Making better conservation decisions

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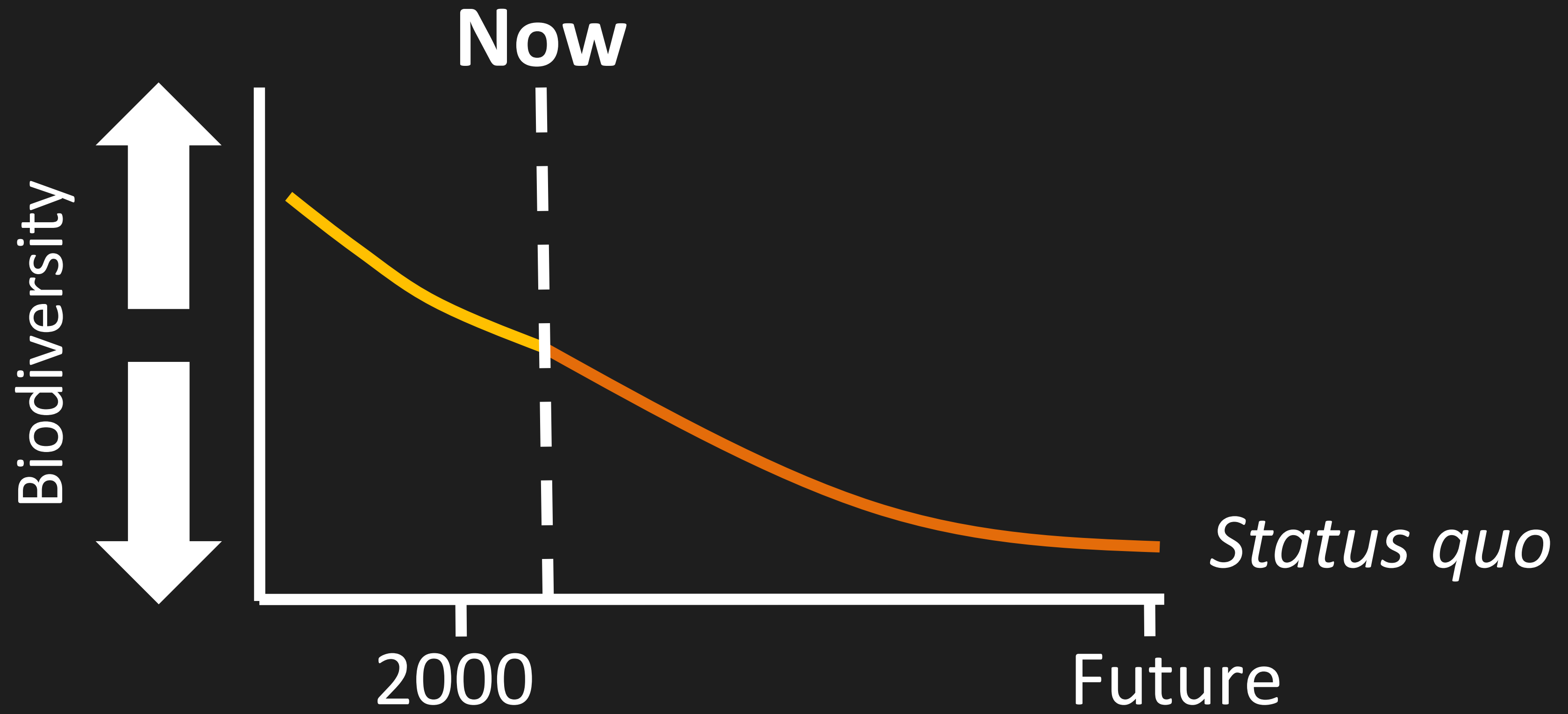
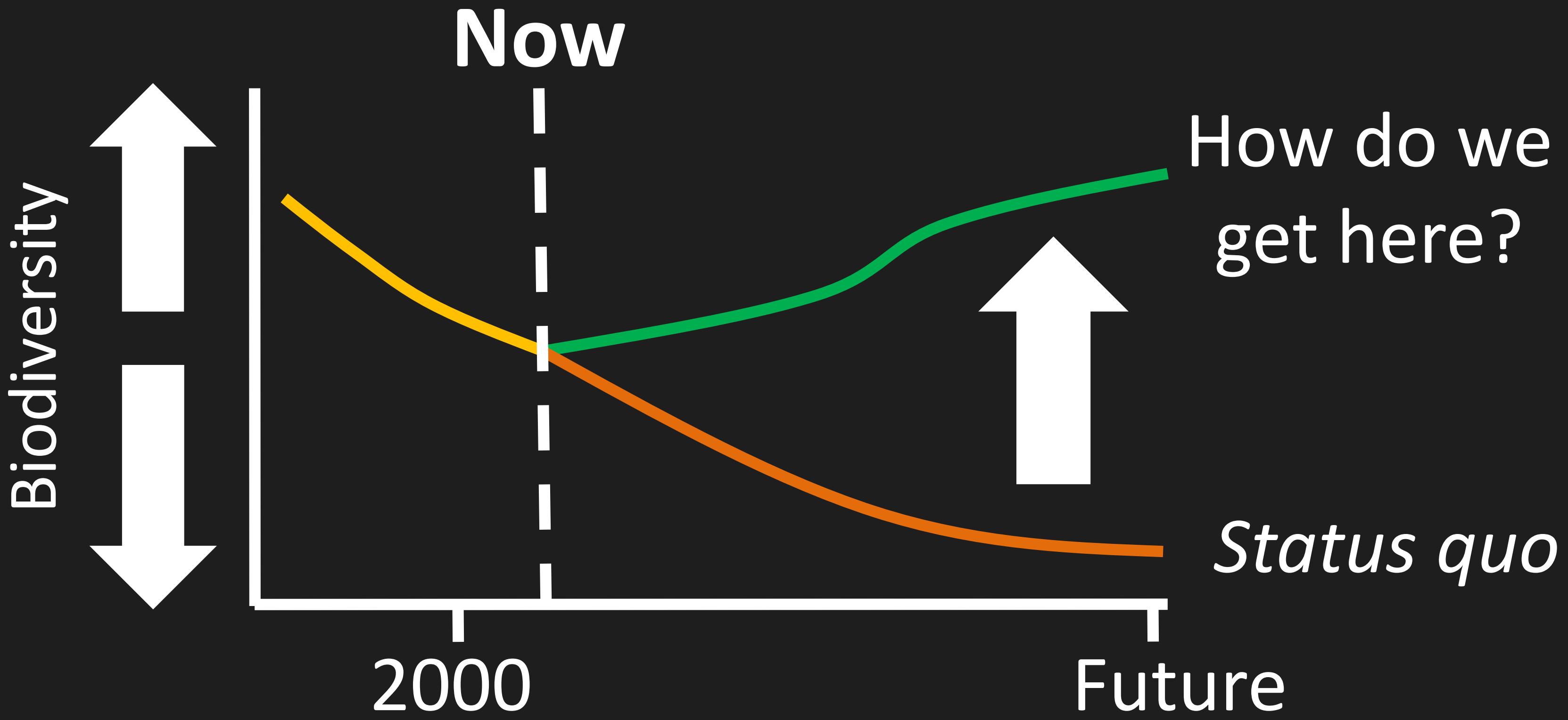

Now
Biodiversity
Status quo
2000
Future

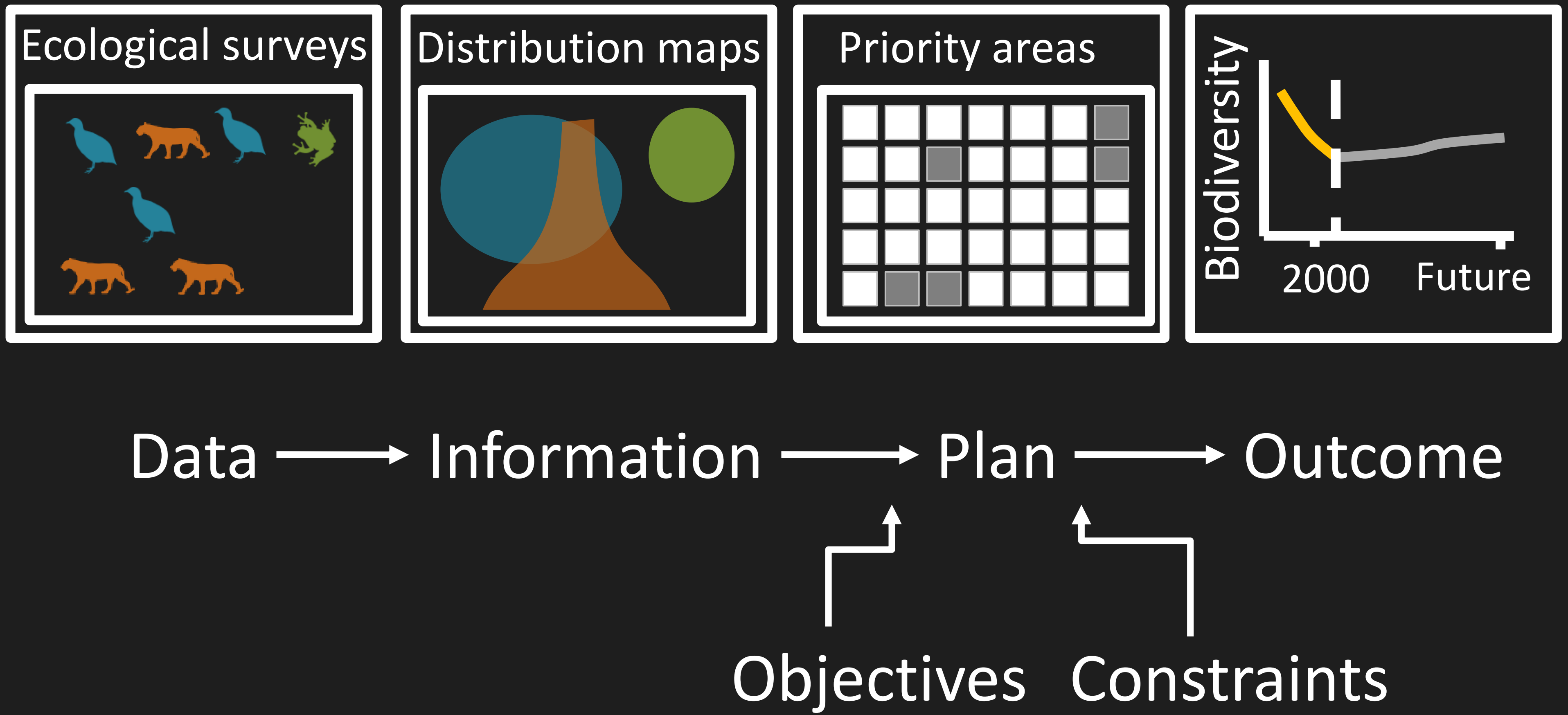

Now
Biodiversity
How do we
get here?
Status quo
2000
Future

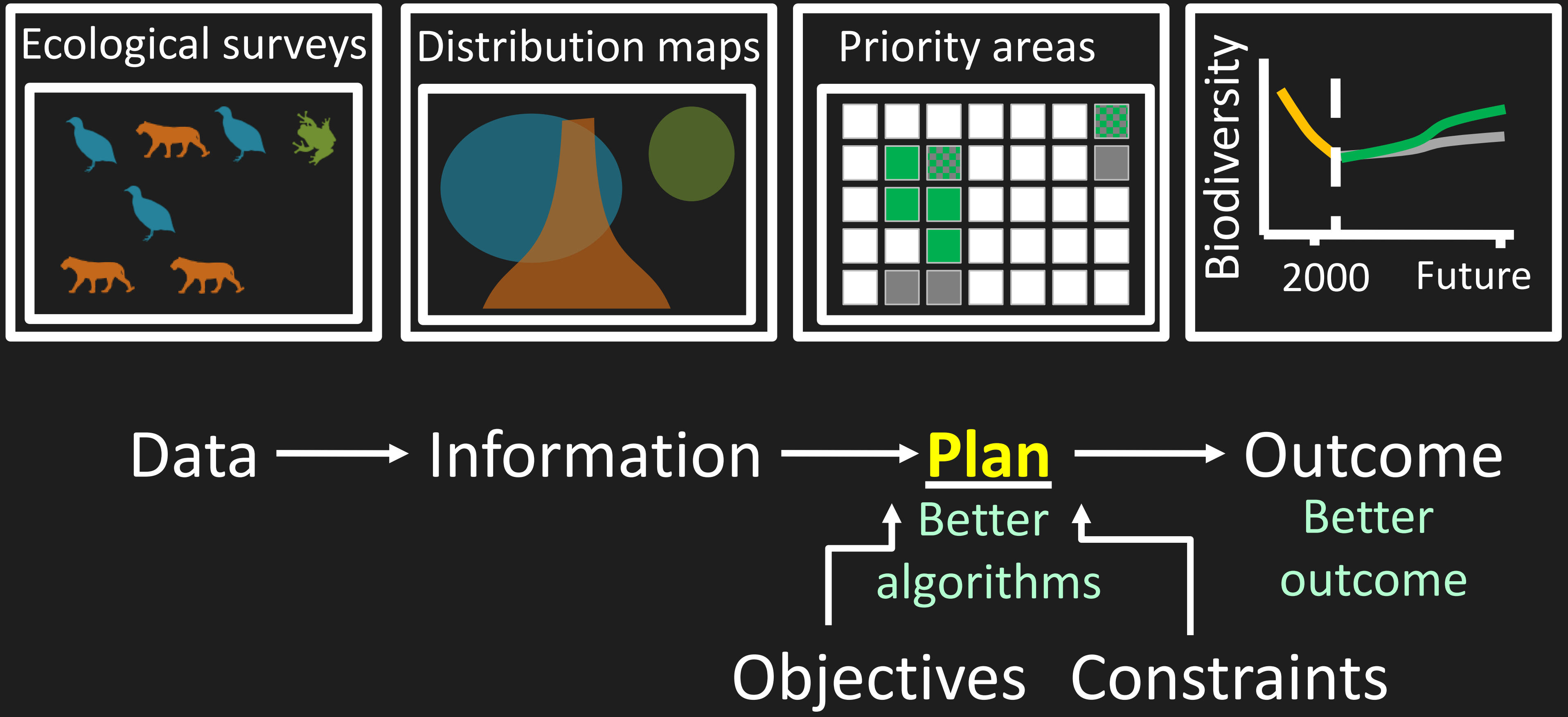
How can we get a better conservation decision?

(1) Better algorithms

(2) Better data

(3) Better surrogates


Ecological surveys
Distribution maps
Priority areas
Biodiversity
2000
Future
Data
Information
Plan
Outcome
Objectives
Constraints



