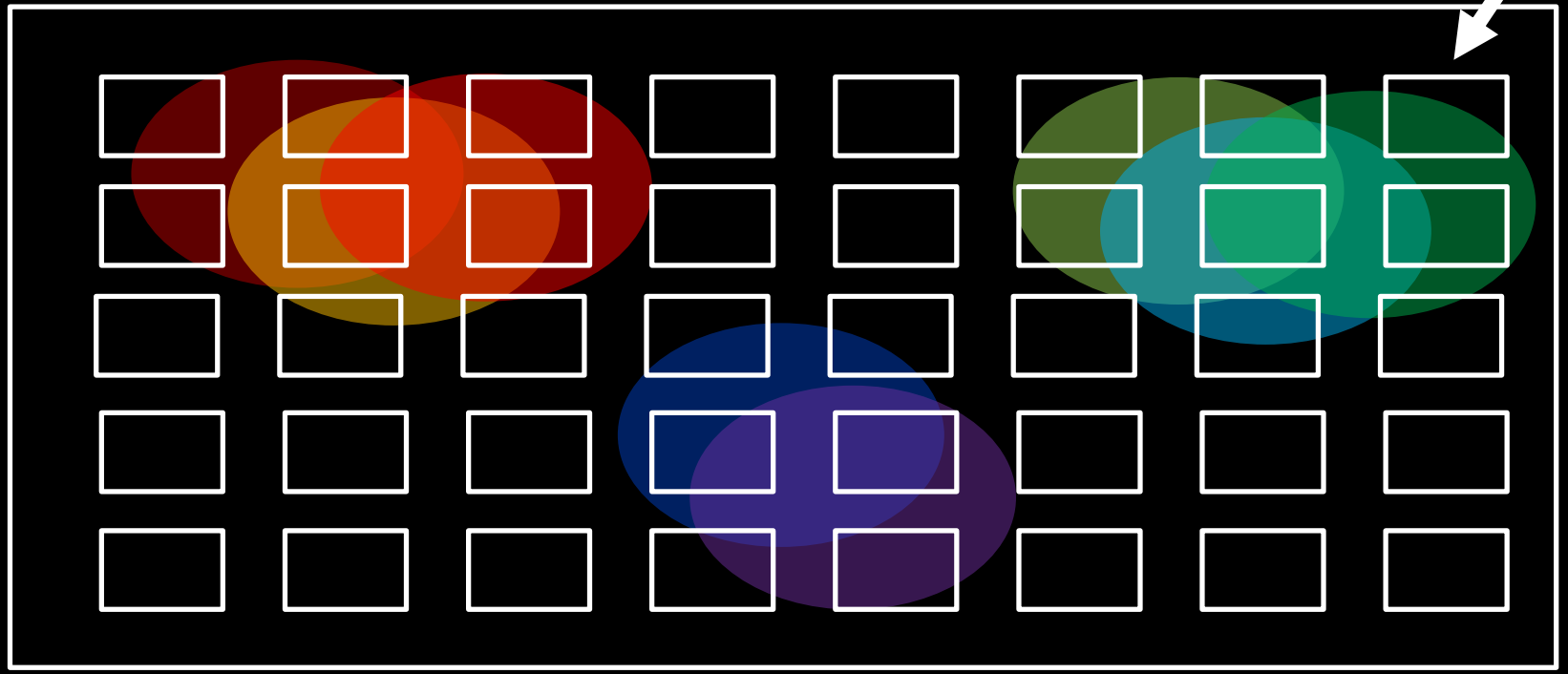

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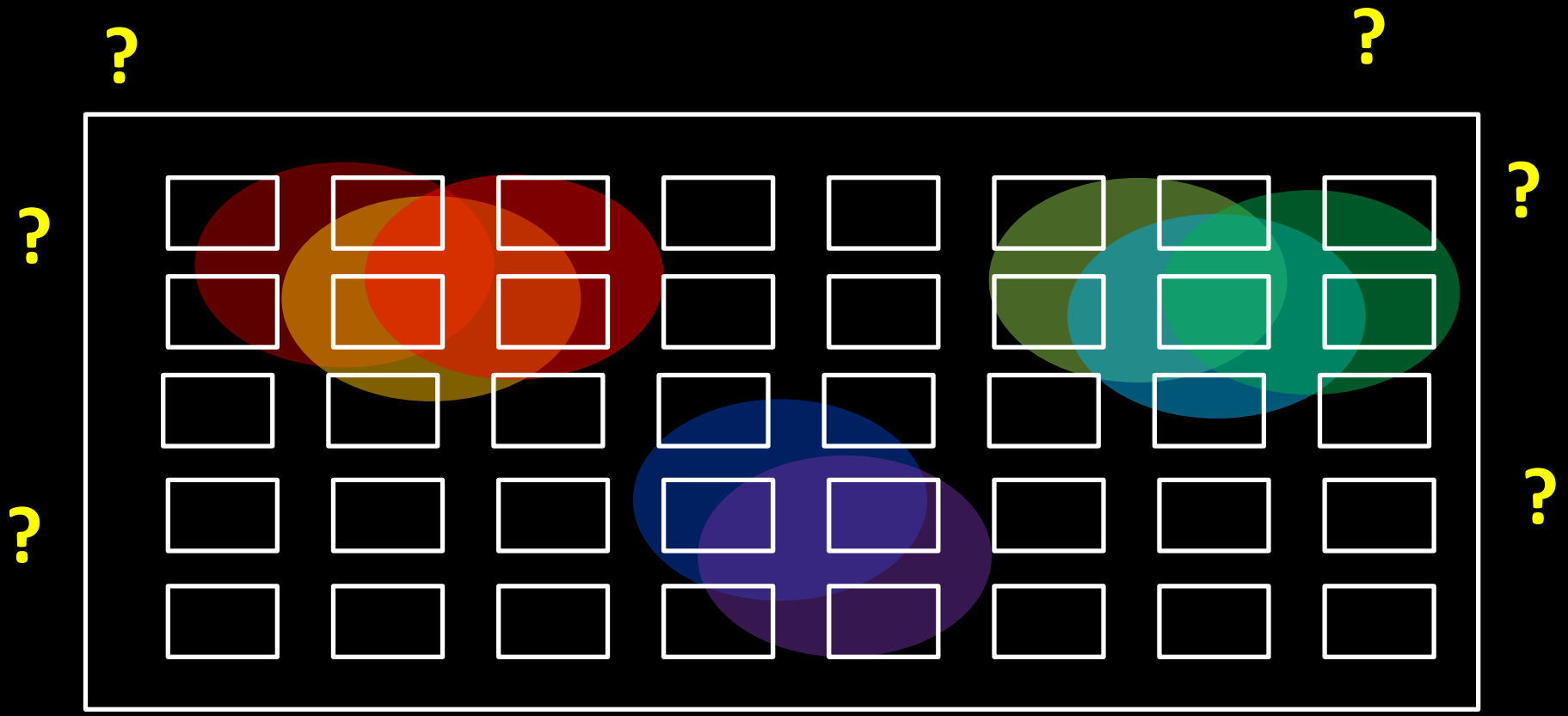
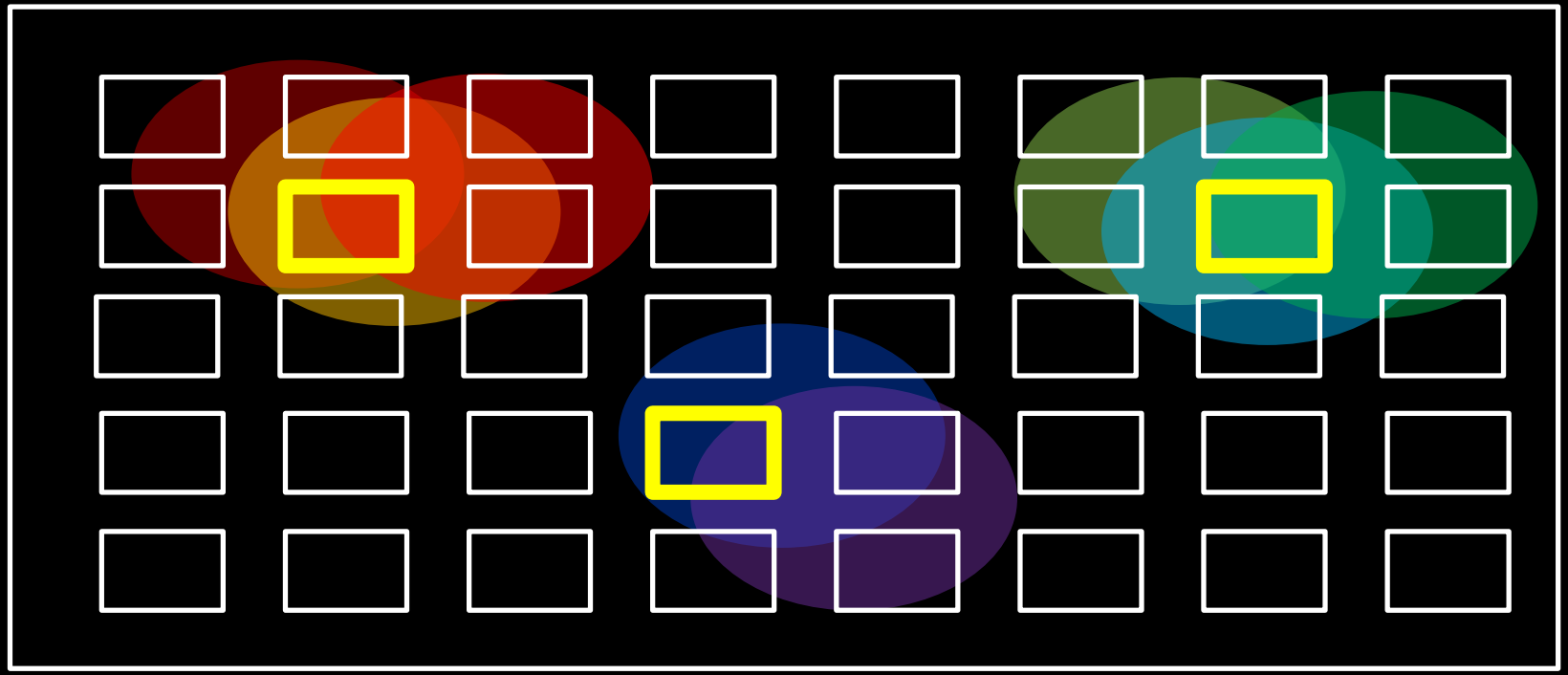