Ecological surveys
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Better algorithms
Better outcome
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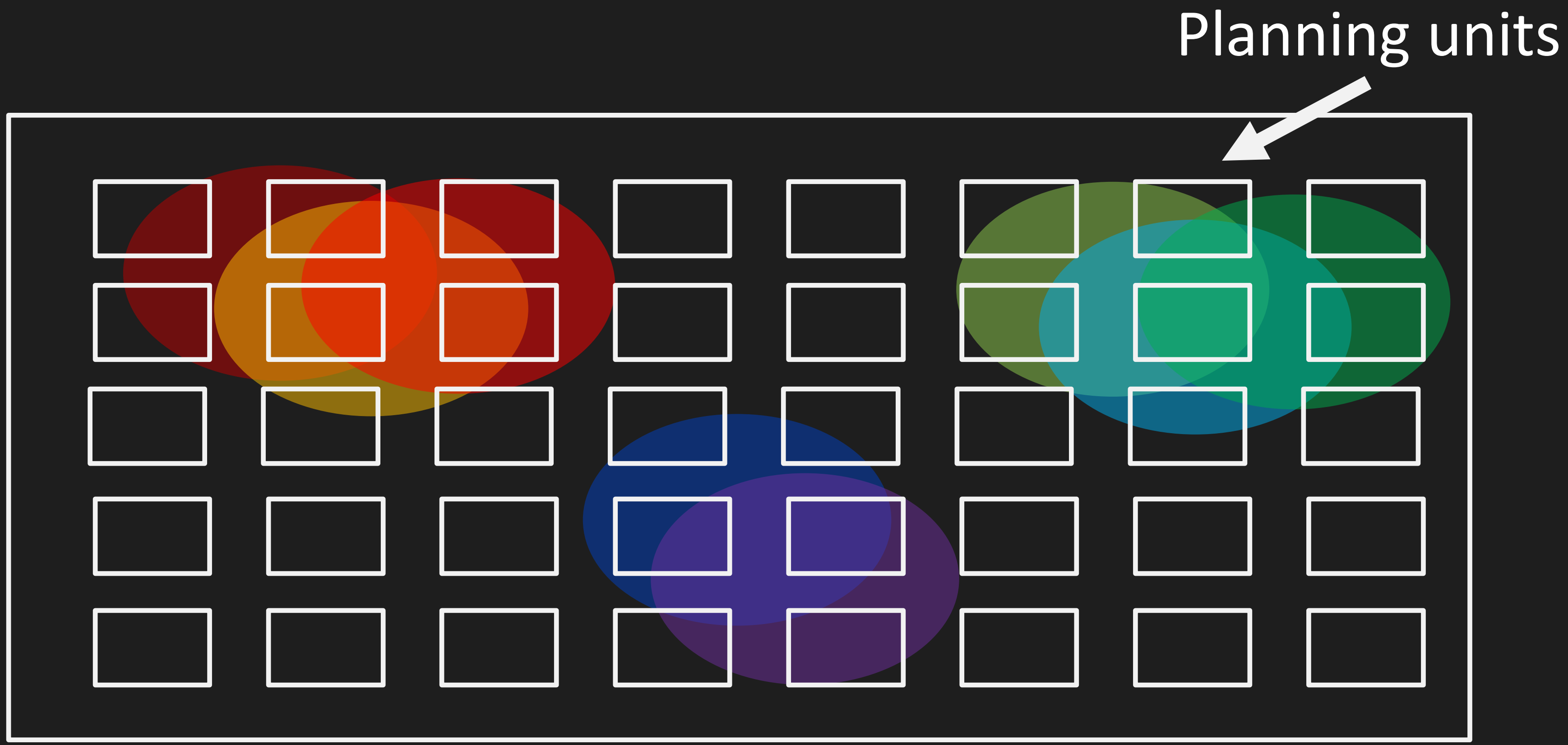
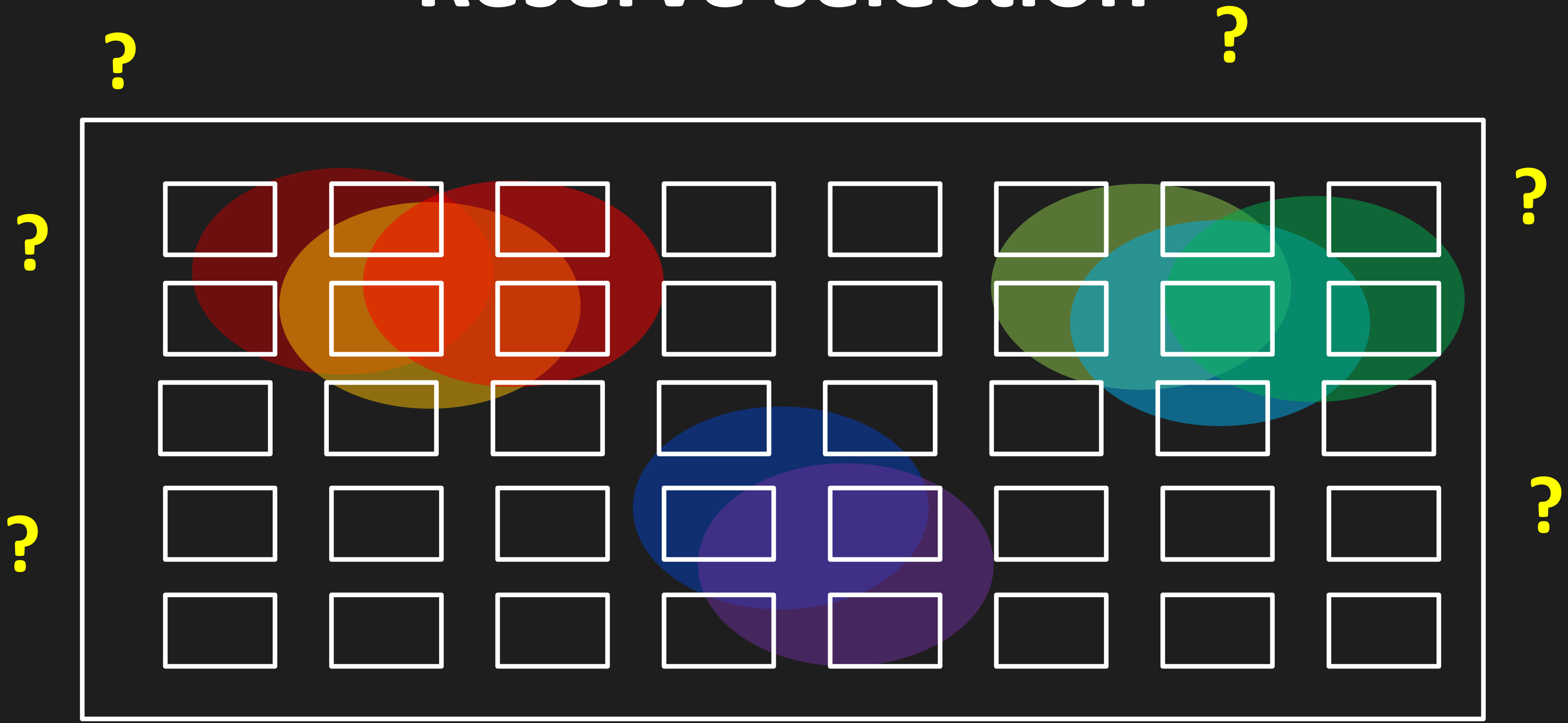
Reserve selection

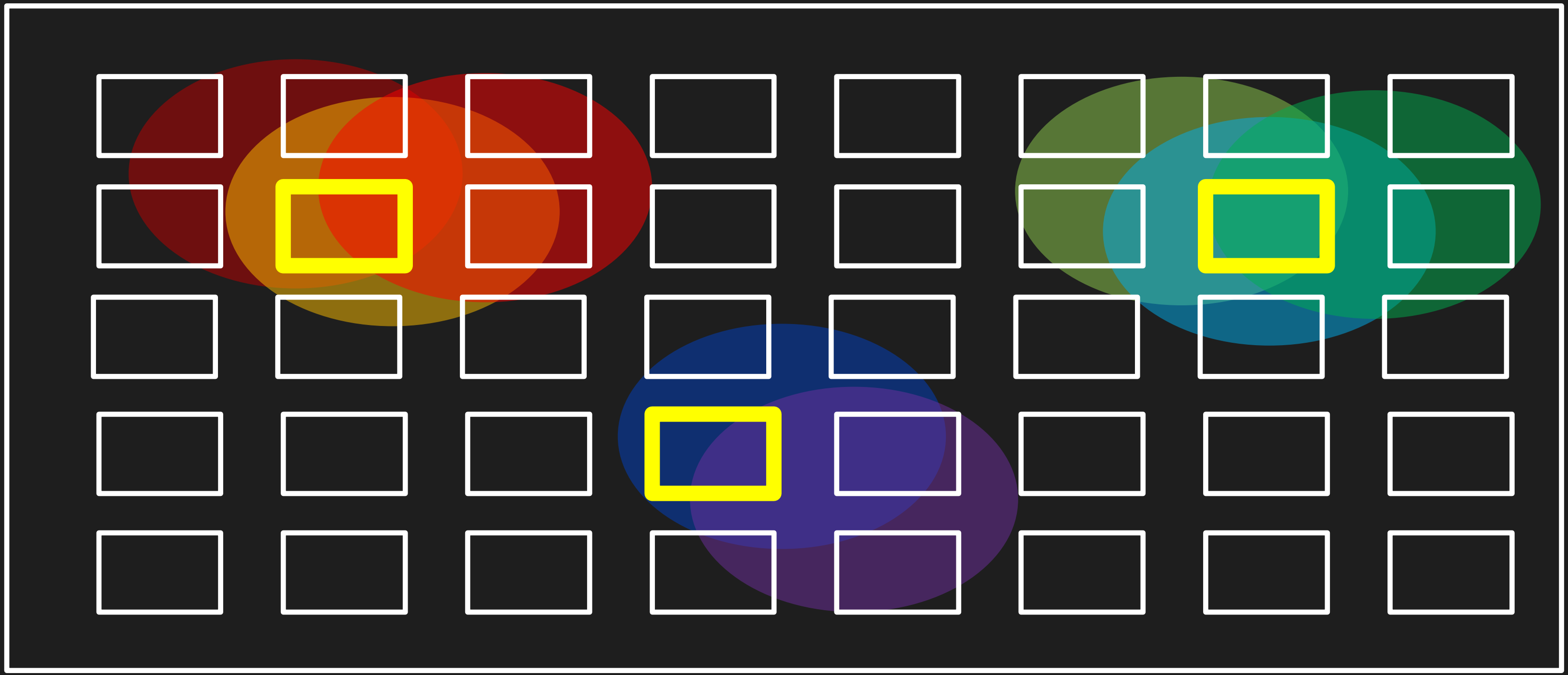
Reserve selection



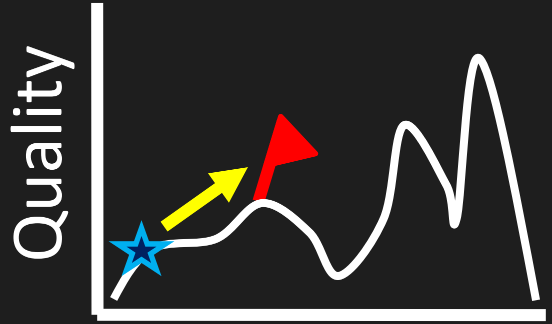
Reserve selection



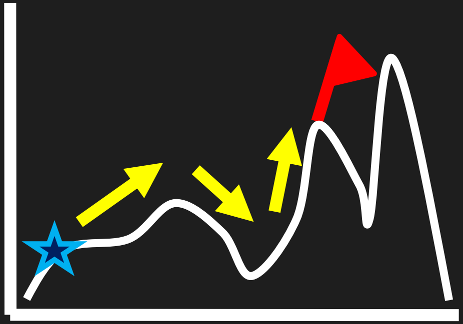
Reserve selection



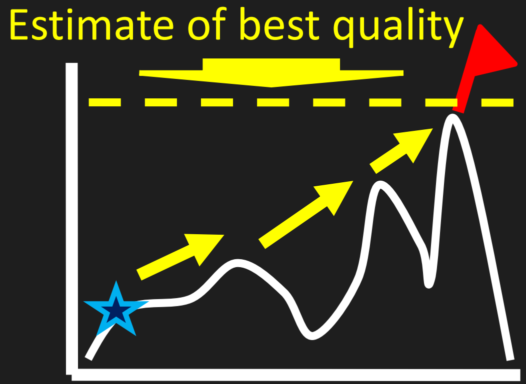
Heuristic algorithm | Meta-heuristic algorithms | Exact algorithms



Different solutions



Different solutions



Different solutions

MARXAN
conservation solutions

GUROBI
OPTIMIZATION

IBM
CPLEX

COIN|OR

prioritizr: Systematic conservation prioritization in R

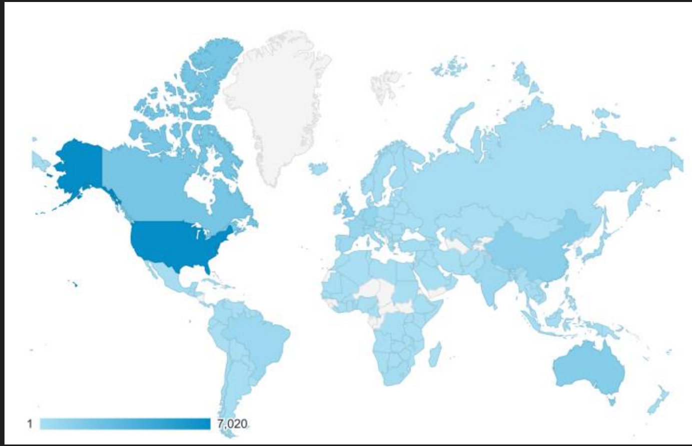
- It’s an R package (yes, this is good)
- First released on CRAN in 2016
- Highly flexible interface
- Supports tabular and GIS data formats
- Supports multiple zones/actions
- Powered by open source and commercial exact algorithm solvers

prioritizr.net

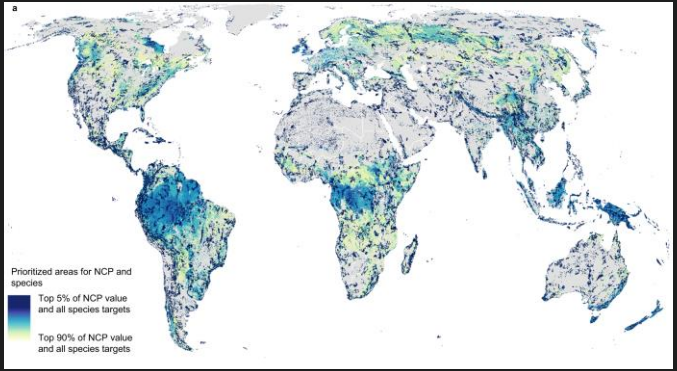
Who uses it?

- 85 scientific publications used it for generating prioritizations
- Conservation International, Nature conservancy Canada, UN Biodiversity Lab, Waitt Institute
- Helped inform planning for Government of Monsterrat, Scottish Government, US Geological Survey, Governments of the Maldives and the Federated States of Micronesia

Web site visitors

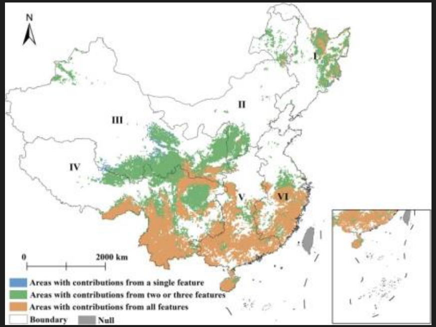


Recent applications



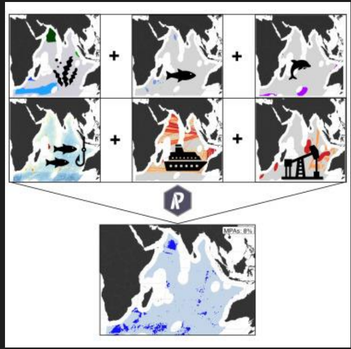
Priority areas for ecosystem services and biodiversity conservation

Neugarten et al. (2024) Nature Comms



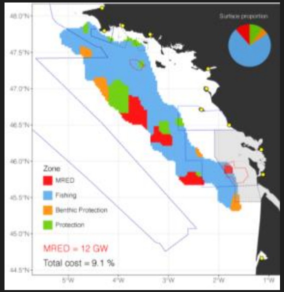
National-scale priority areas for protected areas

Du et al. (2024) Ecol Indic



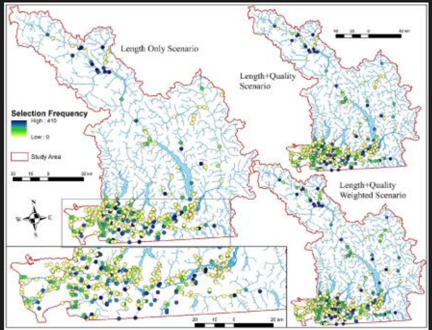
Cross-sectoral marine planning in the high seas

Fourchalt et al. (2024) One Earth



Priority areas for renewable energy areas and marine protected areas

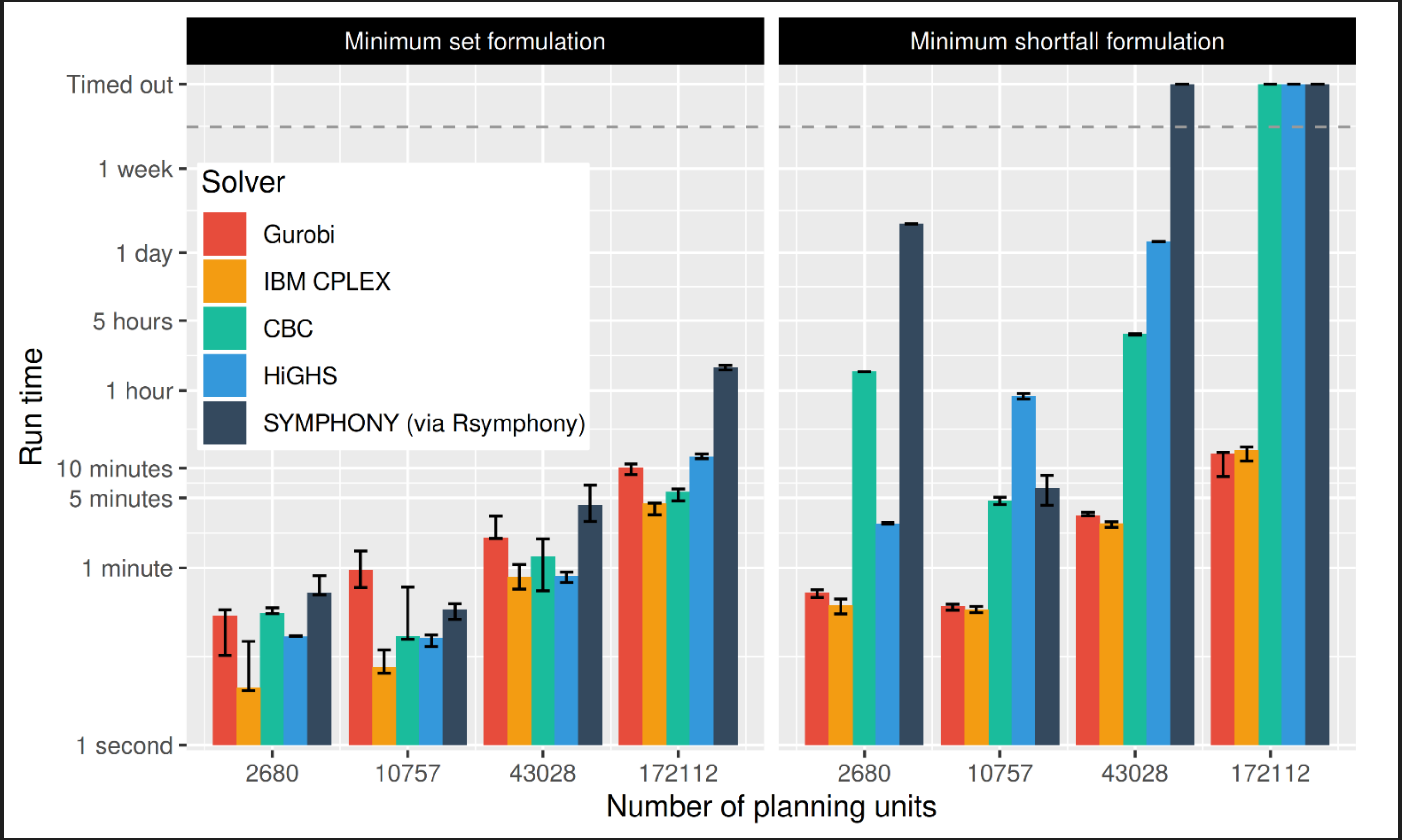
Boussarie et al. (2023) J Env Managem



Priority areas to remove in-stream barriers for salmon connectivity (e.g. dams, weirs, road culverts, pump stations