# Reserve selection

*Prioritization*



# CARE Principles

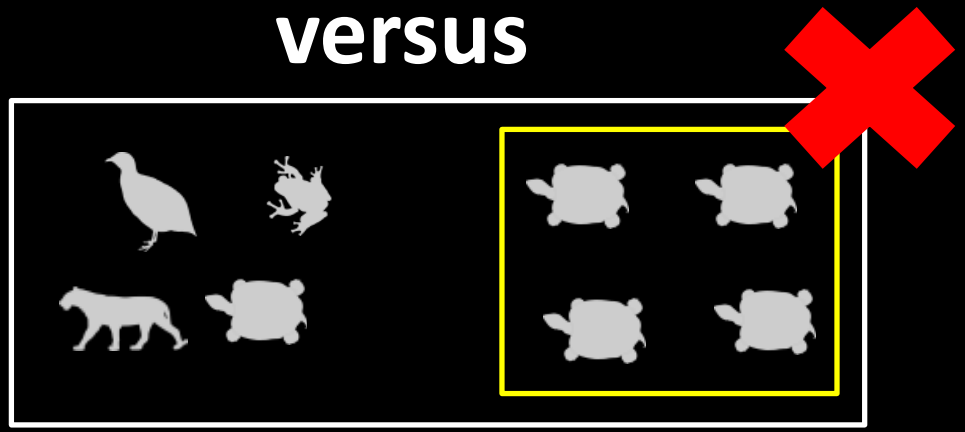
- Comprehensive
- Adequate
- Representative
- Efficient

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

# CARE Principles

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

versus



# CARE Principles

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- Representative
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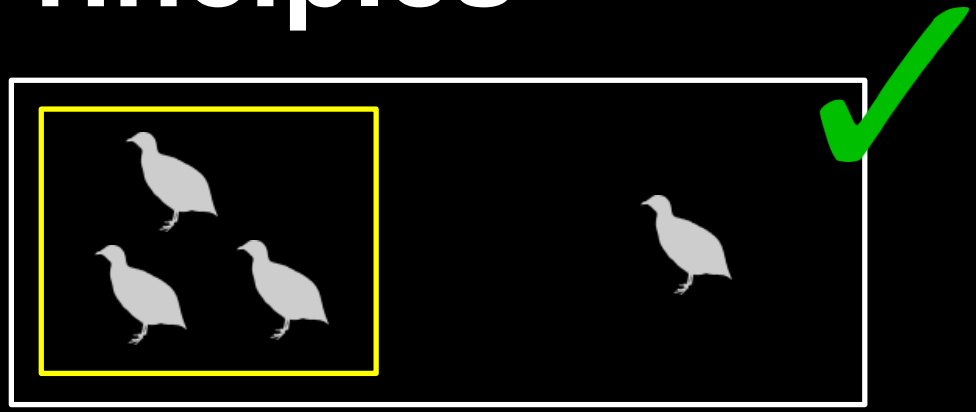
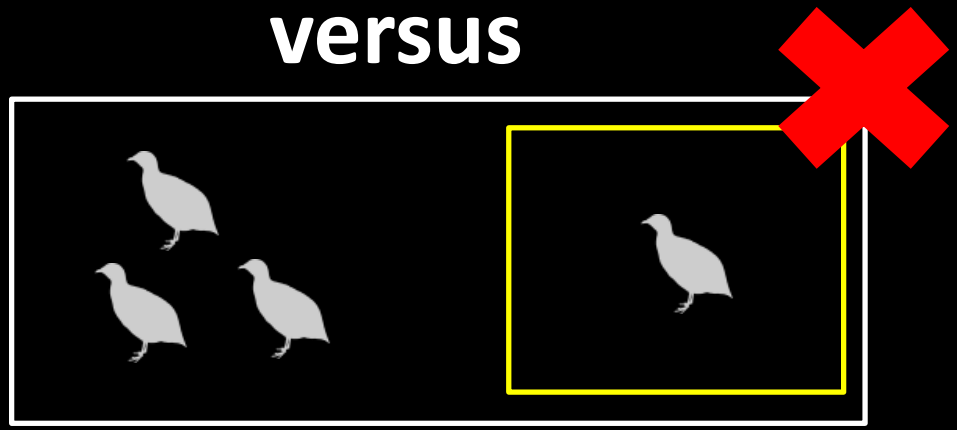


versus



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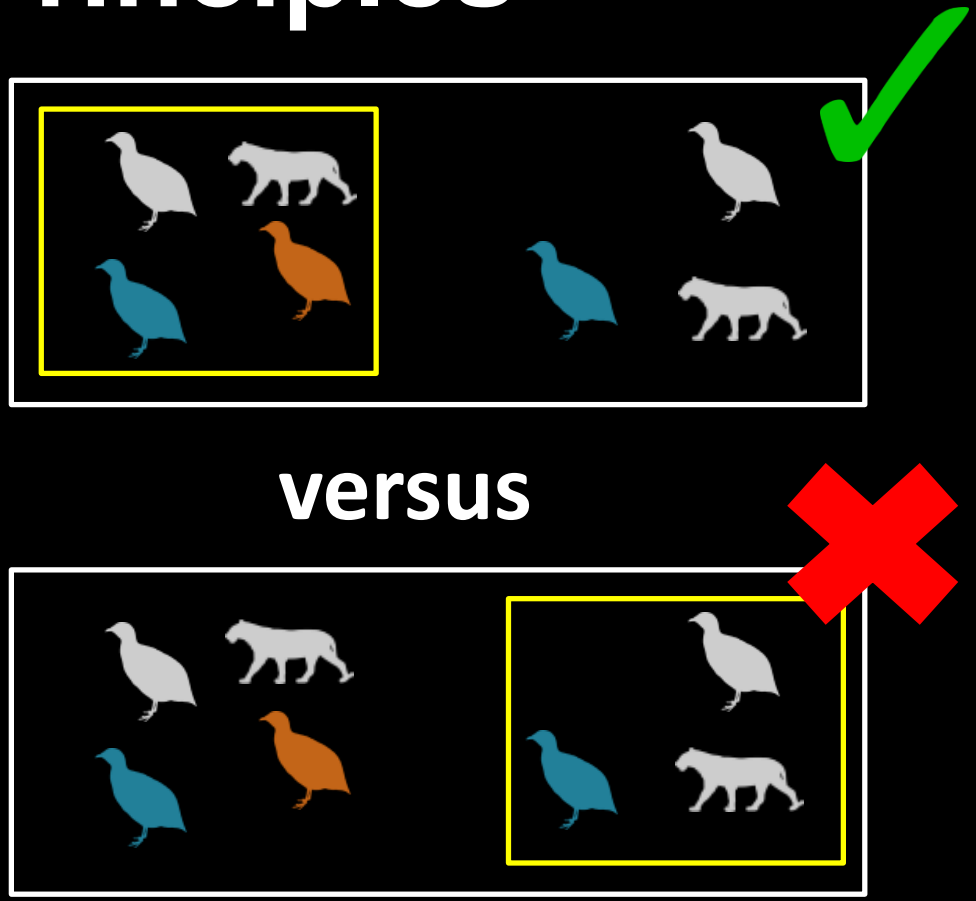

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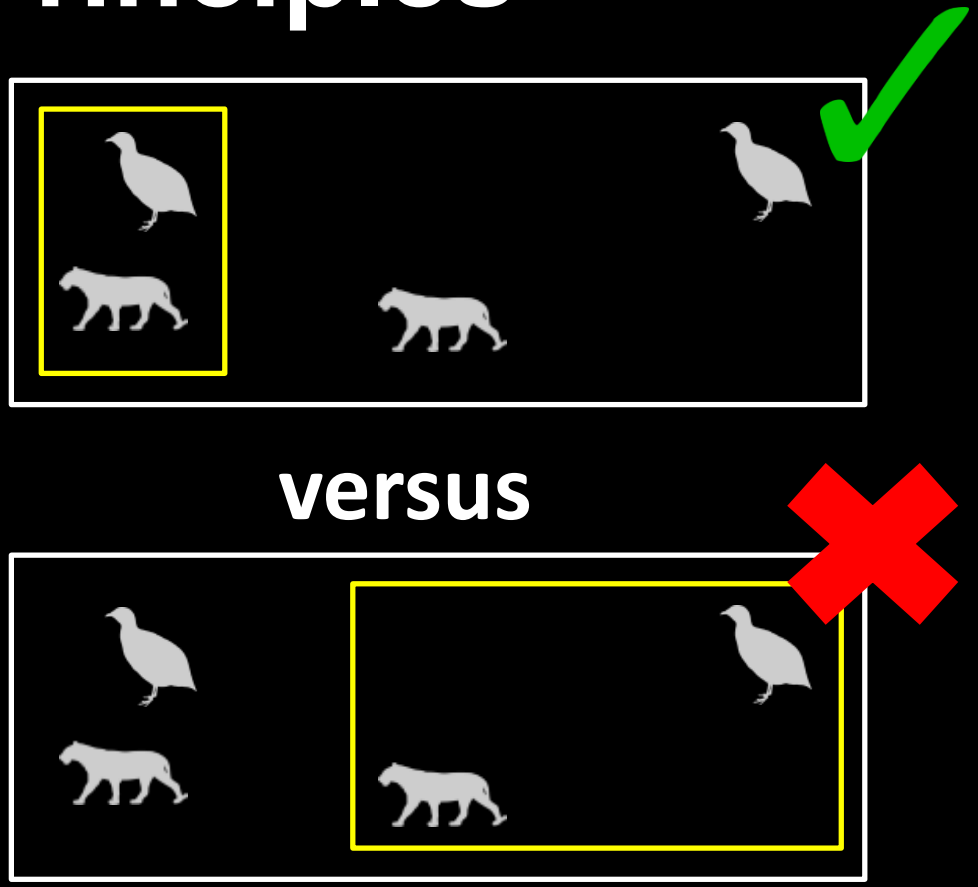
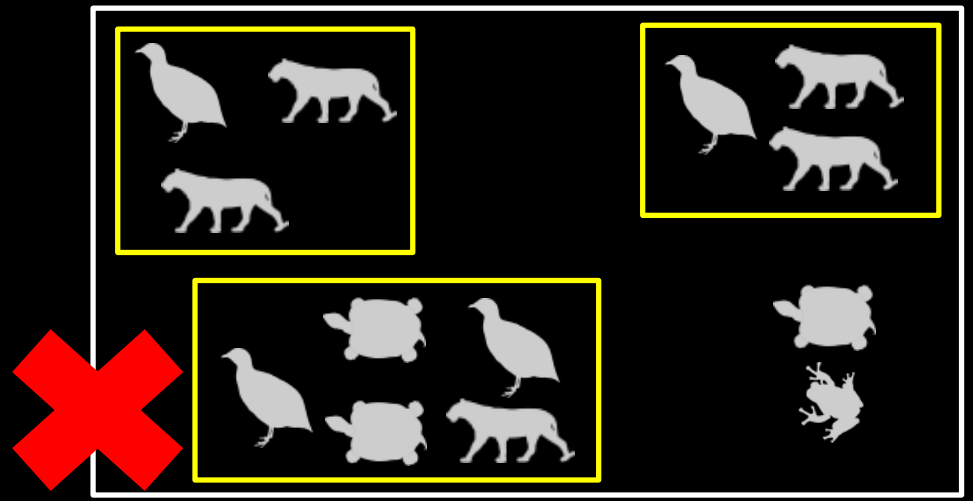
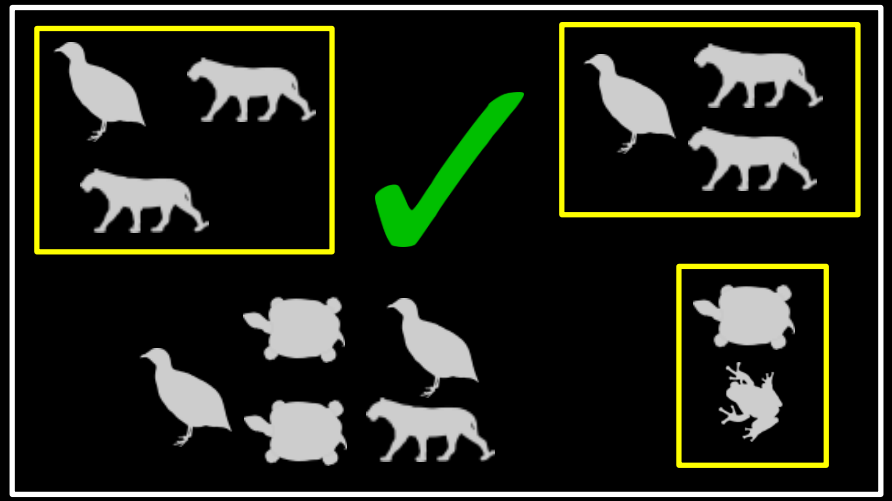