Finn et al. (2023) Cons Sci Prac

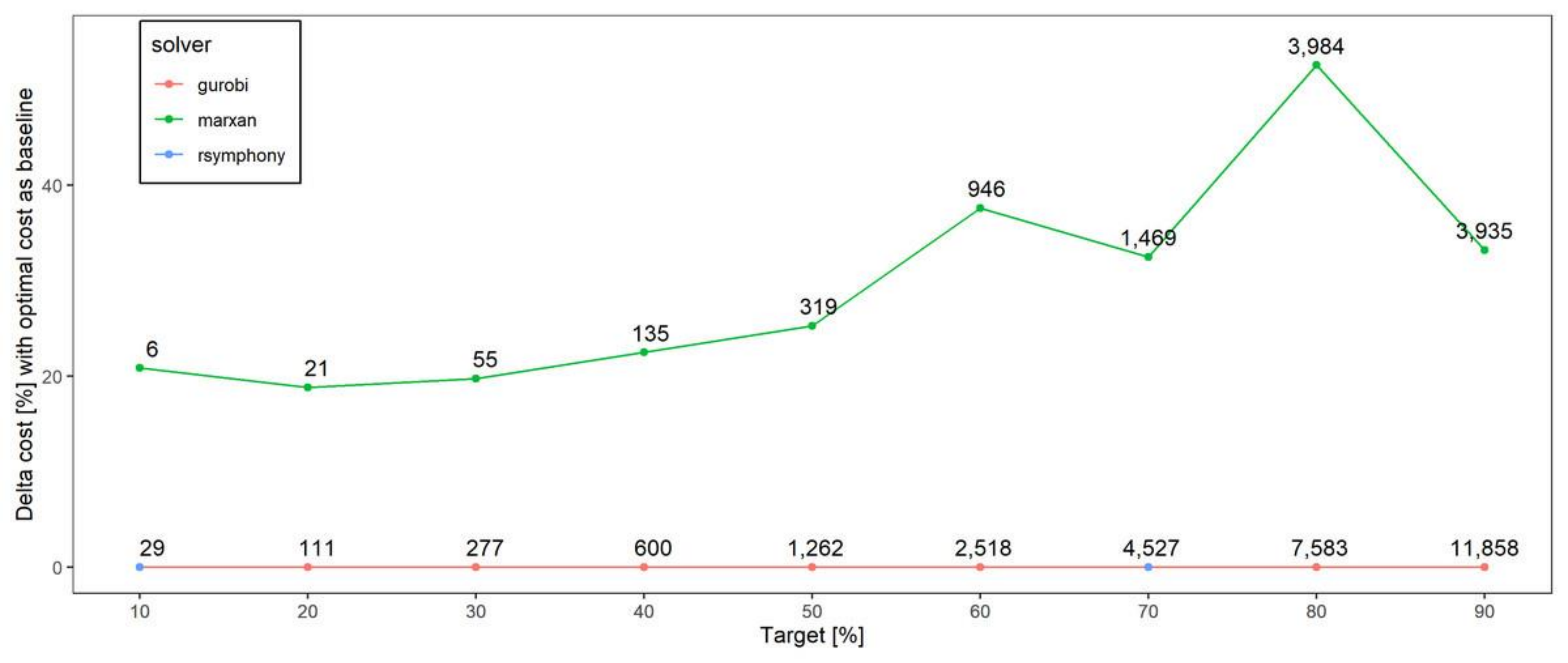
Solve problems pretty quickly!



Notes: 396 features, no planning units locked in or out, prioritizations ≤ 10% from optimality

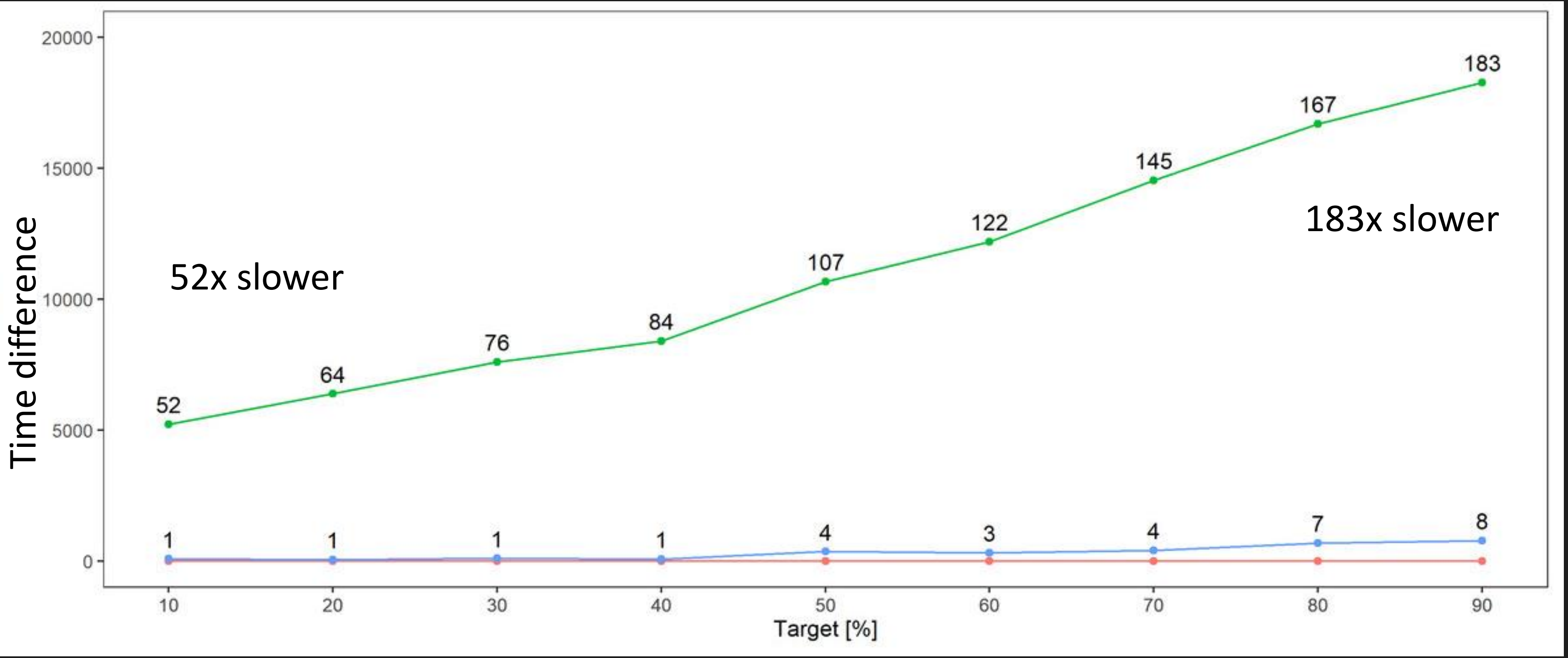
Hanson *et al.* under review

Better solutions



Schuster *et al.* 2020 PeerJ

Faster too



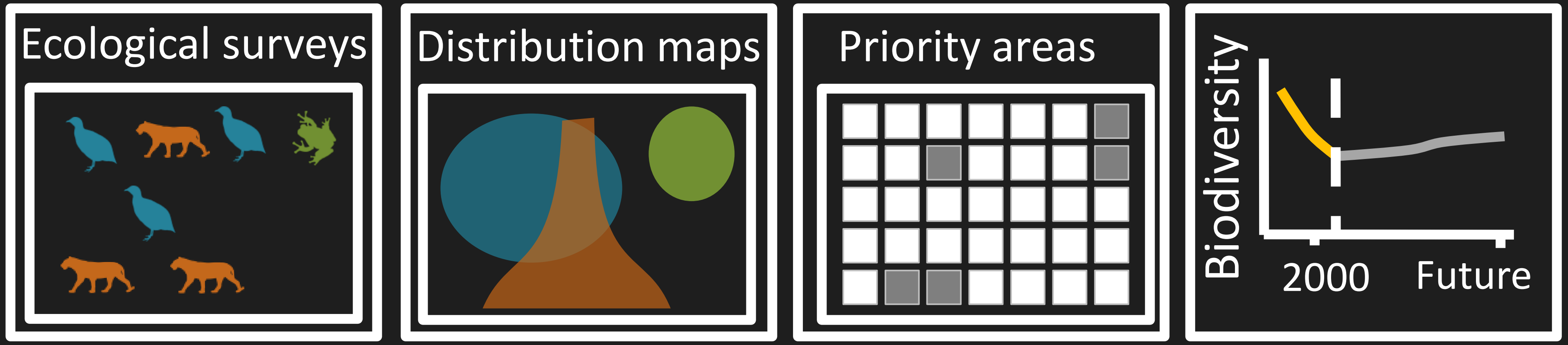
Schuster *et al.* 2020 PeerJ

How can we get a better conservation decision?

(1) Better algorithms

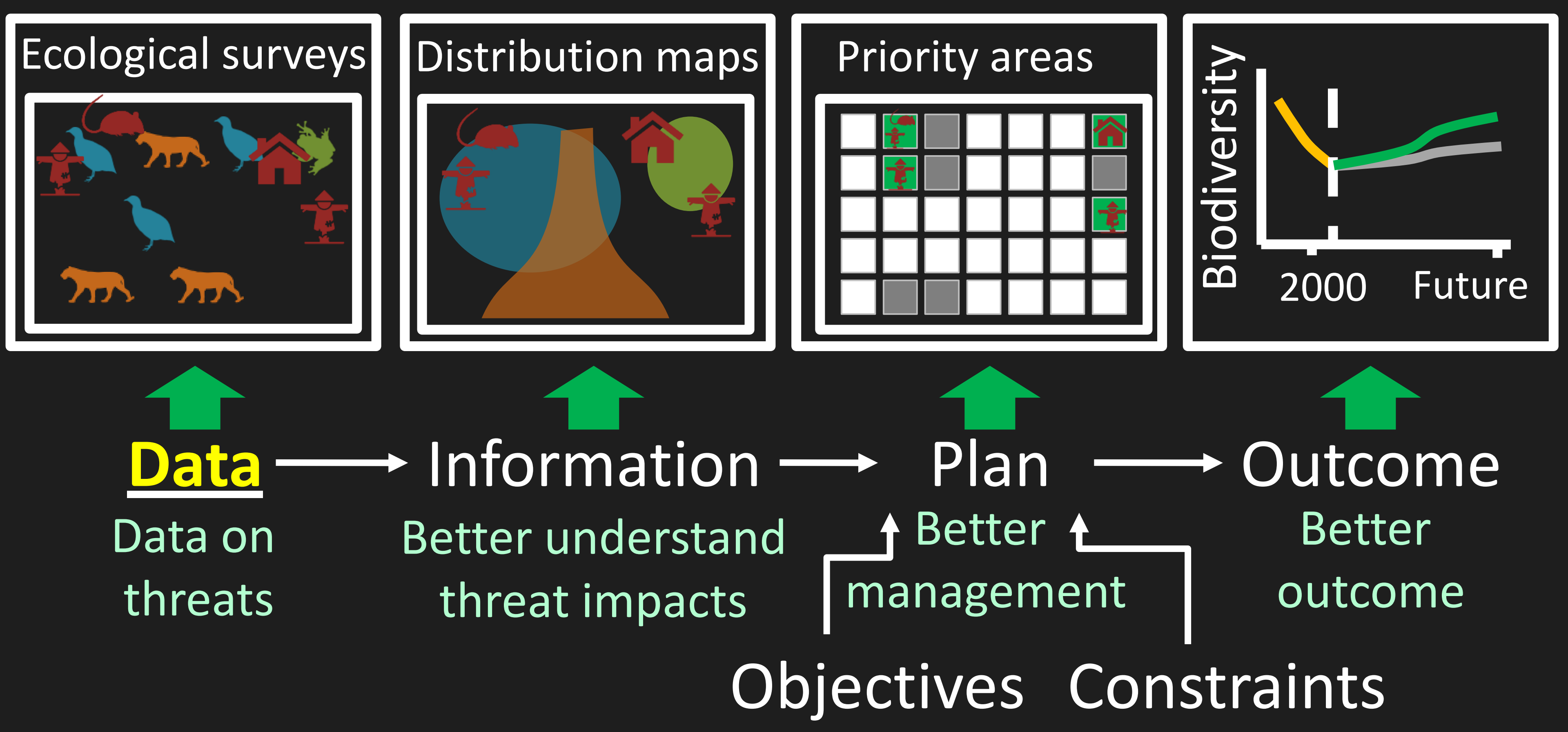
(2) Better data

(3) Better surrogates



Data → Information → Plan → Outcome

Objectives ↑ Constraints ↑



Ecological surveys
Distribution maps
Priority areas
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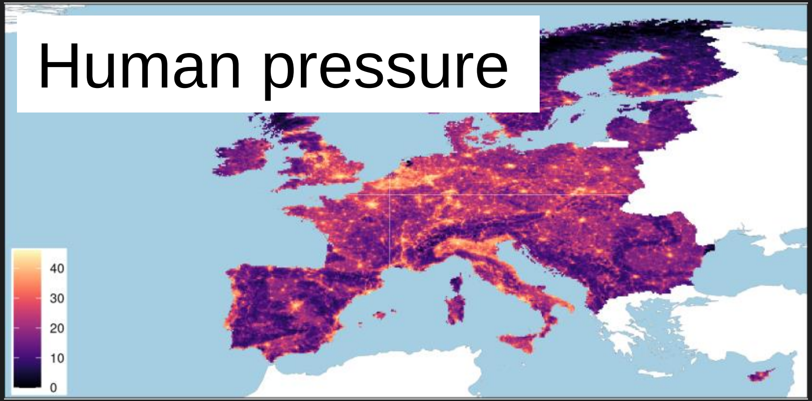
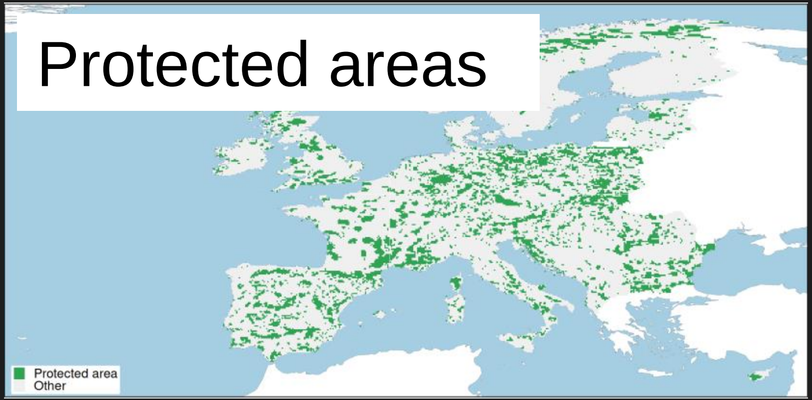
2000
Future
Data
Information
Plan
Outcome
Data on threats
Better understand threat impacts
Better management
Better outcome
Objectives
Constraints

European case study

- Majority of terrestrial vertebrate species
  - 81 amphibian species
  - 378 bird species
  - 156 mammal species
  - 95 reptile species
- 43 countries
- 10 × 10 km resolution planning units
- Conservation benefit for a species = amount of threat-free habitat in conservation areas

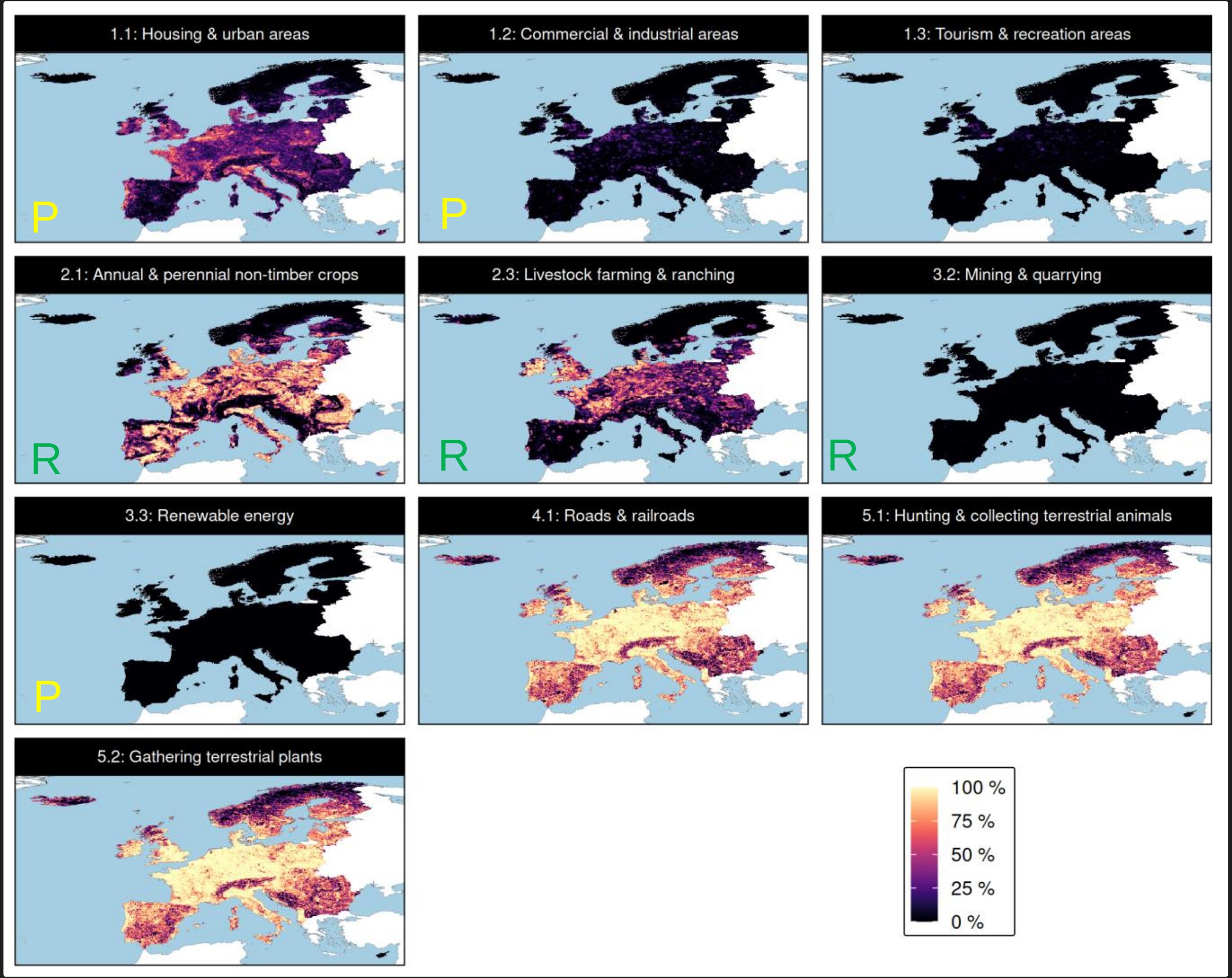




Hanson *et al.* In prep

Threats

- P = Permanent
- R = Restoration
- Management costs modelled using human footprint index as surrogate for opportunity costs



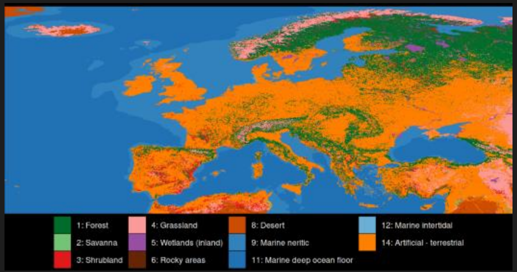
Hanson *et al.* In prep

Mapping suitable habitat for species

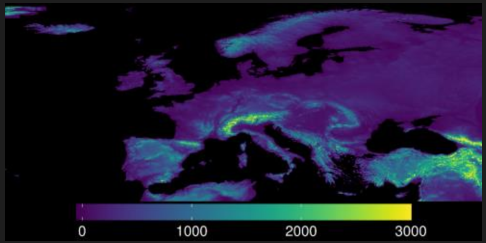
Species

- habitat types
- elevational limits
- threat impacts

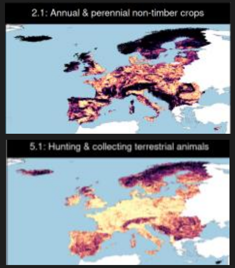
Current land cover



Elevation

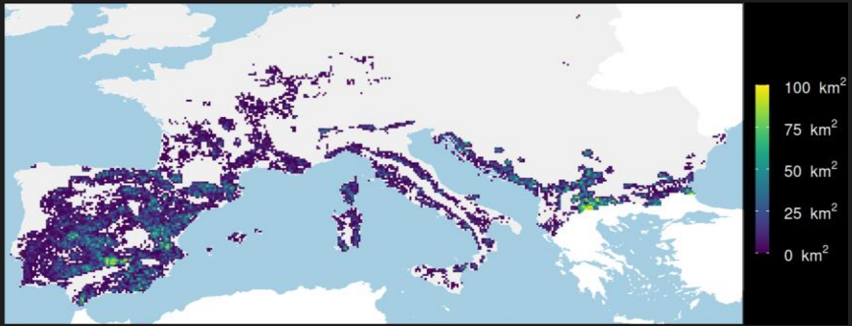


Threats



Woodchat Shrike

Area of threat-free habitat



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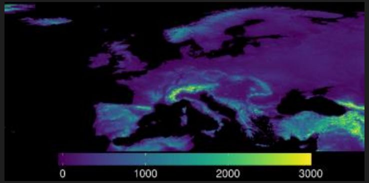
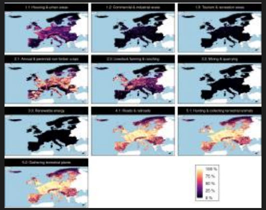
Mapping consequences of managing threats

Species

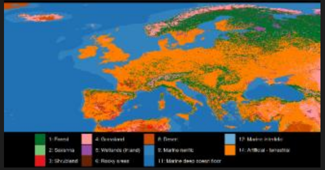
Elevation





Threats

Current land cover



Potential natural vegetation

Woodchat Shrike

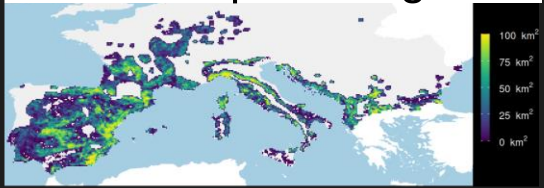
What if?

Existing habitat

Restore croplands

Stop hunting

Restore croplands & stop hunting



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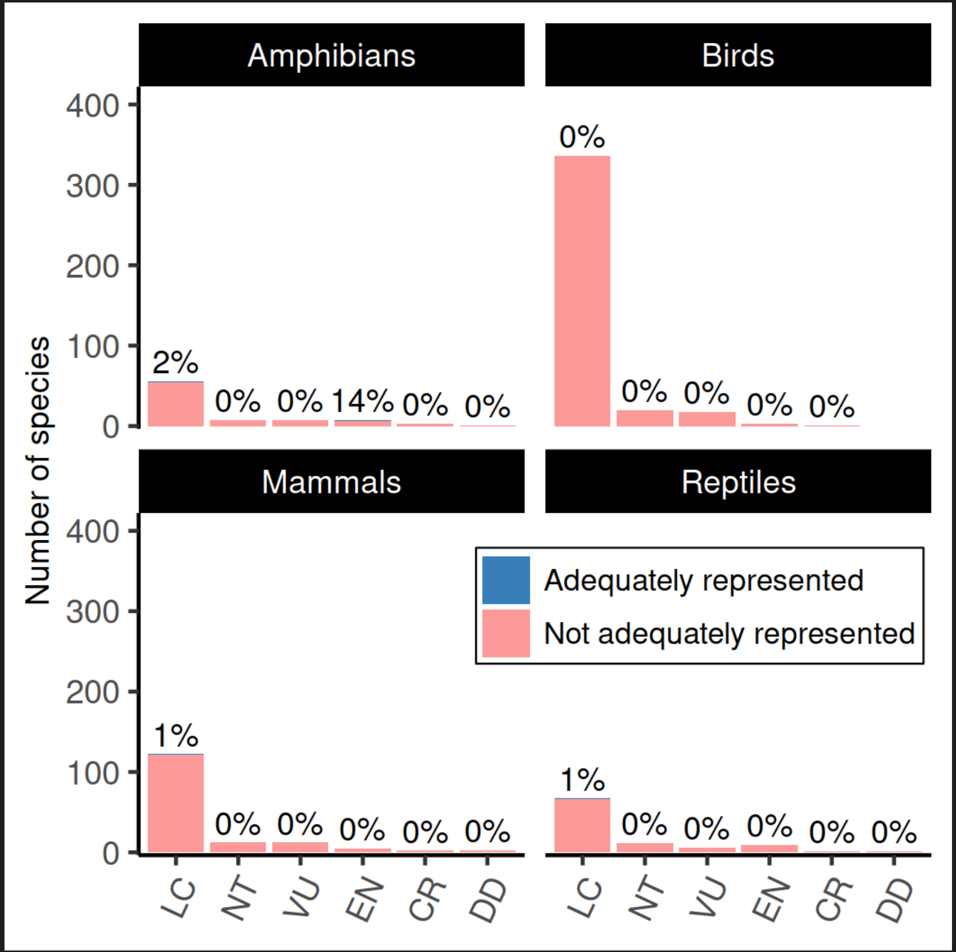
Existing protected areas

- Four (0.56%) species adequately represented when accounting for threats

- Only one of 74 critically endangered species adequately represented when accounting for threats

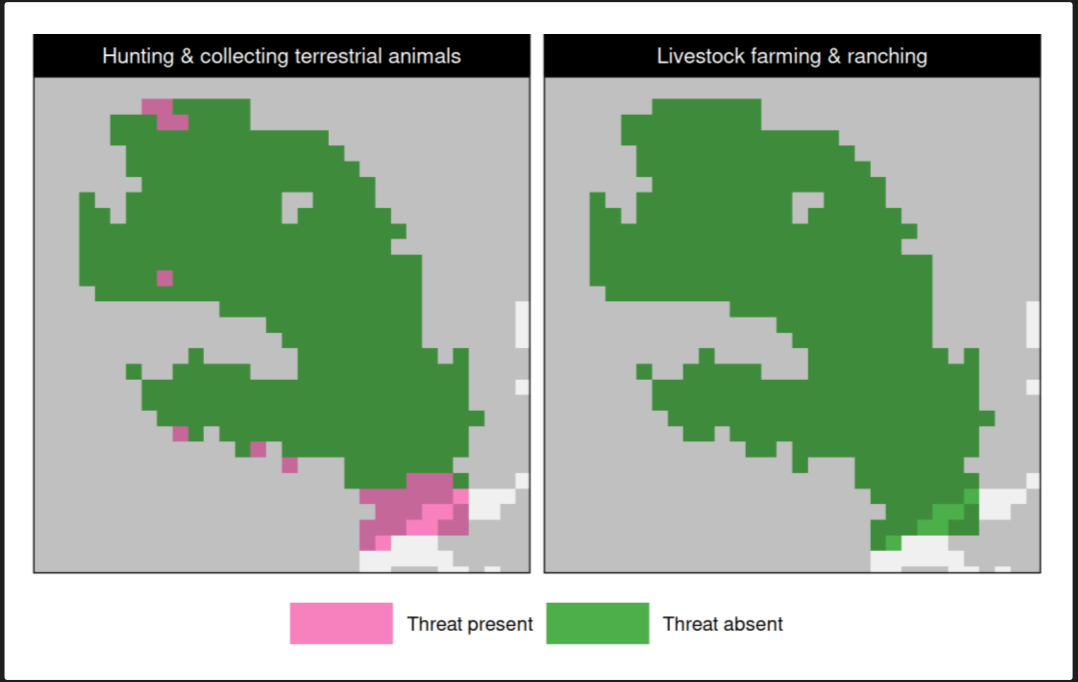


Hanson *et al.* In prep

- 100% representation target, because very small current and potential area of habitat
- We would normally think this species is adequately represented because 100% of its area of habit covered by protected areas
- However, this species needs management across 8% of its potential area of habitat to meet the target

Aurelio's rock lizard (*Iberolacerta aurelioi*)

ENDANGERED EN



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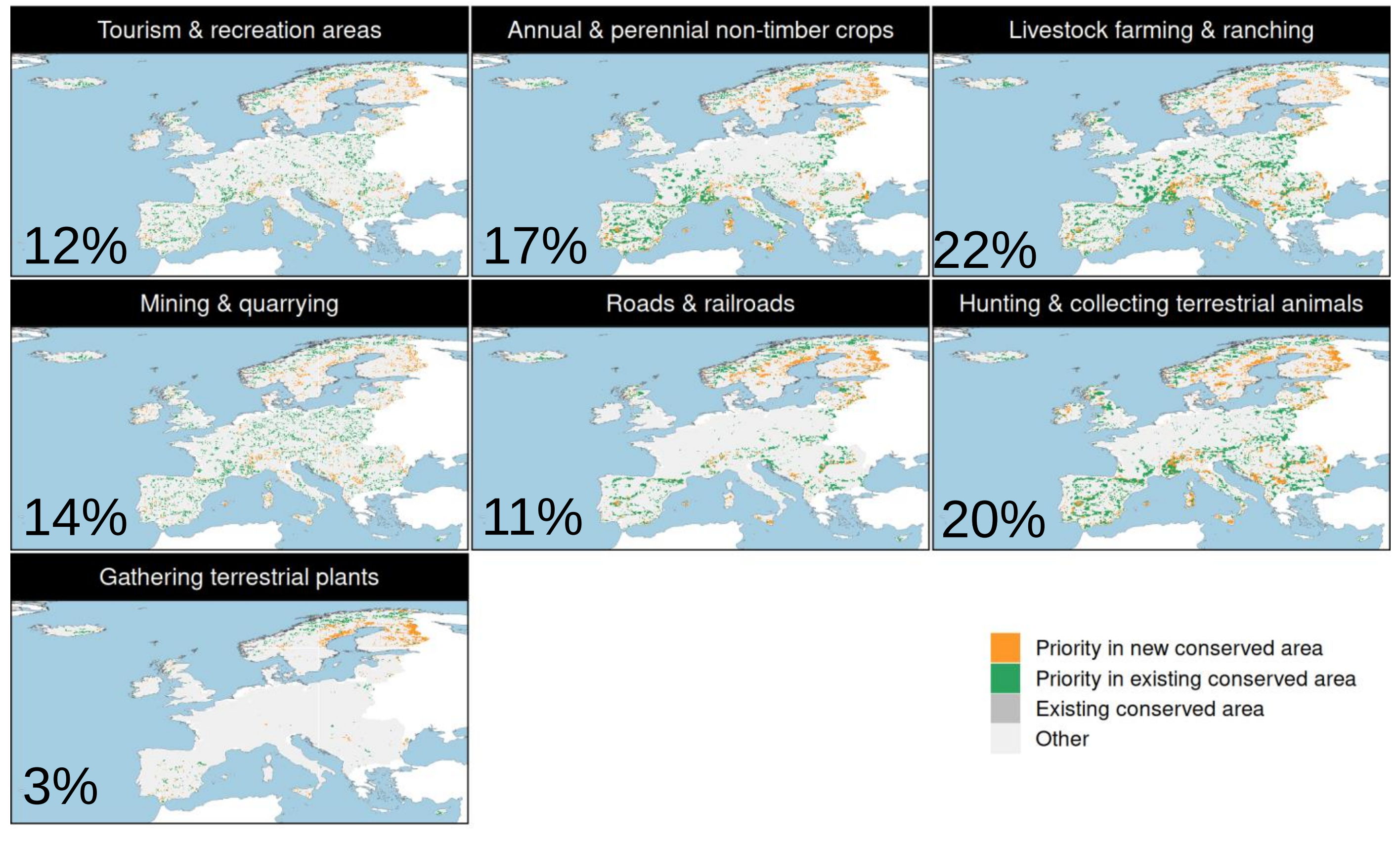
Prioritization to manage threats