# Principle of complementarity

Protected areas should “complement” each other to maximize performance of the overall prioritization



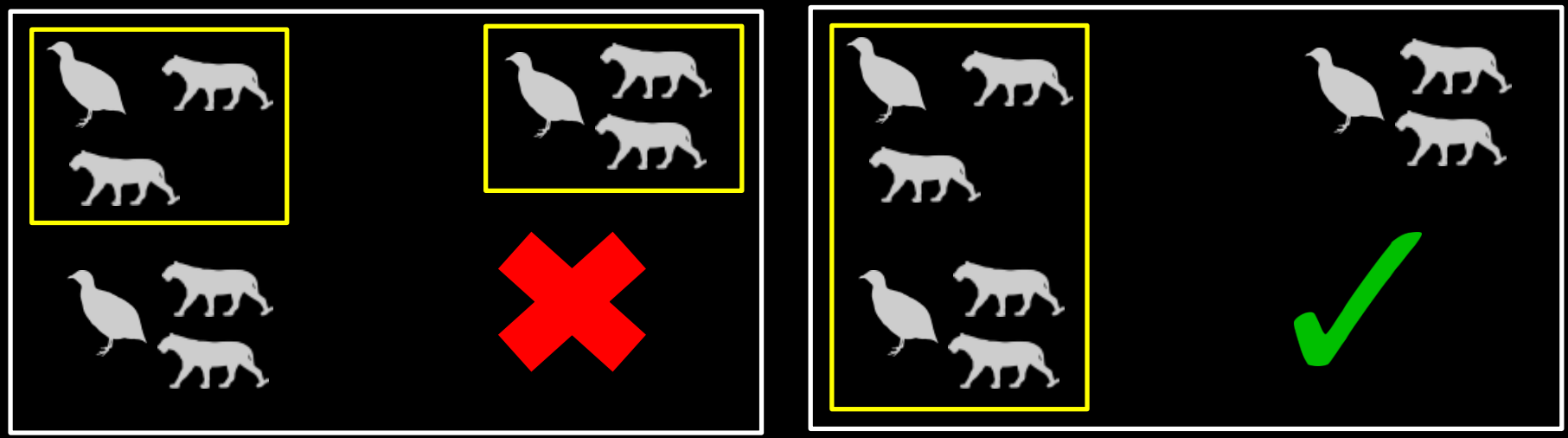


Vane-Wright et al. (1991) Biol Cons, DOI:10.1016/0006-3207(91)90030-D

# Connectivity

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

**Within-reserve connectivity**

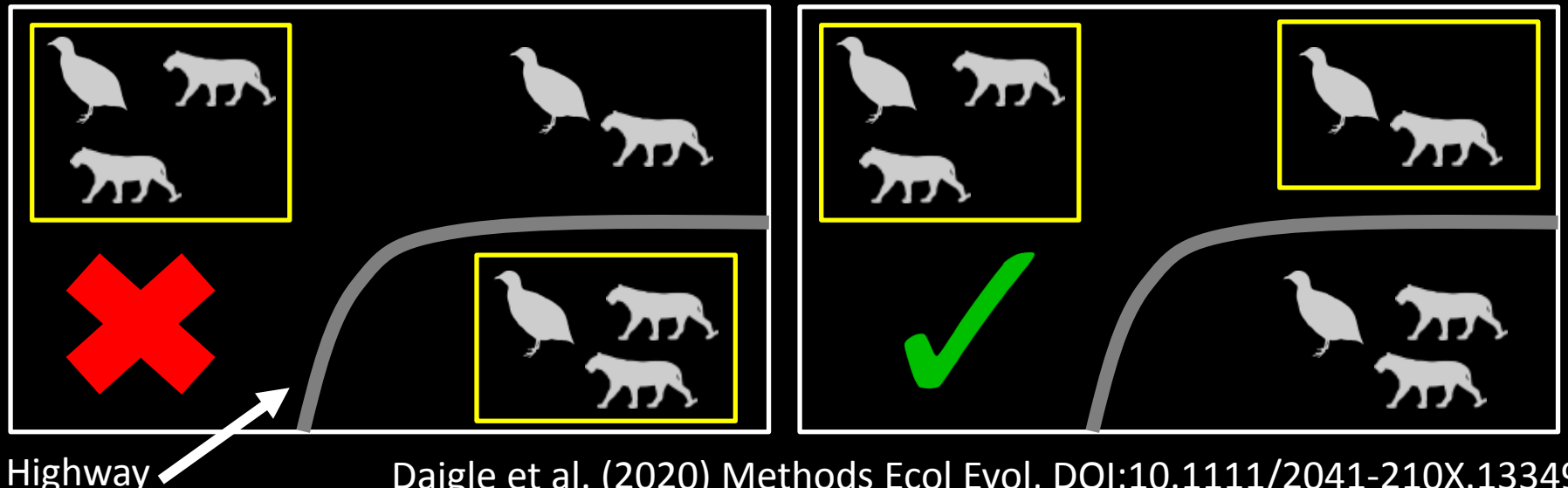


Daigle et al. (2020) Methods Ecol Evol, DOI:10.1111/2041-210X.13349

# Connectivity

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

**Between-reserve connectivity**




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

# 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”

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

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- **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 ”

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- **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 ”
- **Expert 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