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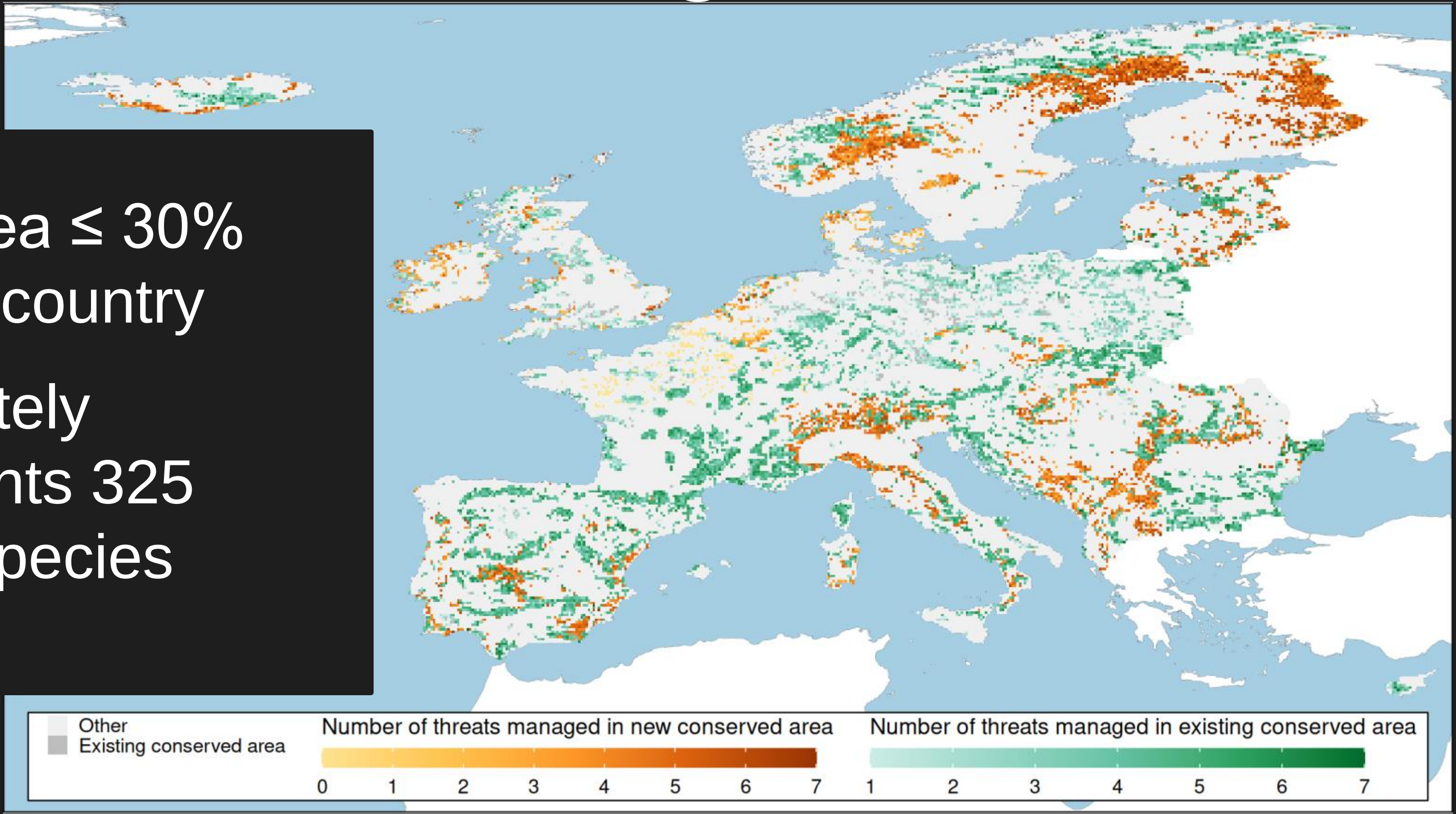
Patterns in management effort

- Total area ≤ 30% of each country
- Adequately represents 325 (45%) species



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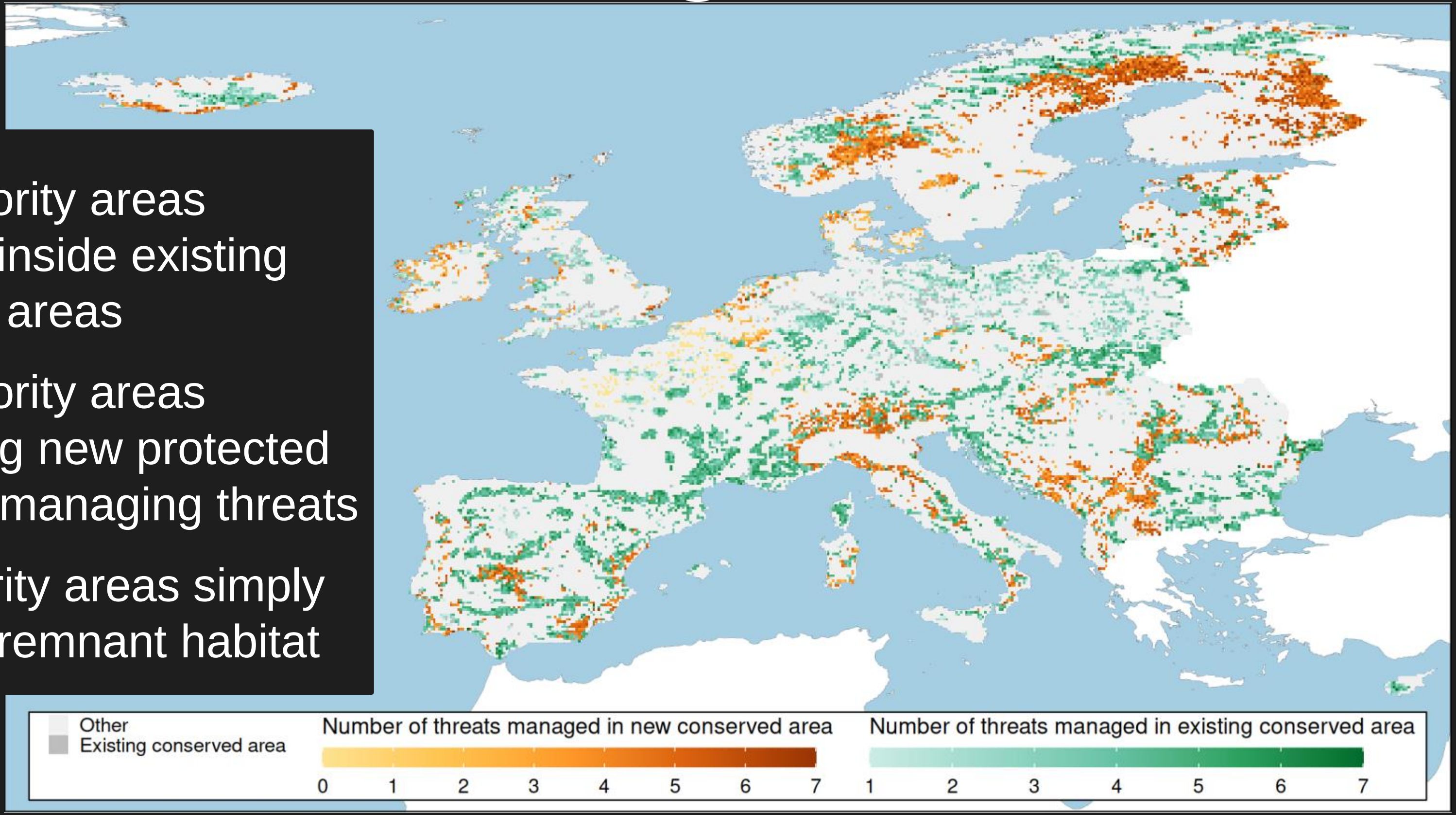
Patterns in management effort

- 66% of priority areas managing inside existing conserved areas
- 32% of priority areas establishing new protected areas and managing threats
- 2% of priority areas simply protecting remnant habitat



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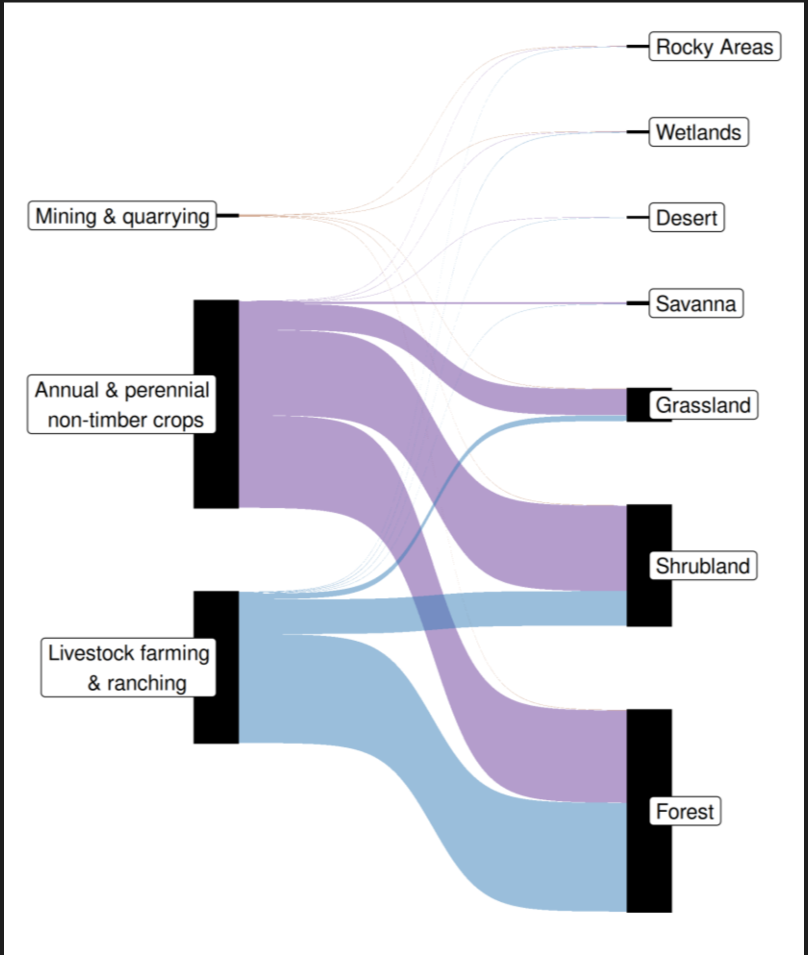
Habitat restoration

- Of the 7 threats that could be managed, 3 associated with restoration actions
- 69% of priority areas involved restoring habitat inside protected areas
- 30% of priority areas involved restoring habitat in newly established protected areas
- 28% of Europe's land prioritized for habitat restoration
- EU pledged to restore 20%



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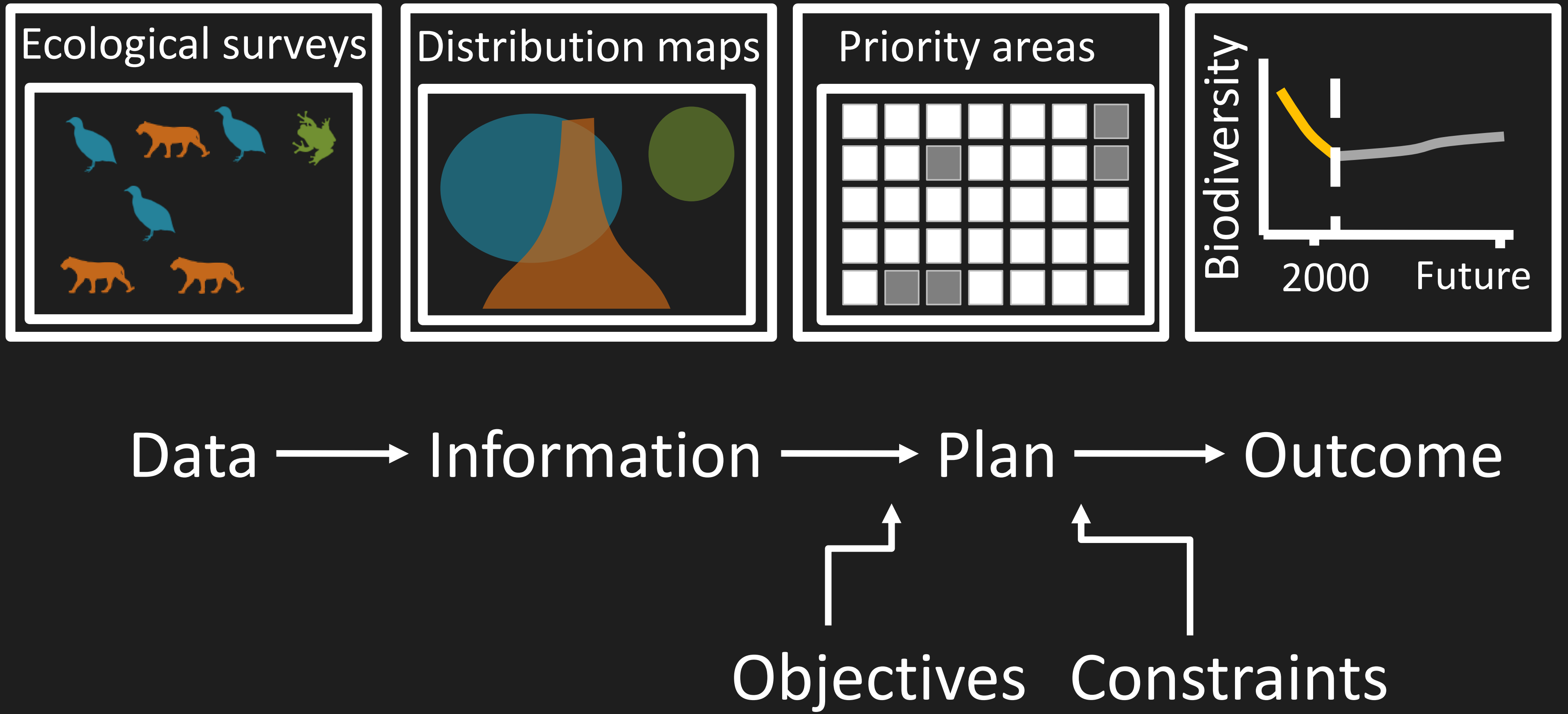
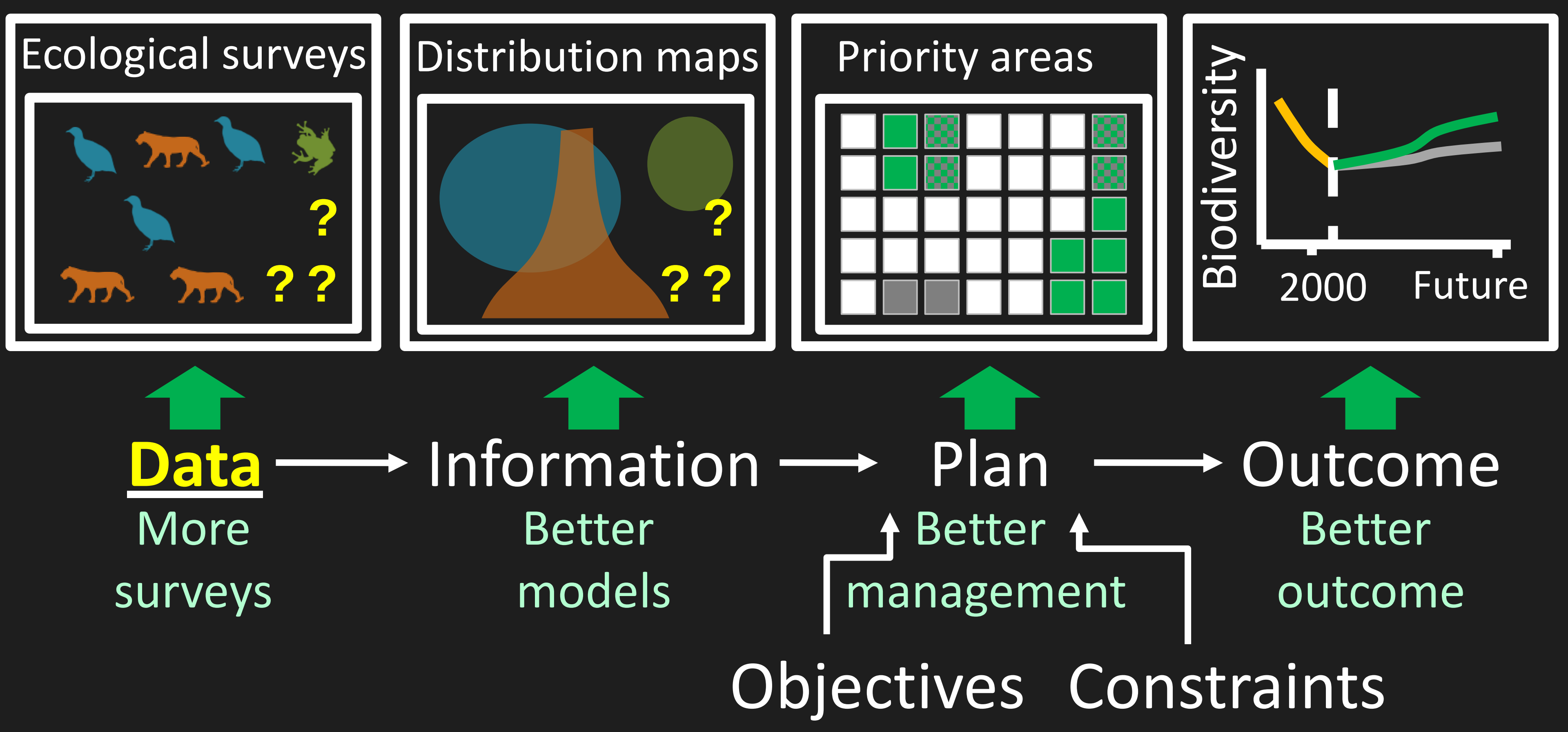
How can we get a better conservation decision?

(1) Better algorithms

(2) Better data

(3) Better surrogates


Ecological surveys
Distribution maps
Priority areas
Biodiversity
2000
Future
Data
Information
Plan
Outcome
Objectives
Constraints



Ecological surveys
? ? ?
Distribution maps
? ? ?
Priority areas
Biodiversity
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Future
Data
More surveys
Information
Better models
Plan
Better management
Outcome
Better outcome
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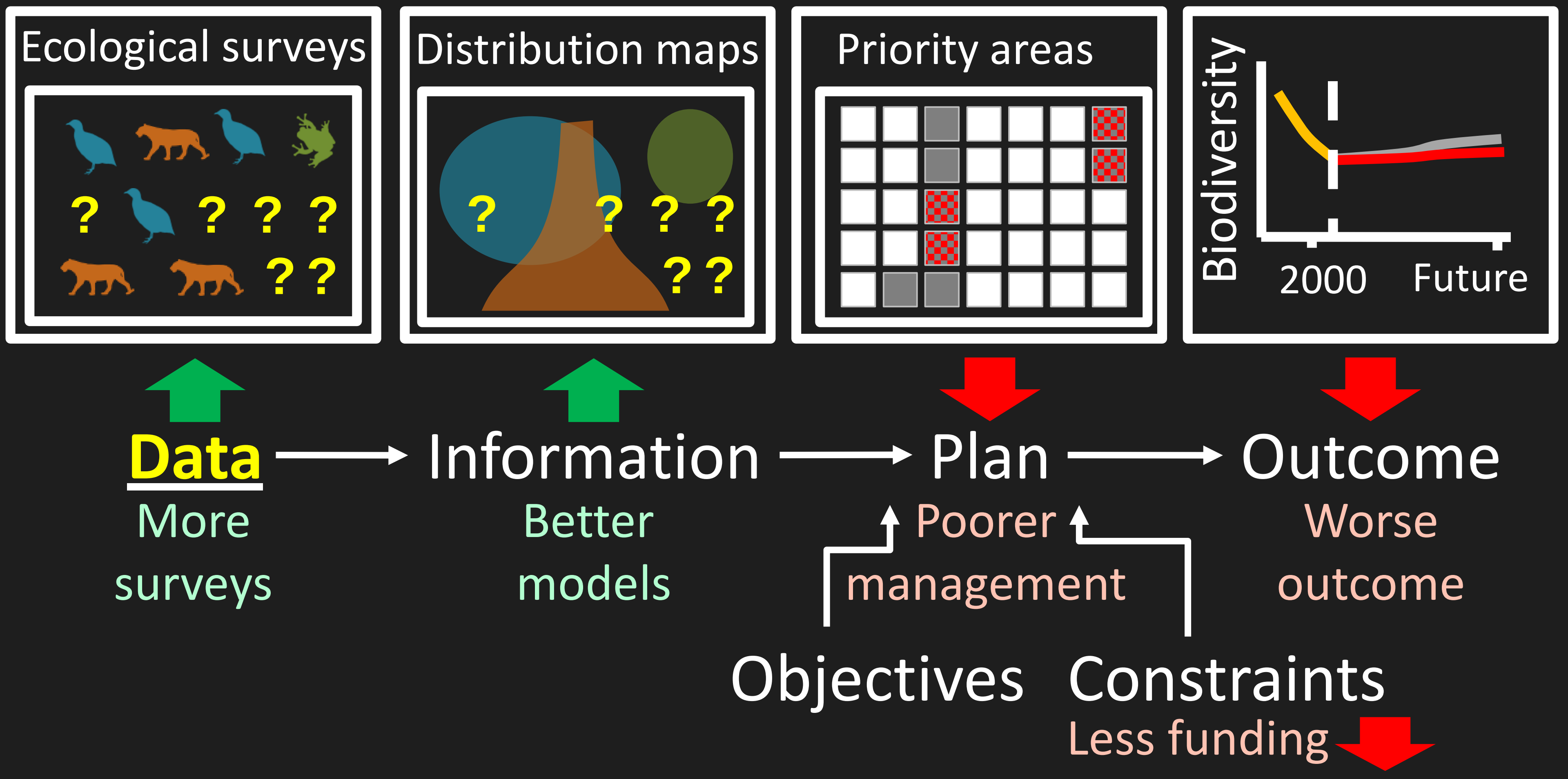
Constraints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? ?
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? ?
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Future
Data
More
surveys
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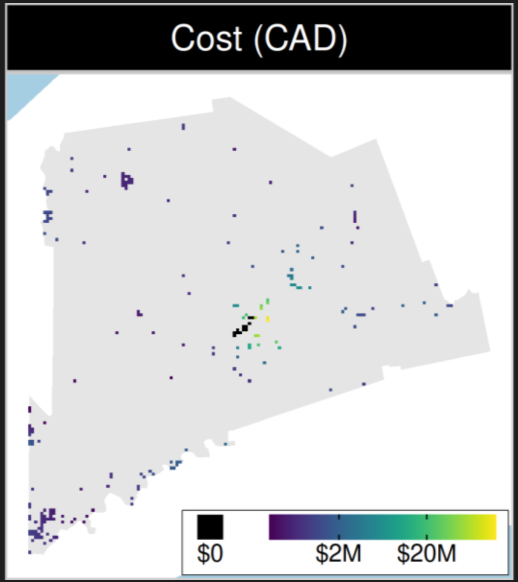
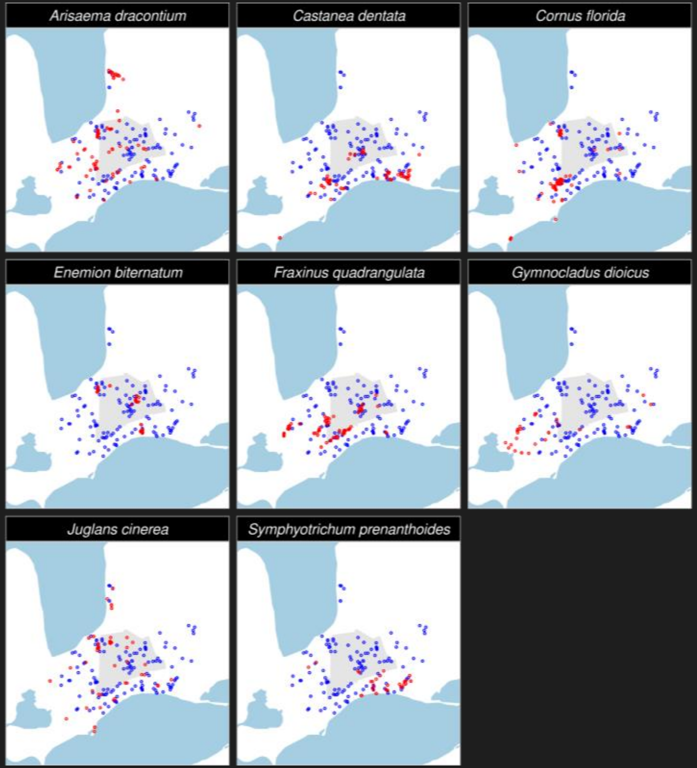
Better
models
Plan
Poorer
management
Outcome
Worse
outcome
Objectives
Constraints
Less funding

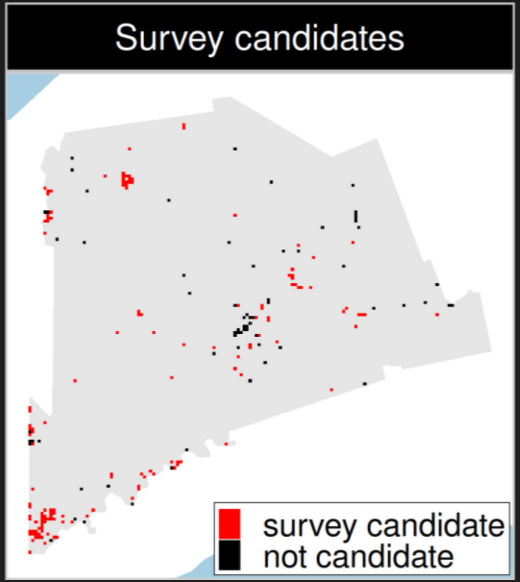
Study system: Middlesex county, Canada



199 places that could potentially be acquired for protected area establishment



8 imperiled plant species



143 places that could potentially be surveyed to improve existing data

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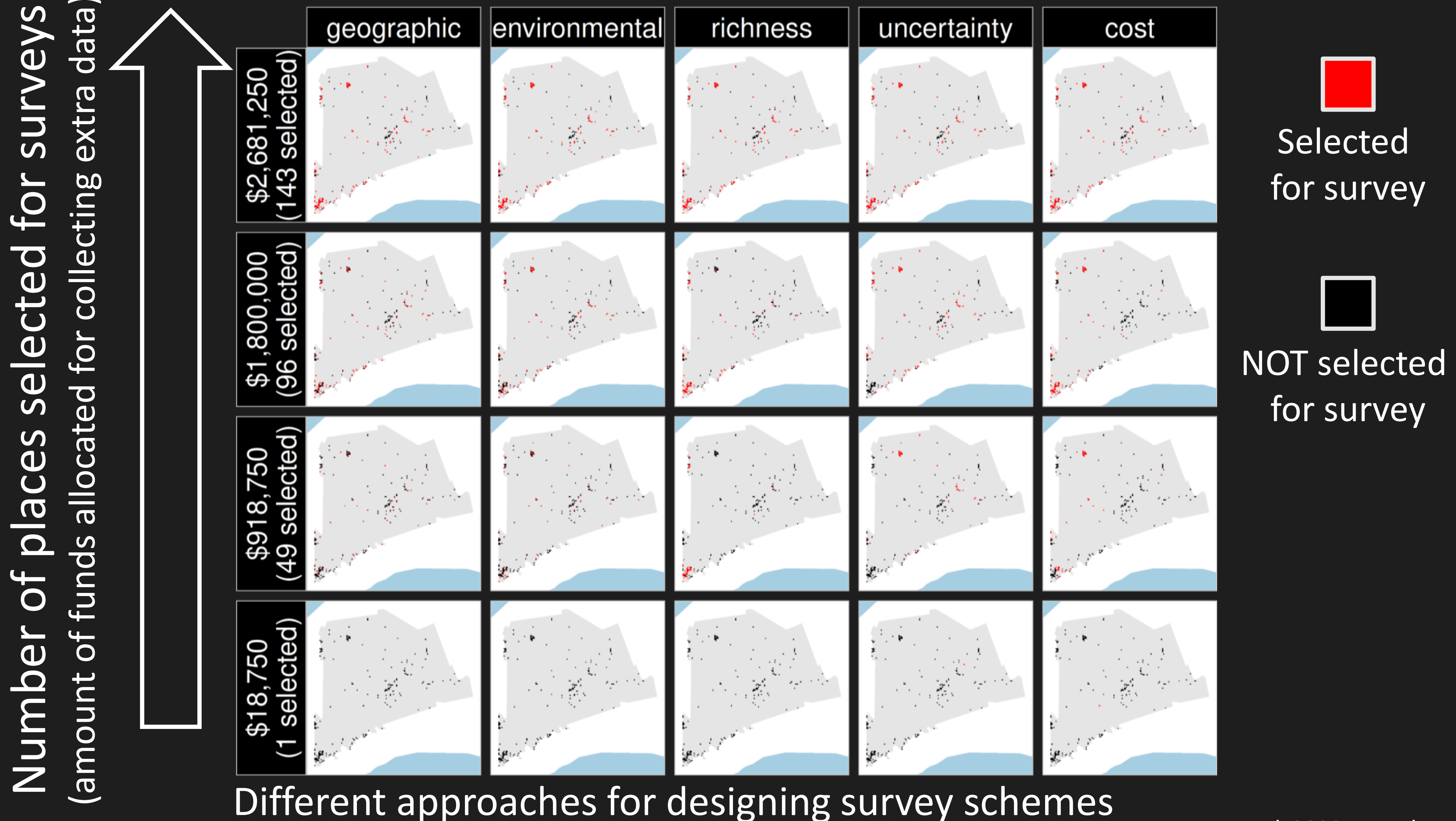

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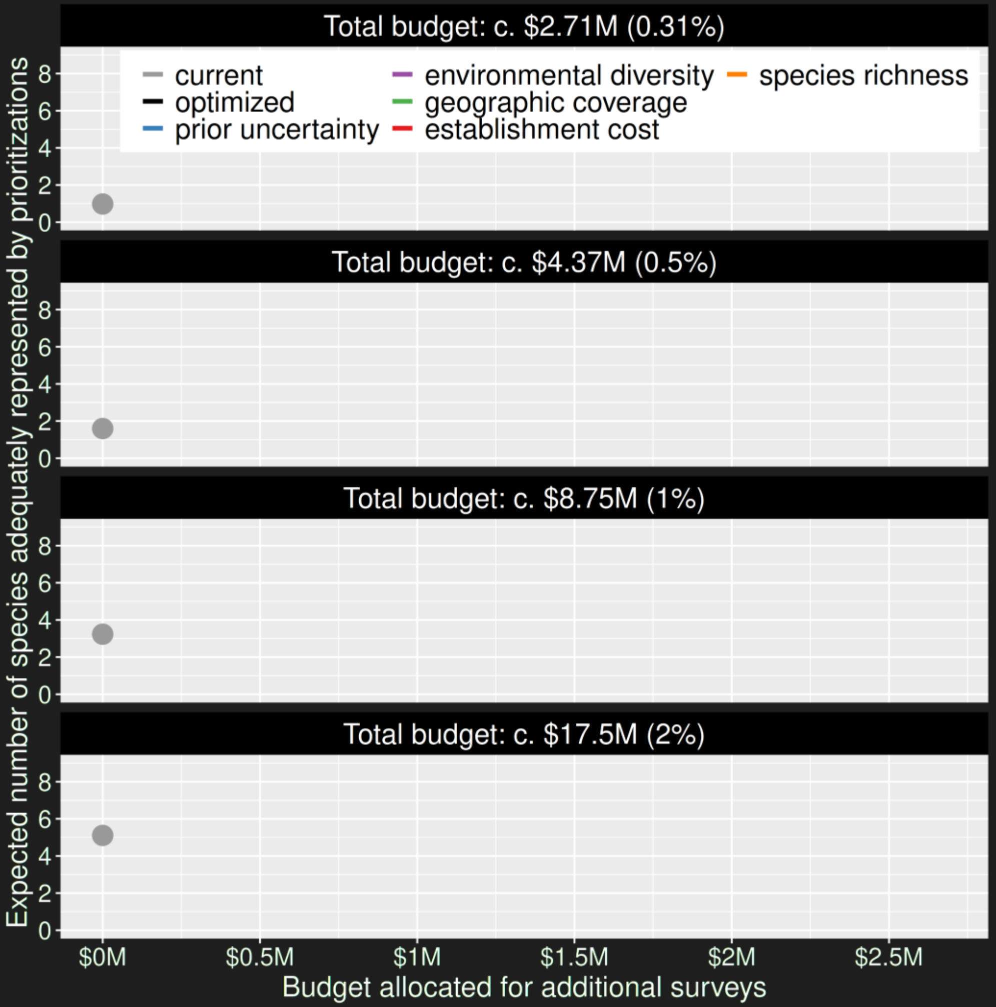
Value of information