# Decision support tools

Zonation

www.github.com/cbig/zonation-core/releases

Marxan


www.marxansolutions.org

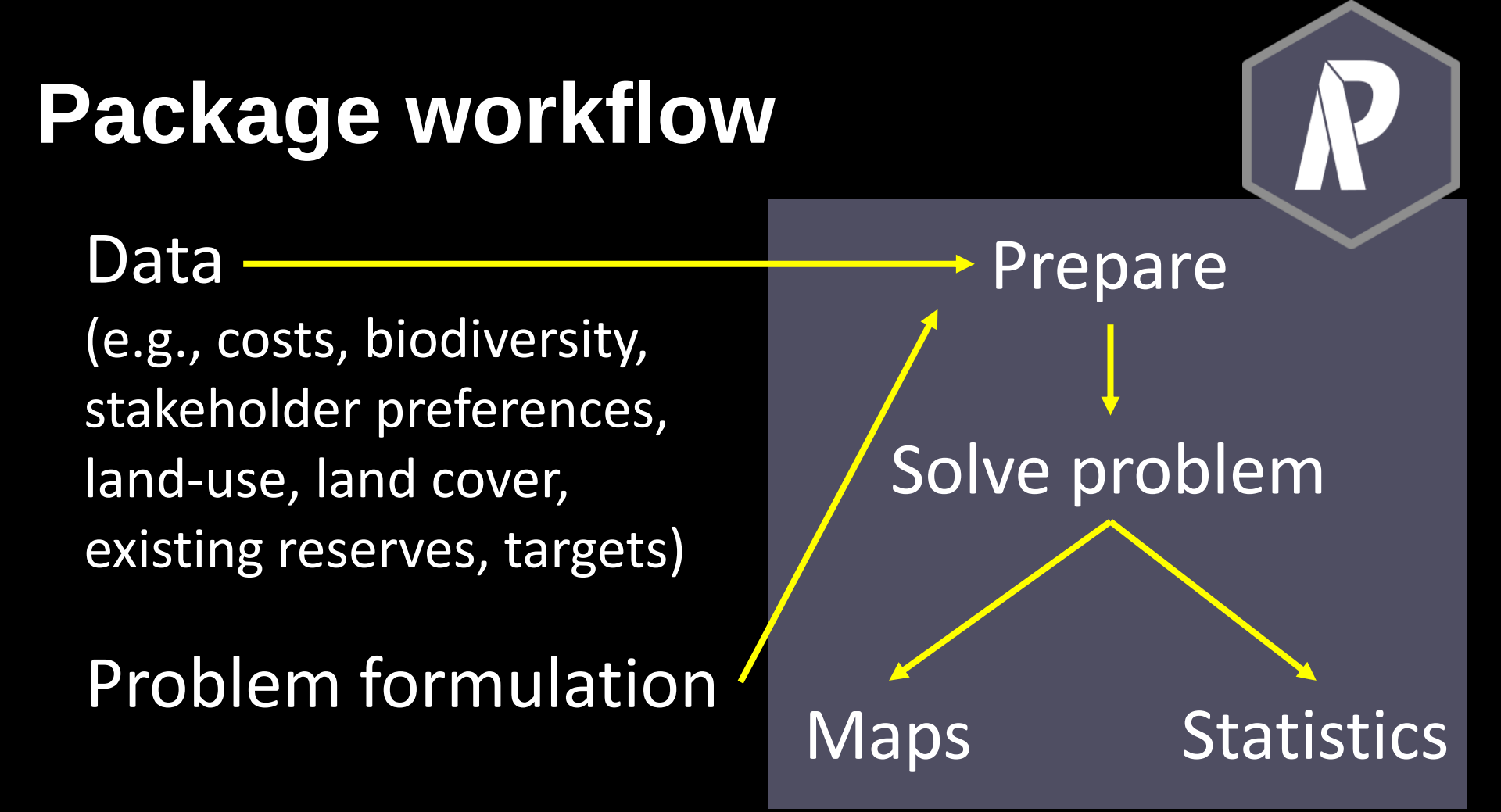
prioritizr

www.prioritizr.net

# prioritizr

- Design your problem
- Guaranteed quality
- Solve it fast

# Package workflow



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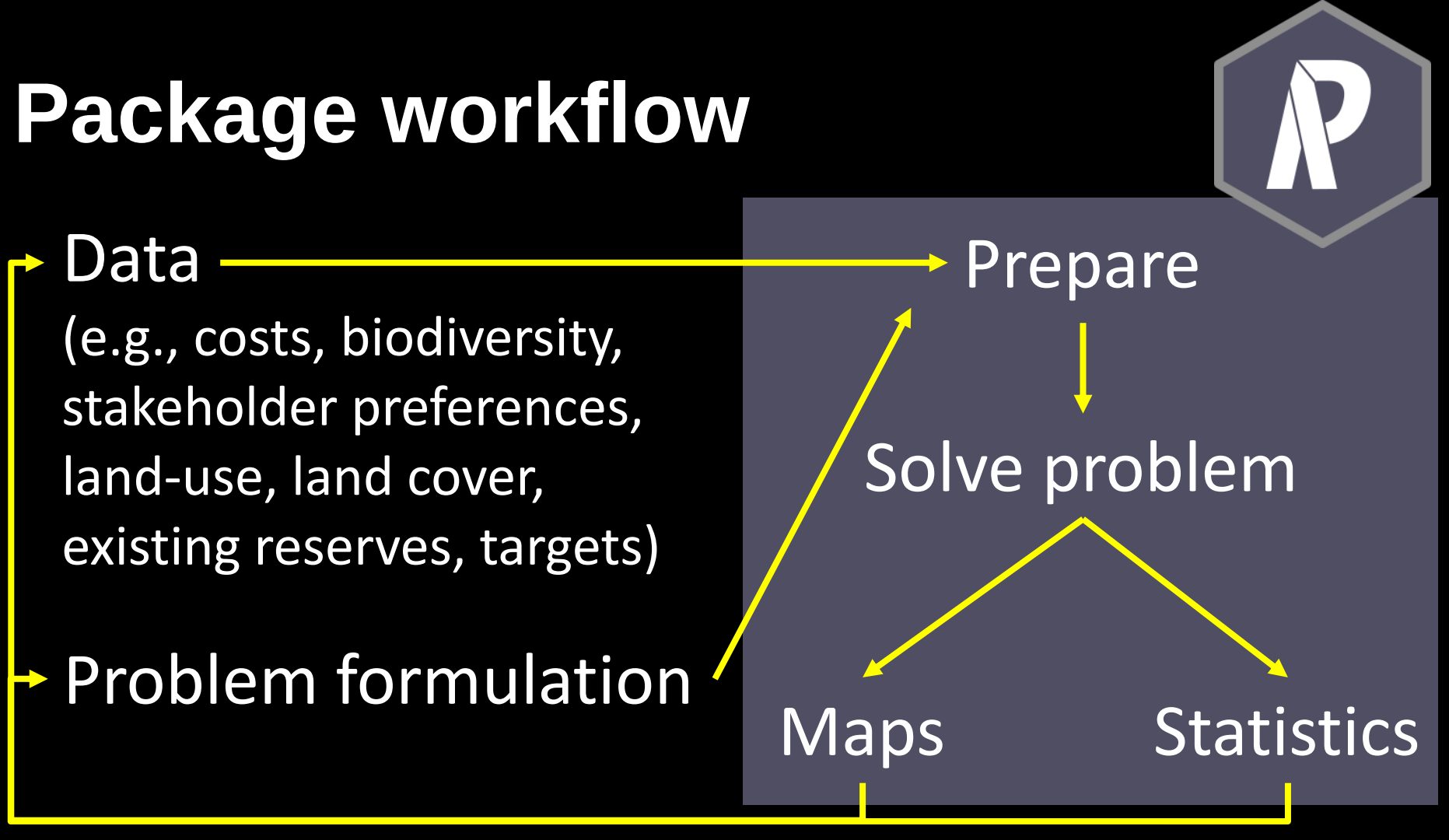


# Design your problem

- Goal: what is our vision for the future?

- Objective: primary quantity we should maximize/minimize?
- Penalties: additional quantities we should minimize/maximize?
- Targets: what is the minimum desirable amount of each feature?
- Constraints: what limits our ability to implement actions in certain planning units, or certain combinations of planning units?
- Decisions: what type of action(s) can we implement?

# Design your problem

- Objective:

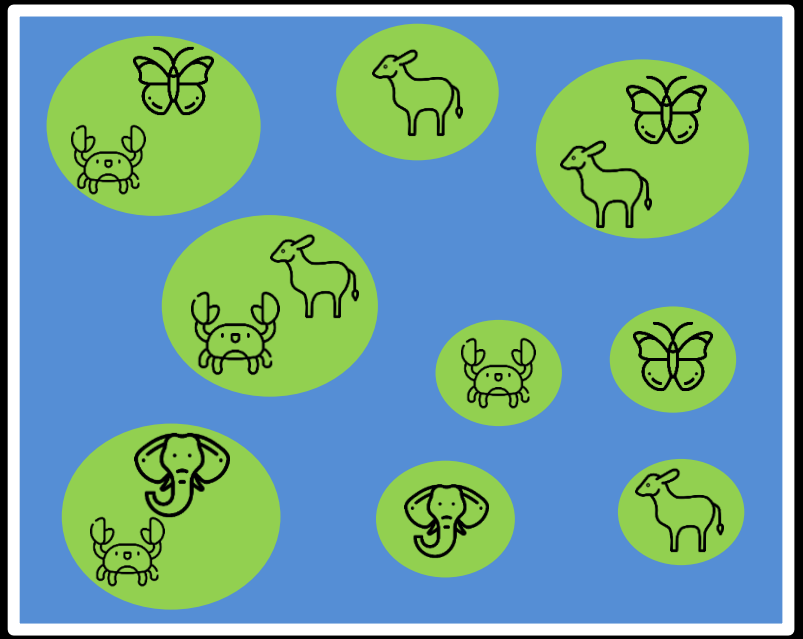
  minimize # islands
- Targets:

  ≥ 1 population per species
- Constraints:

  none
- Decisions:

  protect or not (binary)

What's the solution?



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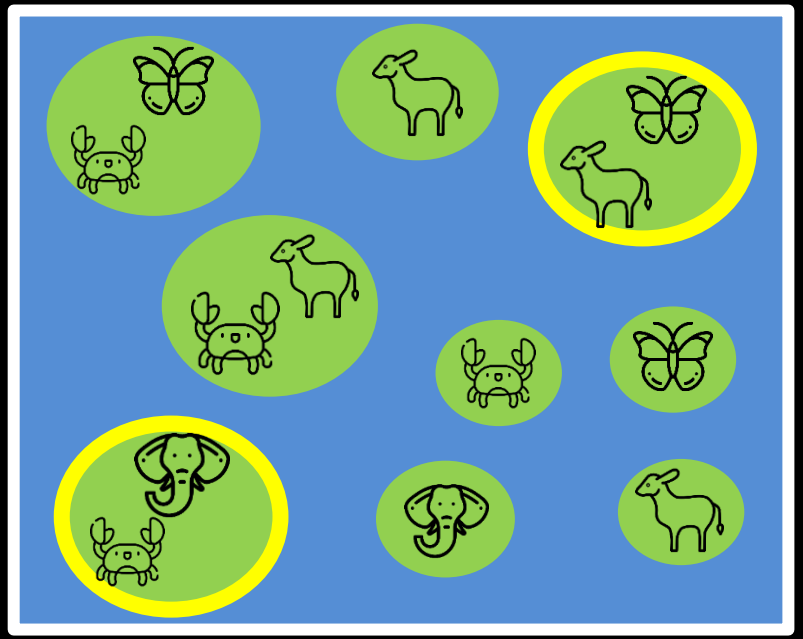

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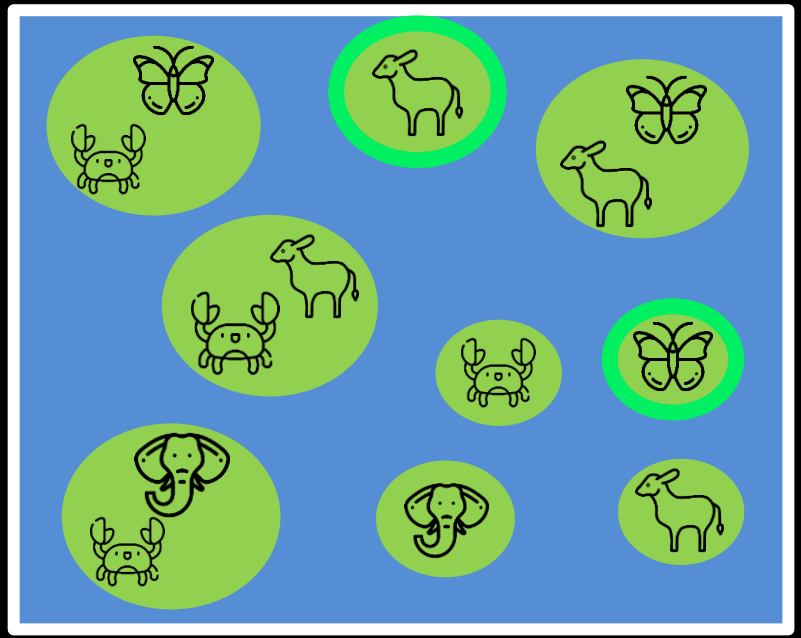

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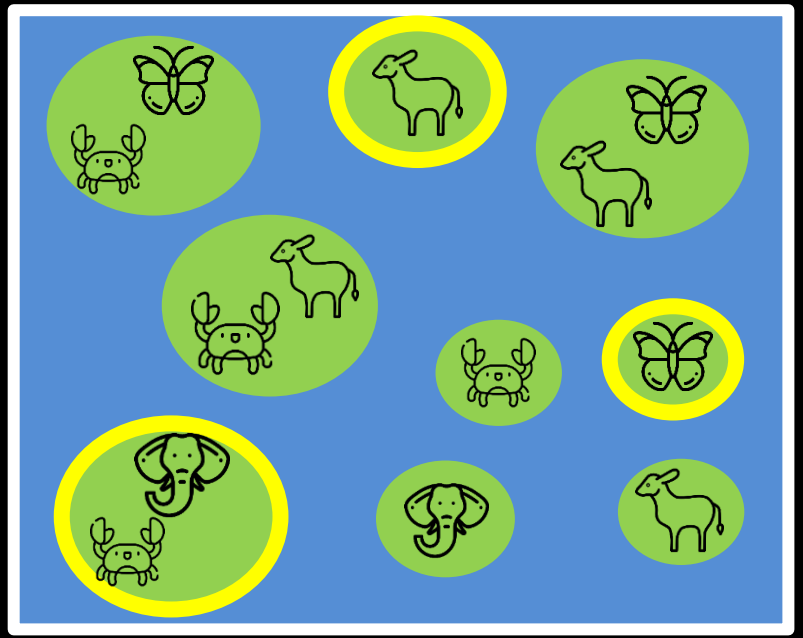