- Existing data leads to positive outcomes
- More budget means better outcomes



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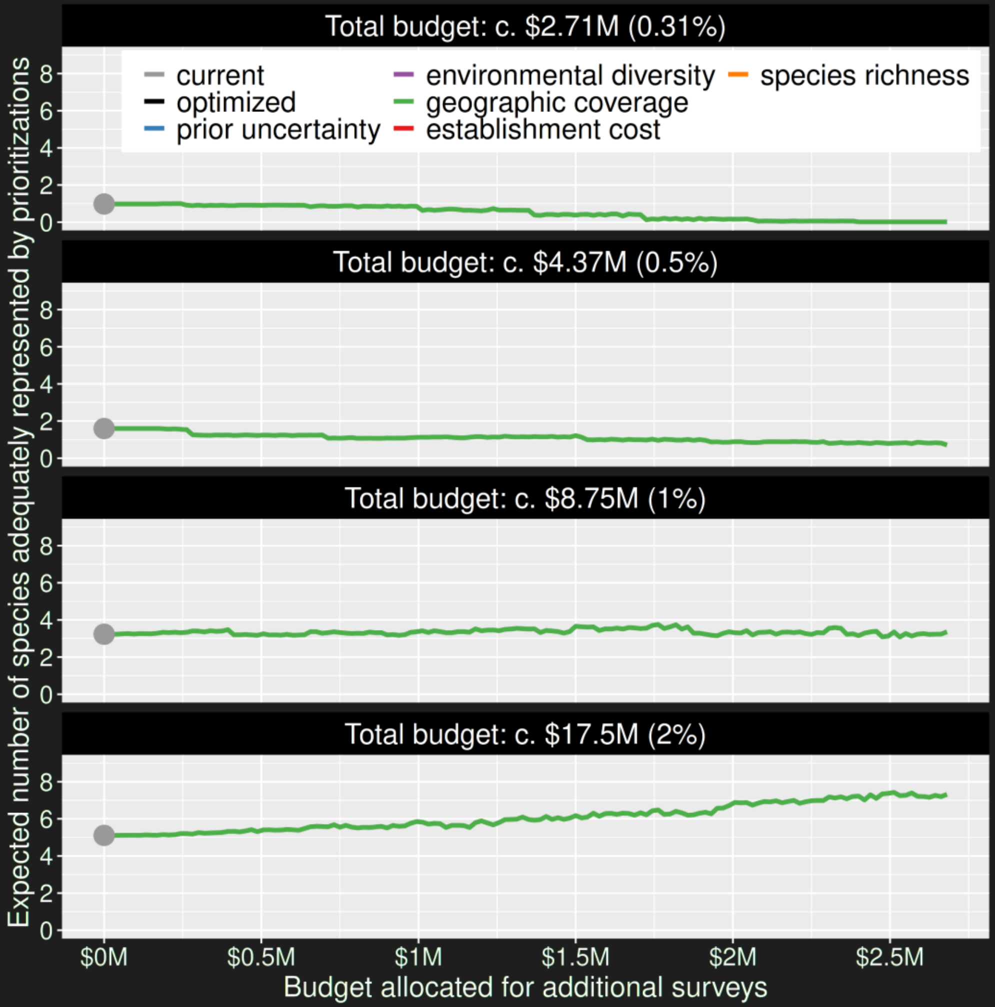
Value of information

- Allocating funds for gathering more data can mean worse outcomes
- Allocating funds for gathering more data can mean better outcomes too



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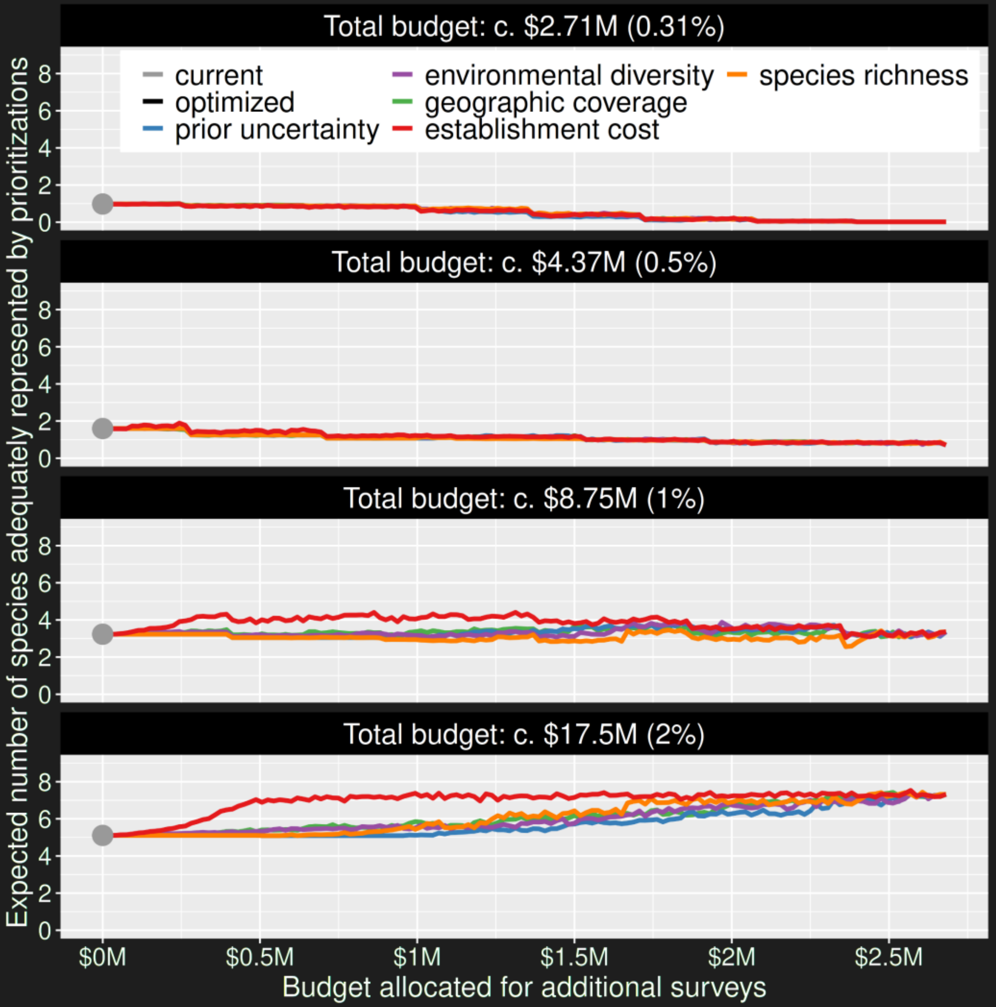
Value of information

- Conventional approaches for gathering additional evidence have different performance
- Performance of these approaches depends on available funds
- All of them could lead to lead to worse outcomes



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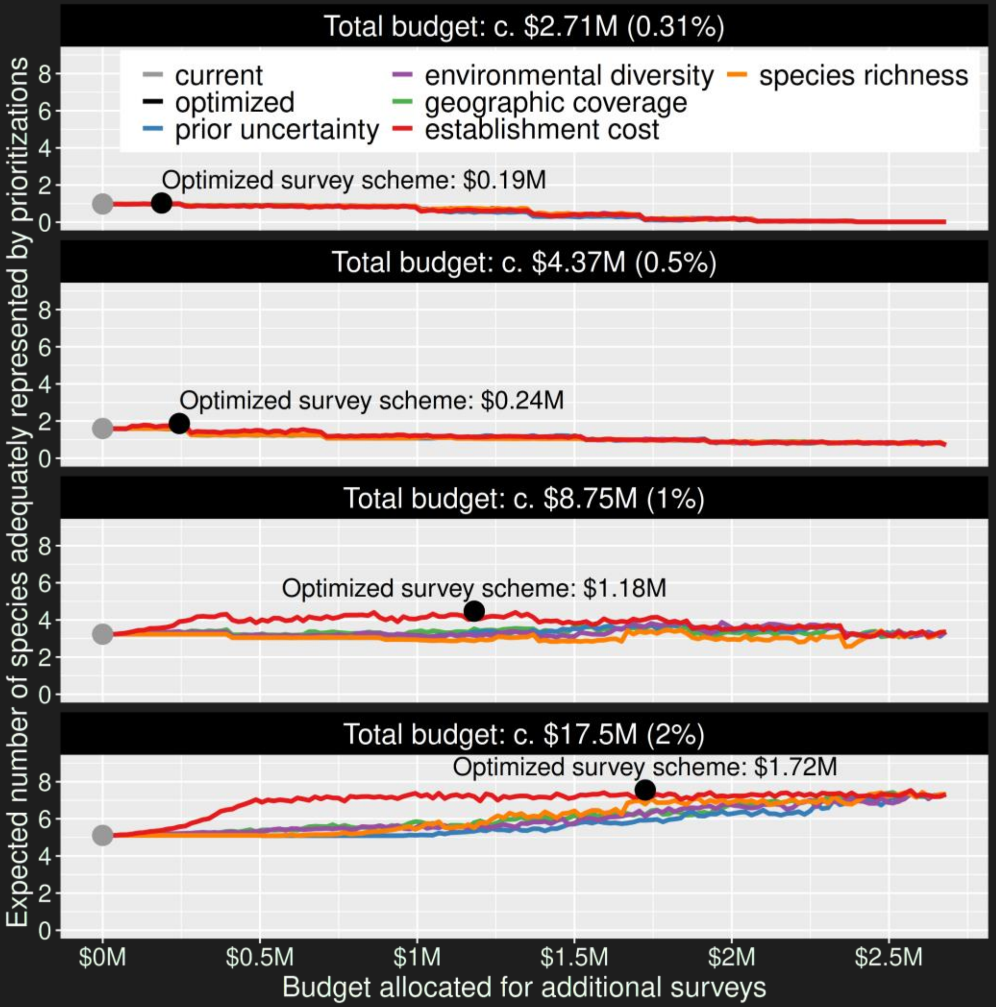
Value of information

- Directly maximizing return on investment is best method for additional data
- This considers objectives and constraints that underpin conservation plans and their success
- You can do this with: surveyvoi R package



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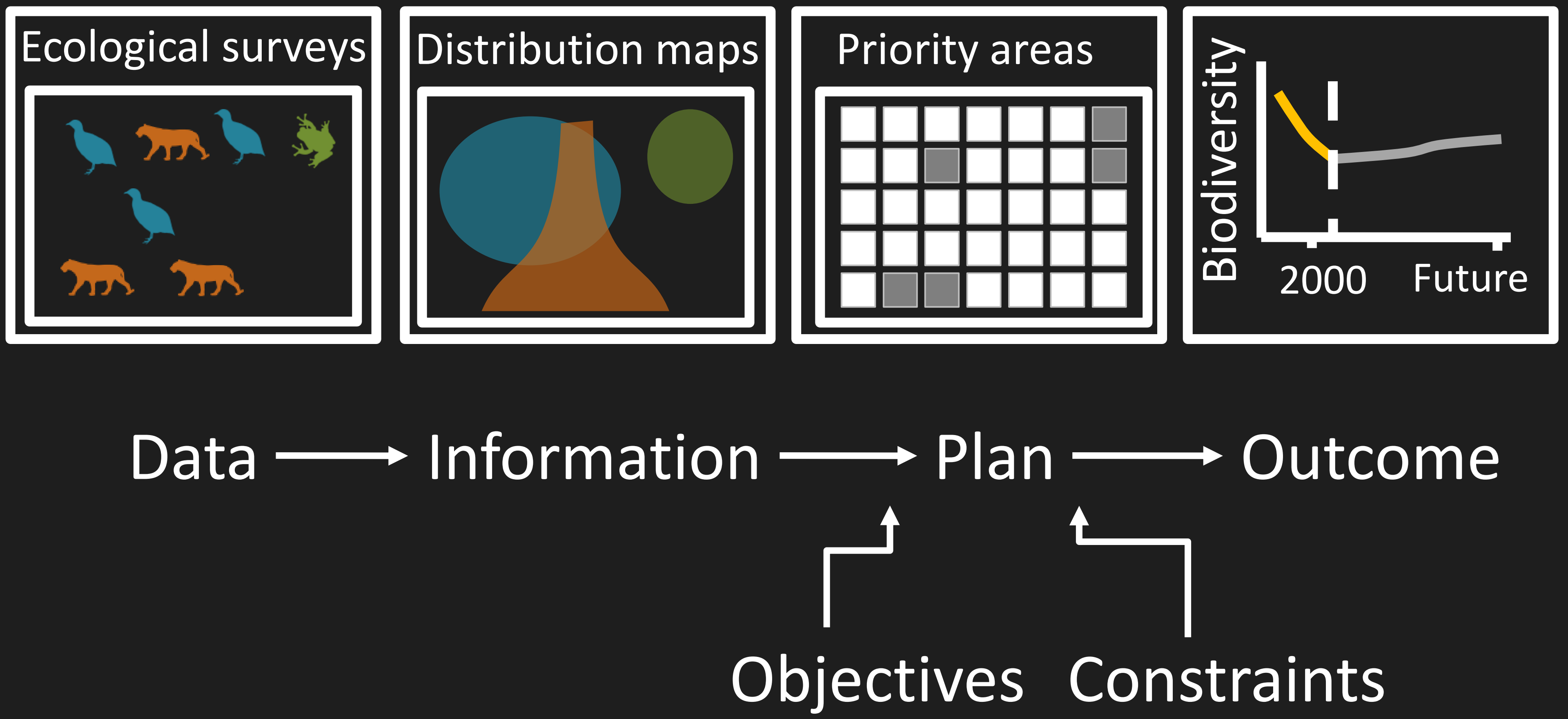
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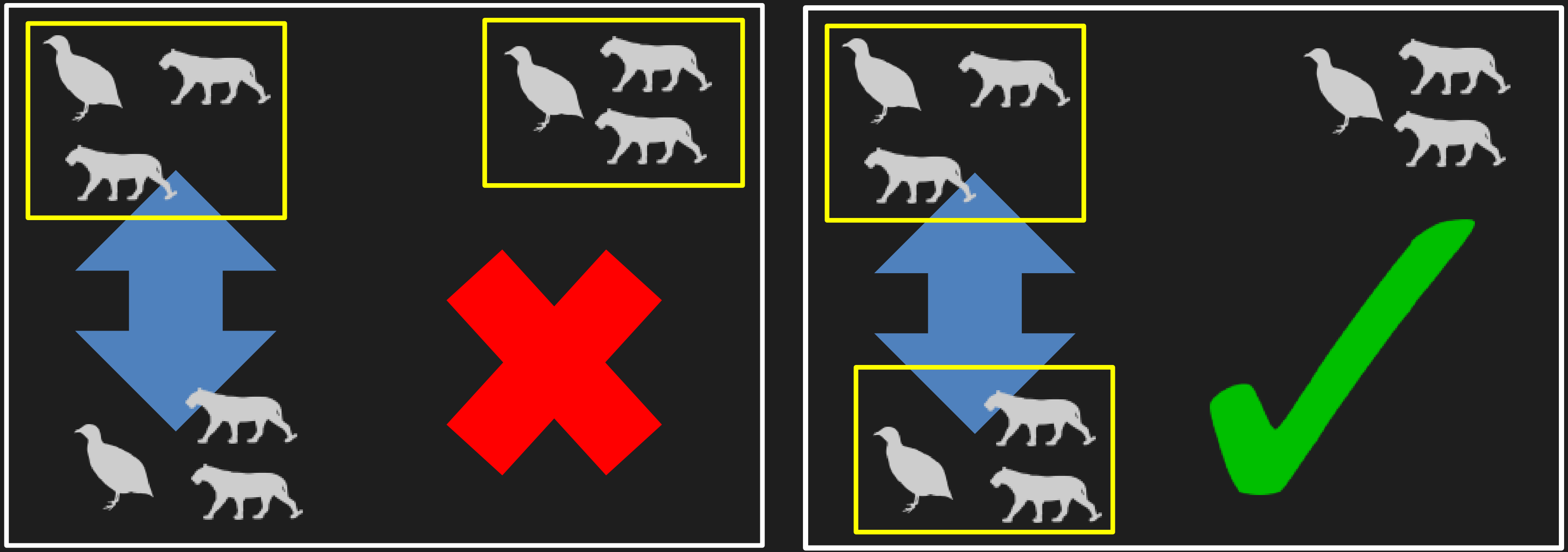
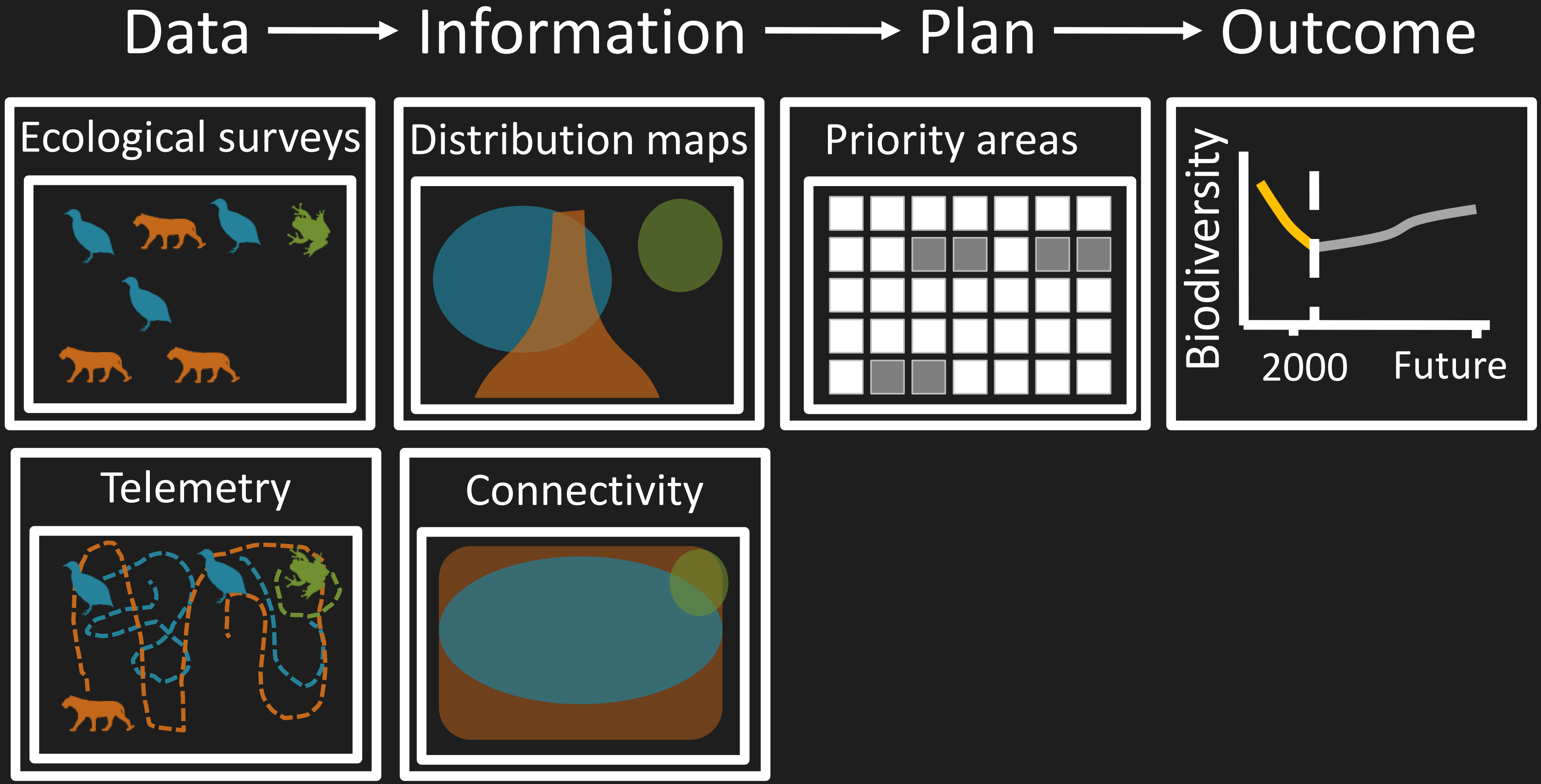
Connectivity in reserve design