# Design your problem

- Objective:

  minimize opportunity cost
- Targets:

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- Constraints:

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- Decisions:

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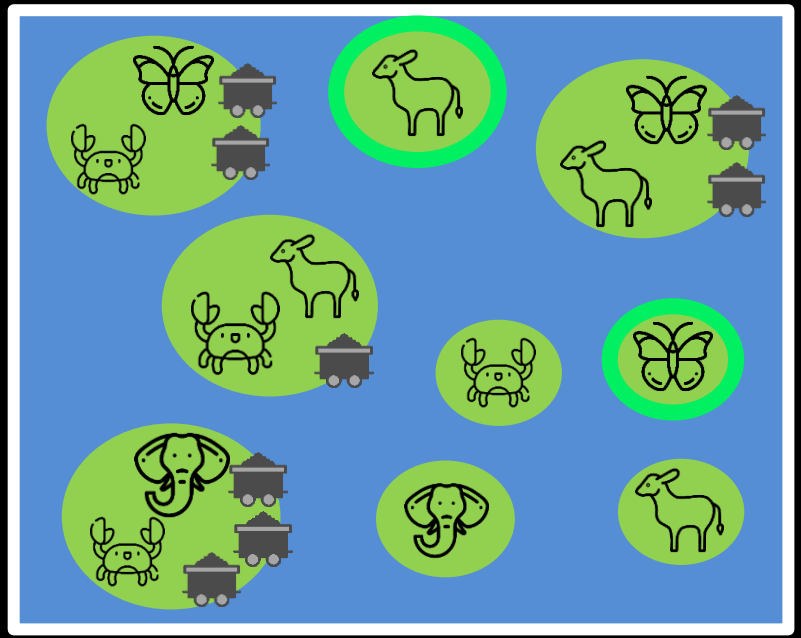
What's the solution?



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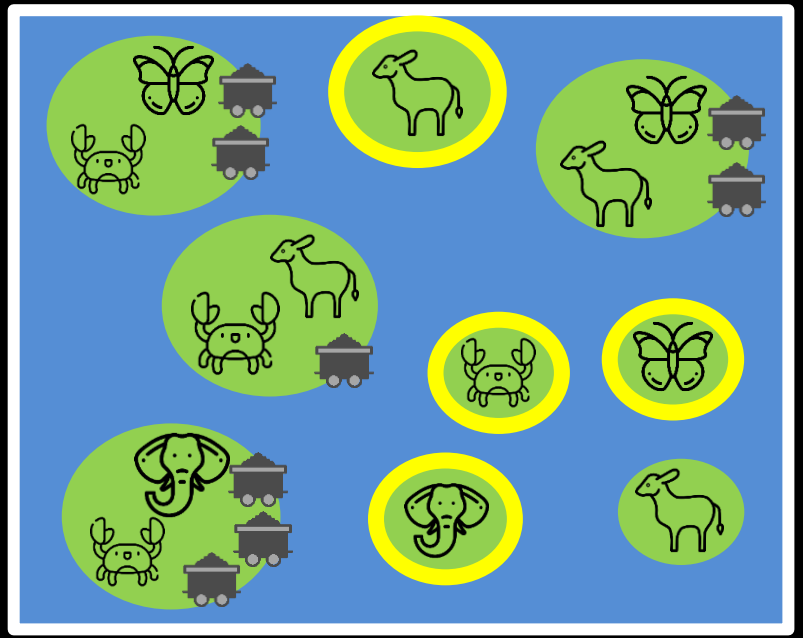
Prioritization



# Design your problem

Mental model

```
problem <- data +
           objective +
           penalties +
           targets +
           constraints +
           decision type +
           solver

solution <- solve(problem)
```

# Design your problem

## Mental model

```
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           penalties +
           targets +
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solution <- solve(problem)
```
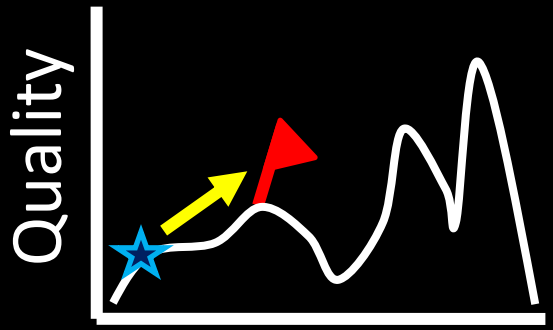

## R Code

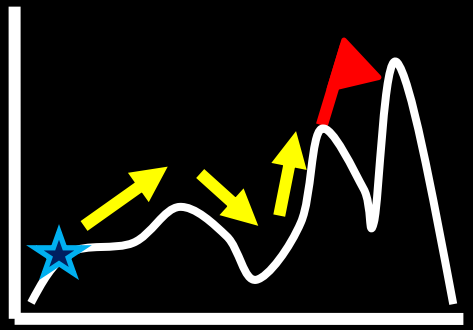
```
p <- problem(areas, feats) %>%
 add_min_set_objective() %>%
 add_boundary_penalties(5) %>%
 add_relative_targets(0.1) %>%
 add_locked_in_constraints("pa") %>%
 add_binary_decisions() %>%
 add_cbc_solver()


solution <- solve(p)
```

# Guaranteed quality

## Heuristic algorithms

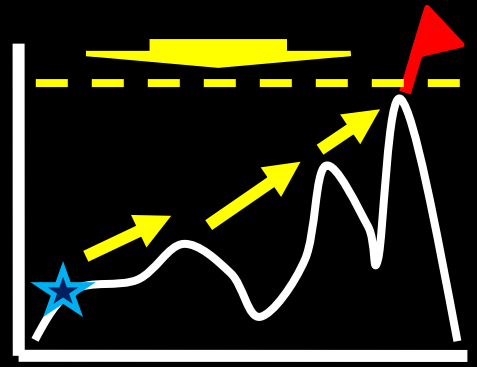



## Meta-heuristic algorithms




## Exact algorithms

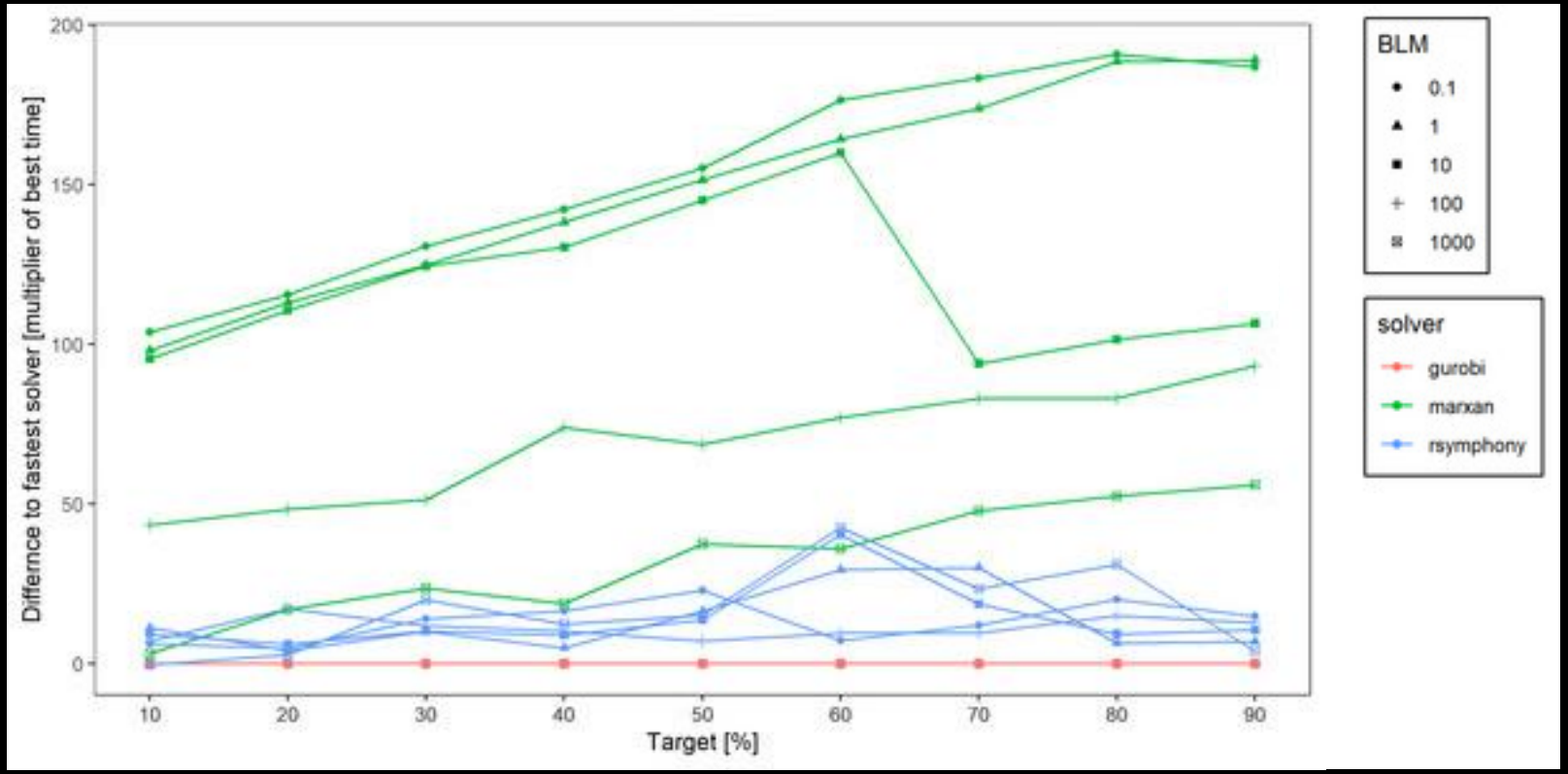
Estimate of best solution




MARXAN
conservation solutions

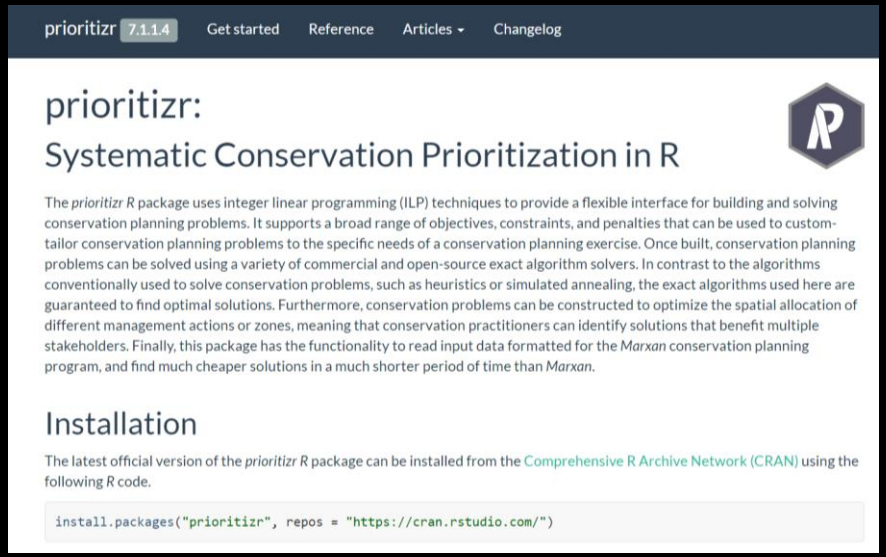
GUROBI OPTIMIZATION
IBM CPLEX
COIN|OR

# Solve it fast!

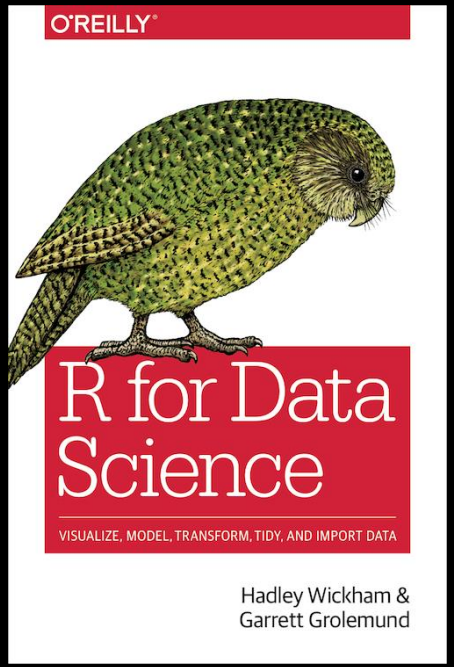



Schuster et al. (2020) PeerJ, DOI:10.7717/peerj.9258

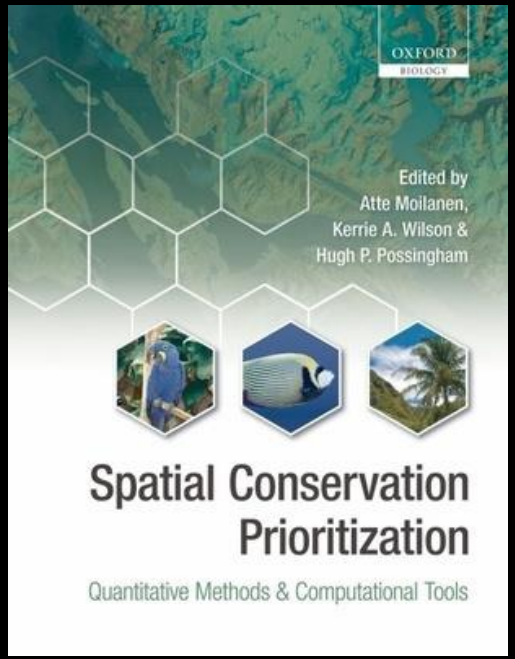
# Getting help




Manual, tutorials, news updates,
and links to code repository to submit
bug reports and ask questions:
https://prioritizr.net



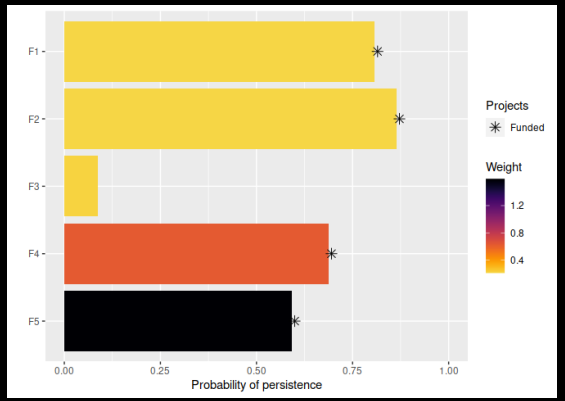

Available for free:
https://r4ds.had.co.nz




Amazing book!

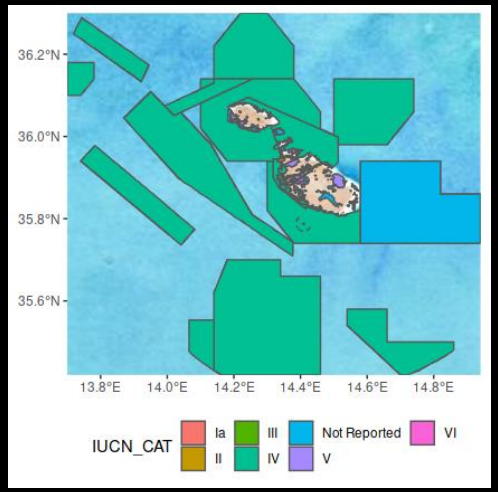
# You might also be interested in…

## oppr R package



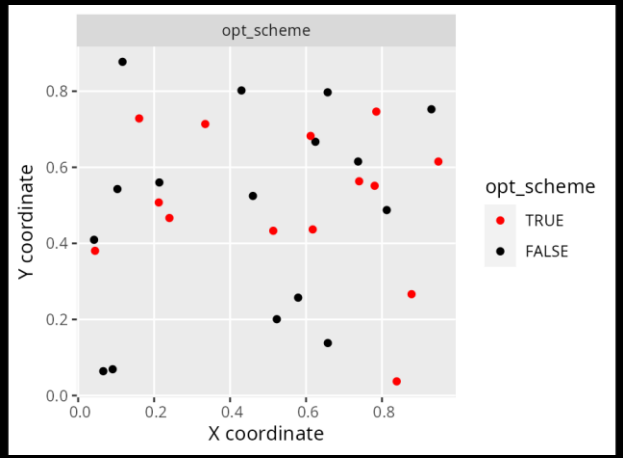

Prioritize projects for funding using exact algorithms (PPP and PTM problems)

## wdpar R package




Download and clean WDPA and WDOECM data from ProtectedPlanet

## surveyvoi R package*




Prioritize sites for ecological surveys by maximizing value of information

*under review

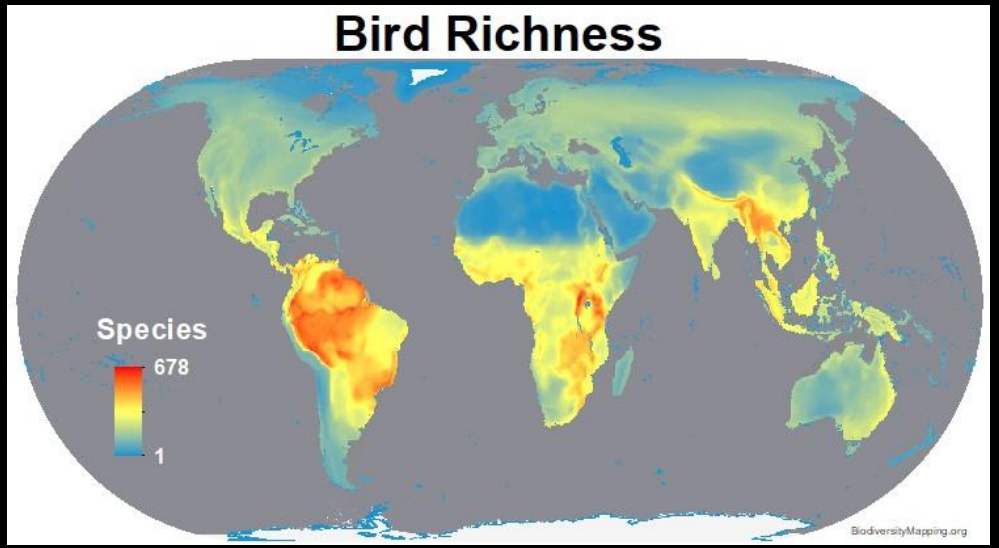
# DEMO

# Frequently asked questions

# Can’t we just protect places with the greatest species richness/diversity?

Doesn’t account for:

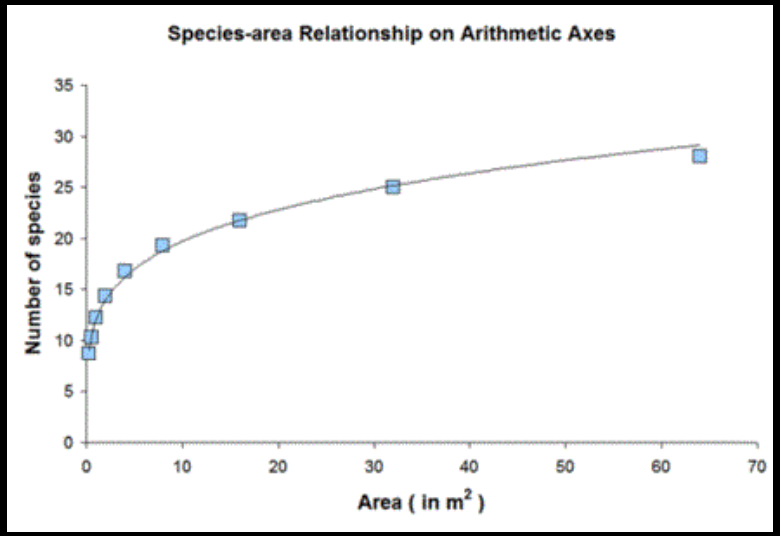
- Costs
- Species’ requirements
- Connectivity
- Complementarity
- Stakeholder preferences
- Previous conservation efforts




https://biodiversitymapping.org

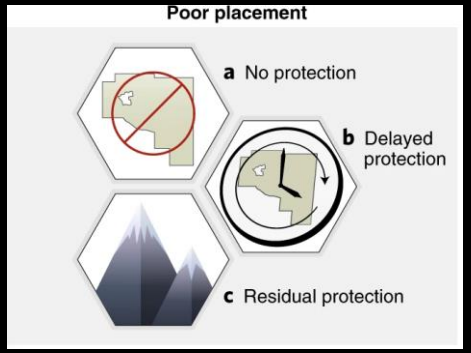
Brown et al. (2015) PNAS, DOI:10.1073/pnas.1509189112

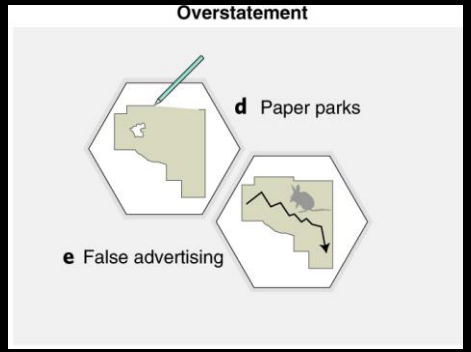
# Biogeography says you get more species with larger area, so why not just maximize total amount of land inside protected areas?



# Focussing on protected area size creates perverse incentives

a) Failure to protect highly threatened, diverse, connected but small areas
b) Expansion results in delayed protection in areas where protected area (PA) establishment could have had much higher biodiversity benefits
c) Protection of low-threat, unrepresentative areas, generating limited protective effect
d) Fails to account for resources allocated to PA management; rewards lack of staff and equipment
e) Biodiversity losses in a PA remain undetected, but the area is celebrated as ‘protected’

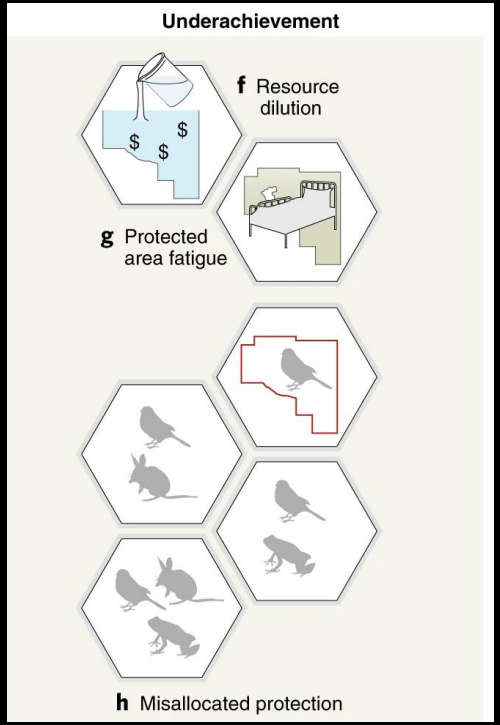



Barnes *et al.* (2018) Nat Eco Evol, DOI:10.1038/s41559-018-0501-y

# Focussing on protected area size creates perverse incentives

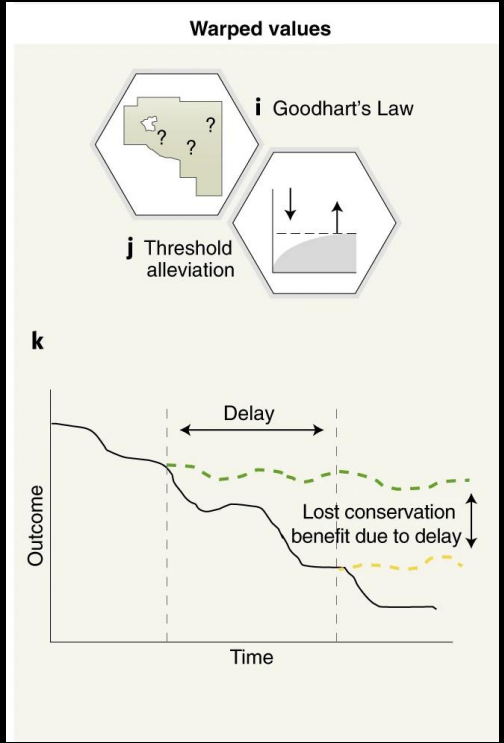
f) Protected area (PA) expansion without associated increases in budget or staff capacity reduces management capacity in situ and across the entire PA network.
g) PA expansion may induce apathy or resistance to establishing new PAs.
h) Poorly targeted expansions result […] in actions where biodiversity does not benefit, and limits opportunities for conservation.




Barnes *et al.* (2018) Nat Eco Evol, DOI:10.1038/s41559-018-0501-y

# Focussing on protected area size creates perverse incentives

i) The real underlying values and objectives of halting biodiversity decline are subsumed by the metric of just protecting more land
j) As existing protected area coverage targets are thresholds, perceptions of success are binary, failing to account for continual improvements
k) Any delay or misallocation of limited resources causes long-term harm that may not be reversible at human timescales.

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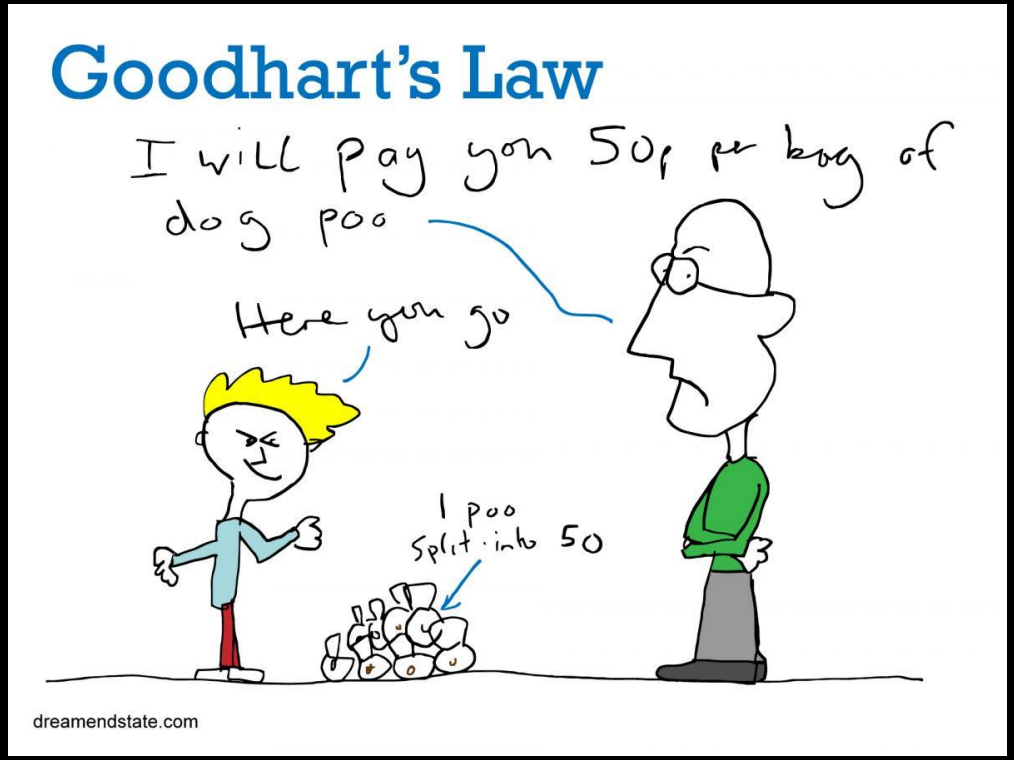


# Can't we just use a scoring system (formula) to rank candidate protected areas?

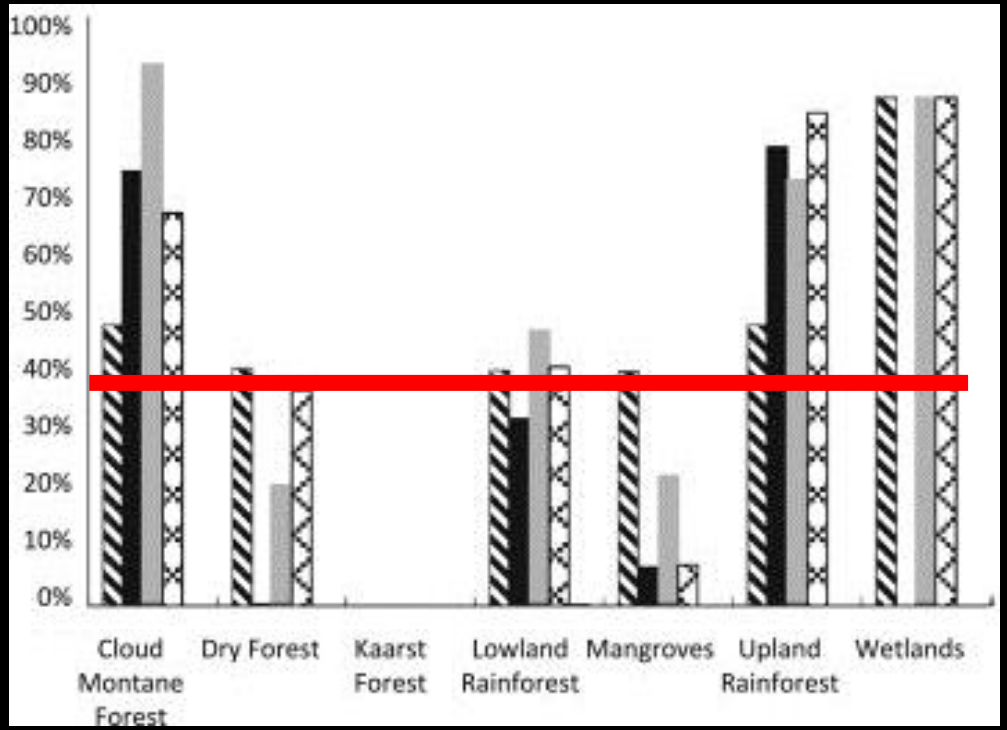
| Factor | Rationale | Ranking Scale |
|---|---|---|
| Endemic species richness | The known endemic species richness of a forest site in comparison with other sites of the same forest type | 1: Low<br>2: Average<br>3: High |
| Number of vegetation types | Number of target vegetation types found within a forest site | 1 point for each vegetation type |
| Economic importance | Expert opinion of known economic importance other than for exploitation (i.e. important watershed for water provisioning or hydropower, tourism site, etc.) | 1: Low<br>2: Average<br>3: High |
| Size | Size of priority forest area (ha) | 0: 0 – 1,000<br>1: >1,000 – 10,000<br>2: >10,000 – 20,000<br>3: >20,000 |
| Degradation | Area of secondary forest and non-forest, amount of logging, density of roads | 1: High<br>2: Average<br>3: Low |
| Rarity | Is the site's forest type replicated elsewhere? | 1: Yes<br>2: Partly<br>3: No |
| Conservation practicality | Expert opinion in attaining conservation judged by: land tenure regime; amount of significant production forest; number of land-owning clans; known clan attitudes; and alignment with Government plans for the site | 1: Difficult<br>2: Average<br>3: Less difficult |
| Cultural importance | Area of known cultural significance | 0: No<br>1: Yes |
| Priority connectivity forest areas | Identified by Jenkins et al. (2010) as catchment with higher intact connectivity with downstream coastal and marine ecosystems | 0: No<br>1: Yes |


Game *et al.* (2013) Cons Biol, DOI:10.1111/cobi.12051

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

Klein *et al.* (2014) Marine Policy, DOI:10.1016/j.marpol.2014.03.008

# Can’t we just use a scoring system (formula) to rank candidate protected areas?



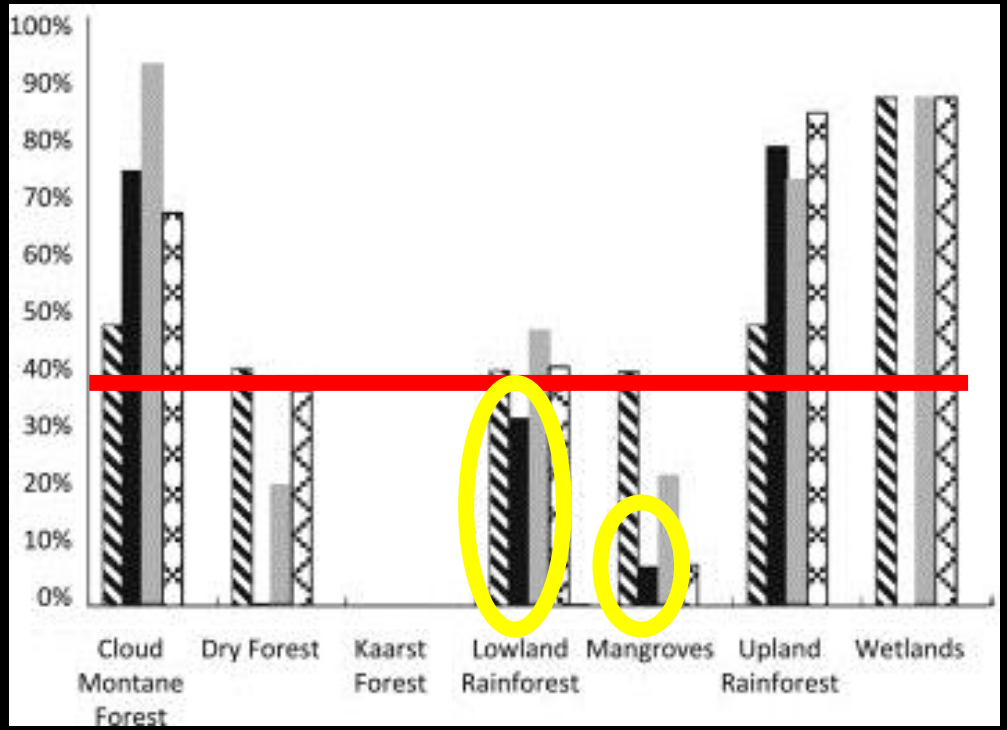

Plan for protected area network based on systematic conservation planning tool

Plan for protected area network based on scoring system

Representation target

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

# Can’t we just use a scoring system (formula) to rank candidate protected areas?




Plan for protected area network based on systematic conservation planning tool

Plan for protected area network based on scoring system

Representation target

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

# Look, I'm sure I could come up with a better formula?

"A major drawback of a listing of priority areas on the basis of a single application of a formula is that there is no guarantee that the priority area second or third on the list might not duplicate the species, communities or habitats that could successfully be preserved in the first priority area."

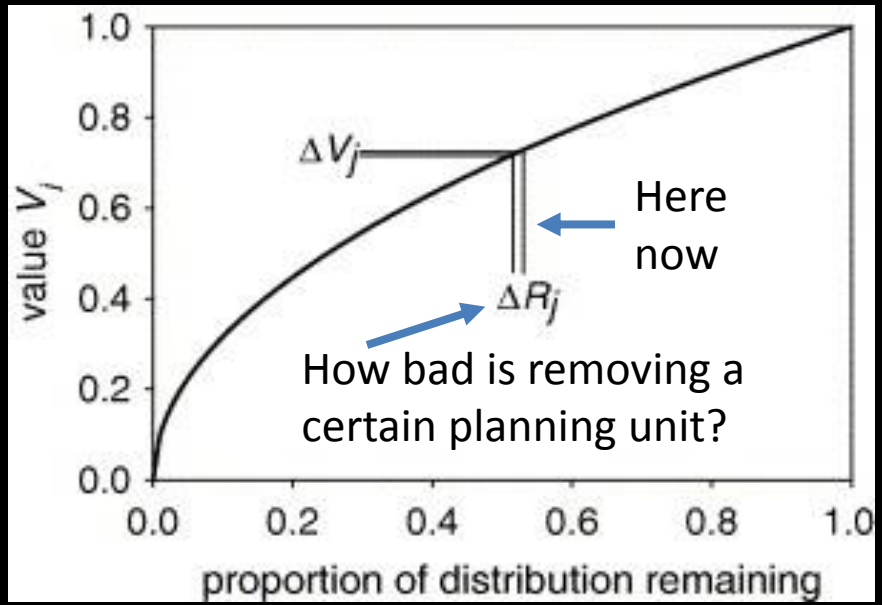
Kirkpatrick (1983) Biol Cons, DOI: 10.1016/0006-3207(83)90056-3

# Representation targets don't seem scientific, can't the algorithm optimize this for me?

Carwardine *et al.* (2009), Cons Lett, DOI:10.1111/j.1755-263X.2008.00042.x

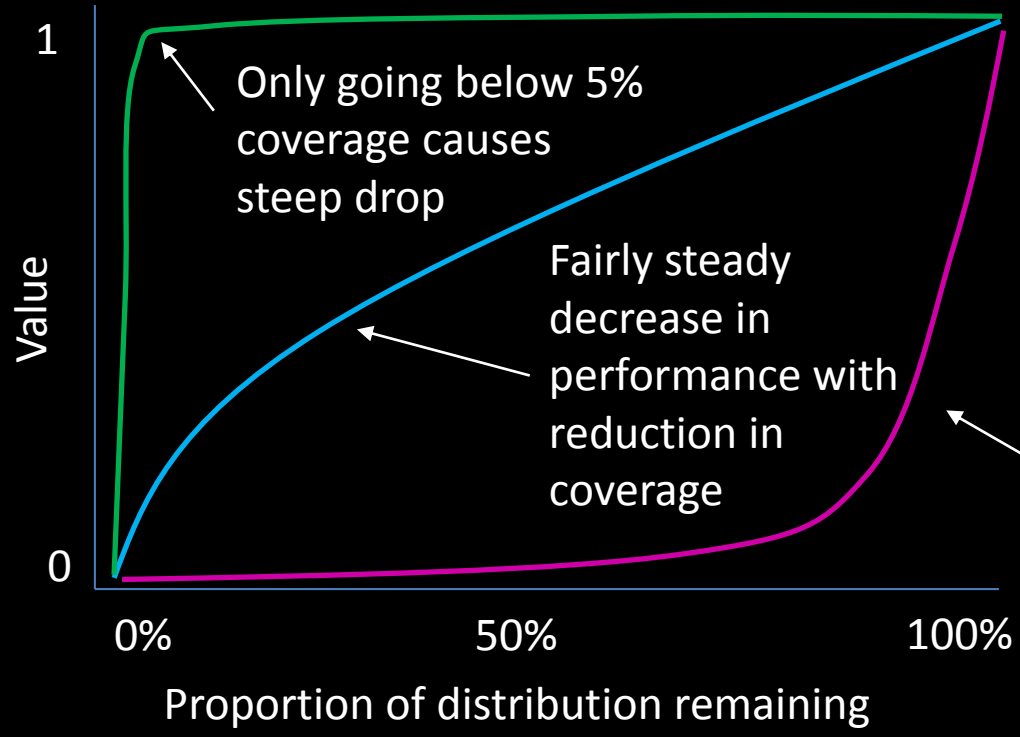
# Zonation doesn't use targets, doesn't that make it more robust?

- Zonation doesn't use targets, but needs you to specify trade-off curves instead
- These specify (1) how much worse covering X% of a species' range is than Y%, and (2) how much worse loosing coverage of one species is compared to another




Moilanen (2007) Biol Cons, DOI:10.1016/j.biocon.2006.09.008

# Zonation doesn't use targets, doesn't that make it more robust?




Examples of different trade-off curves:

- Rare species
- Generalist species
- Culturally important species

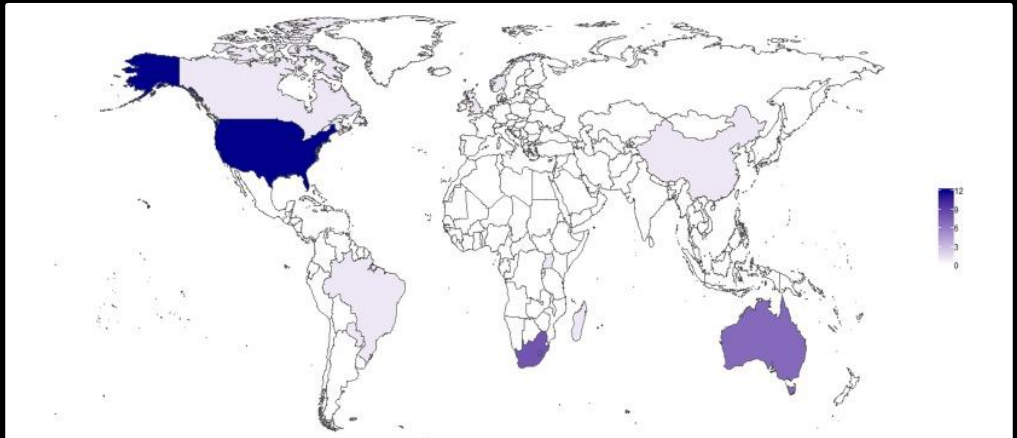
# You really think people will listen to a computer?

Systematic conservation planning helps:

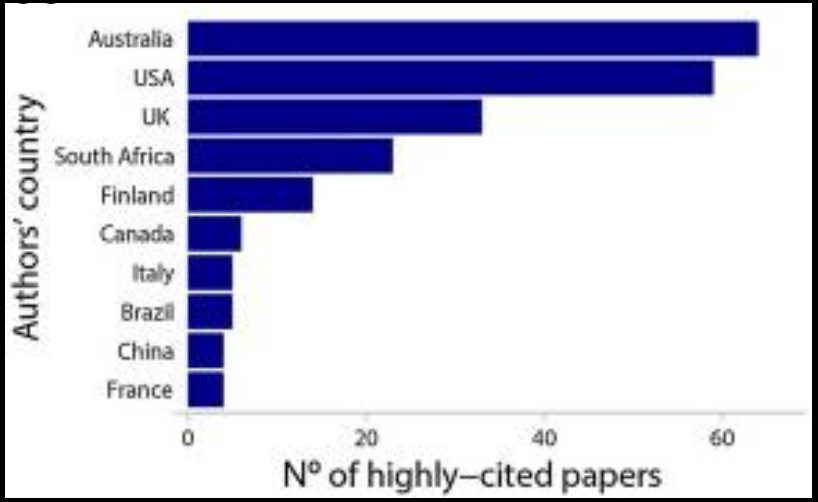
- support decision making – it doesn't make decisions or dictate them
- identify priority areas (just because the algorithm doesn't say a place is a priority doesn't necessarily mean it's not important!)
- facilitate discussions between stakeholders by navigating trade-offs
- land-use and sea-scape planning by considering multiple zones (e.g. prioritizing places for recreational fishing and conservation)
- real-world decision making, such as Great Barrier Reef (Australia), Gulf of California (Mexico), Cape Floristic Region, (South Africa), and marine planning (Montserrat)

Cowling et al. (2003) Biol Cons, DOI:10.1016/S0006-3207(02)00425-1
Álvarez-Romero et al. (2013) Aquatic Conserv, DOI:10.1002/aqc.2334
Fernandes et al. (2005) Conserv Biol, DOI:10.1111/j.1523-1739.2005.00302.x
Flower et al. (2020) Conserv Sci Prac, DOI:10.1111/csp2.158

# Isn’t conservation planning just something Australian’s do?



N° of highly-cited papers, based on study area




Ribeiro & Atadeu (2019) J. Nat. Conserv., DOI:10.1016/j.jnc.2019.125714