movement of individuals and genes between populations



*all else being equal


Data
Information
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Ecological surveys
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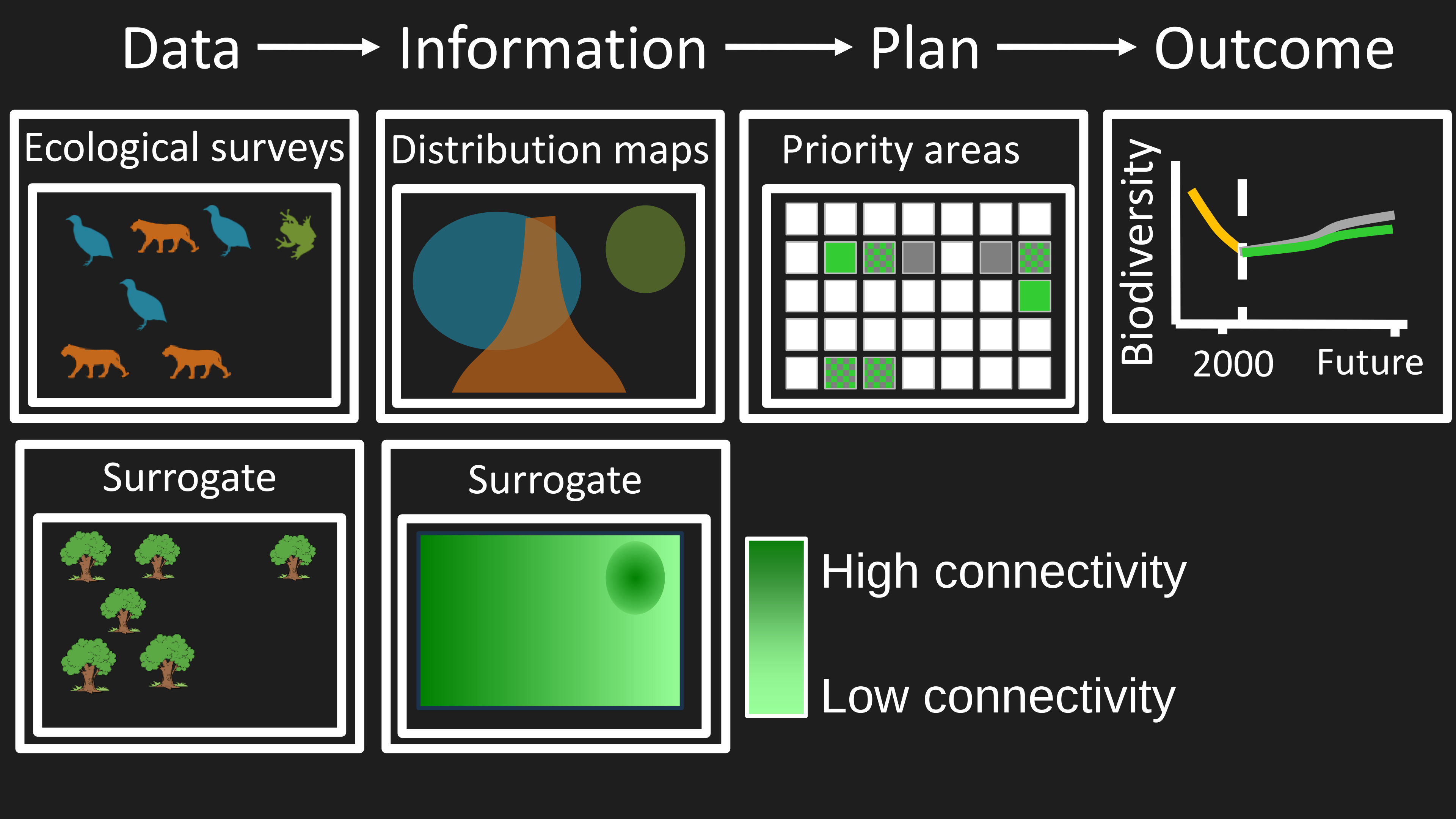
2000
Future
Telemetry
Connectivity

But getting connectivity data is hard

Animal telemetry

Molecular ecology



Data
Information
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Outcome
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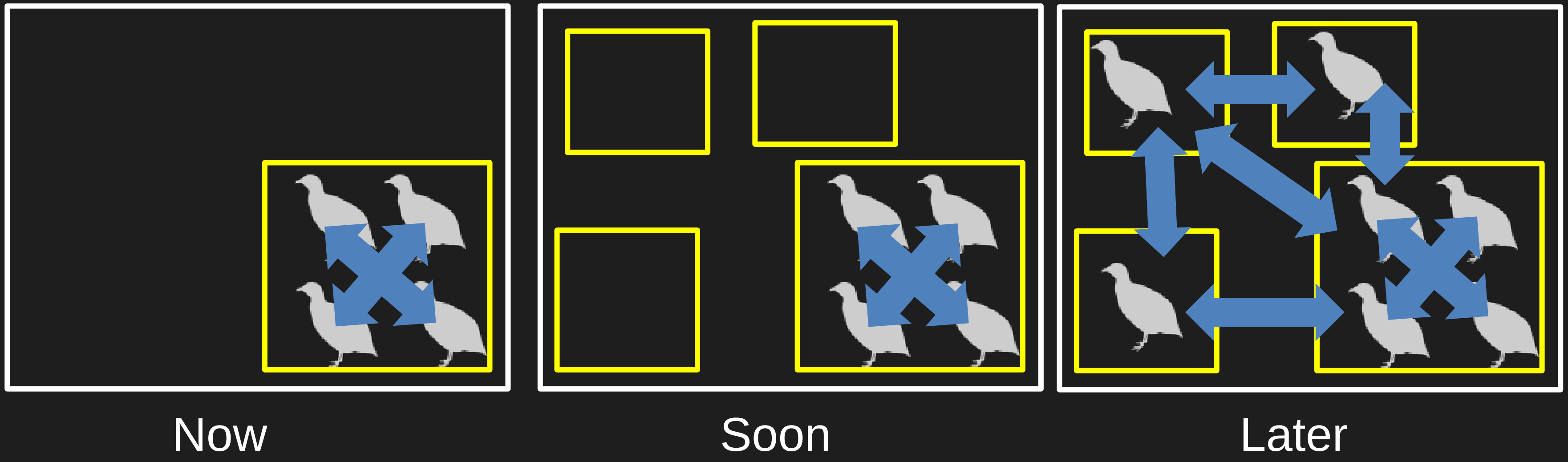
Priority areas
Biodiversity
2000
Future
Surrogate
Surrogate
High connectivity
Low connectivity

Many surrogates are often available, how do our choices affect the results?

Rules of thumb for connectivity

More habitat = More connectivity

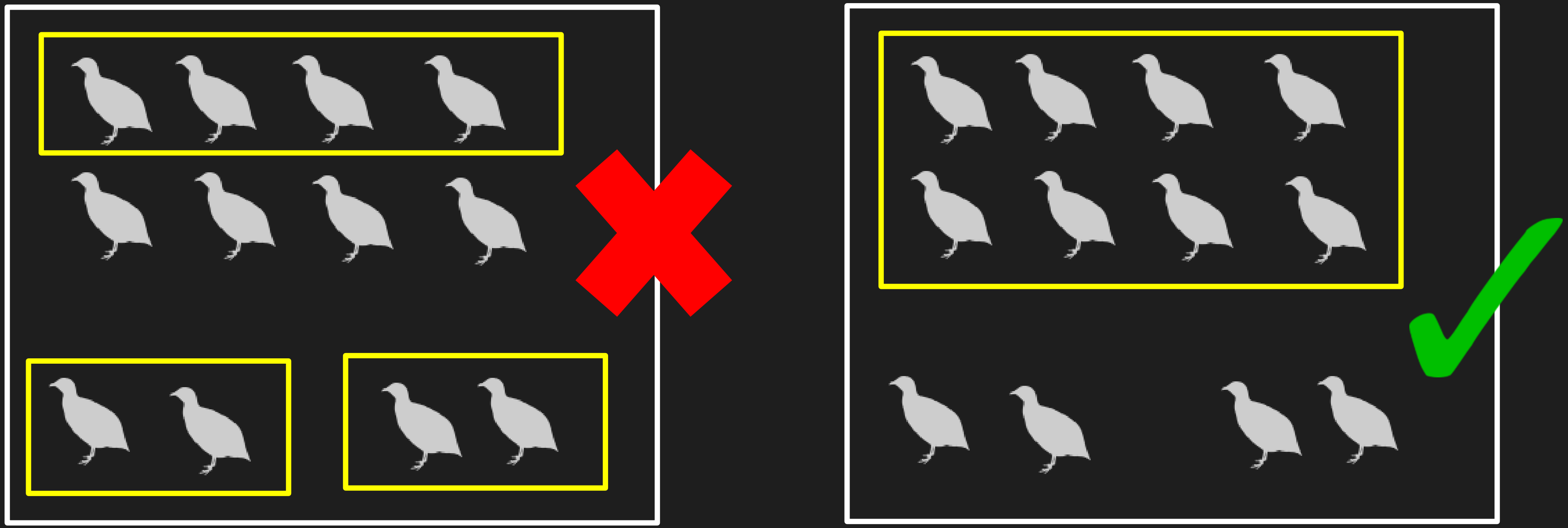
- Total area protected
- Species representation



Rules of thumb for connectivity

More spatial clustering = More connectivity

- Boundary length



Rules of thumb for connectivity

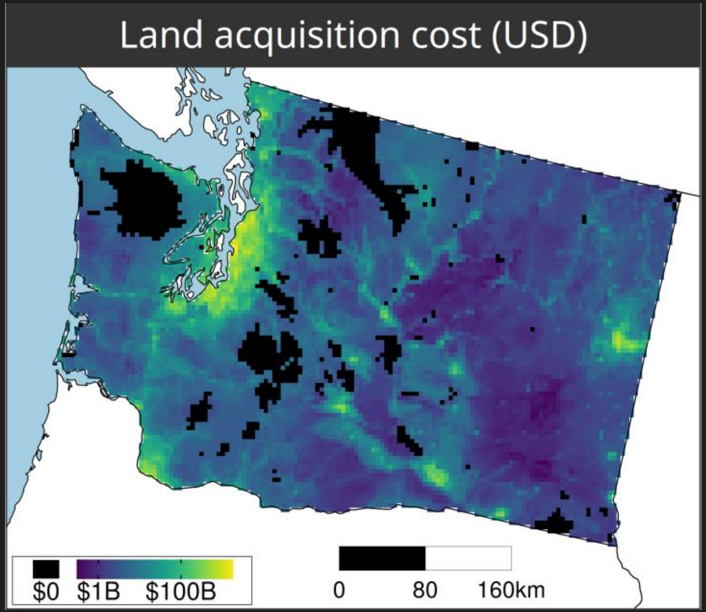
Protect clusters of low resistance = More connectivity

- Human pressure
- Naturalness based landscape resistance
- Focal species landscape resistance
- Habitat heterogeneity
- Environmental similarity

A comparison of approaches for including connectivity in systematic conservation planning

Washington State, USA

- 261 bird species
- Land acquisition costs
- Existing protected areas
- Multiple land-uses
- Multiple eco-systems



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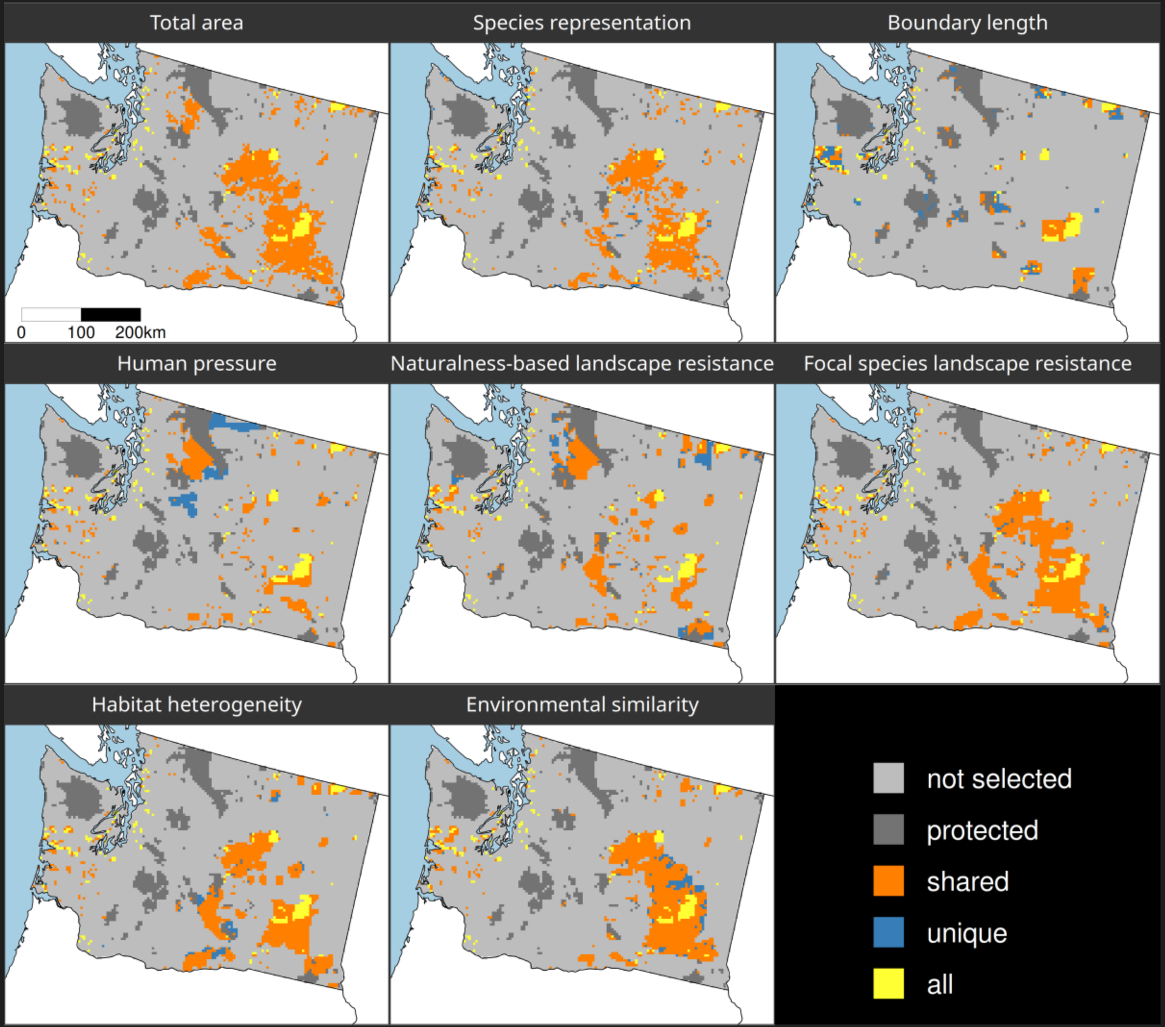
- Different connectivity approaches produce different prioritizations

- Different connectivity approaches can yield similar prioritizations



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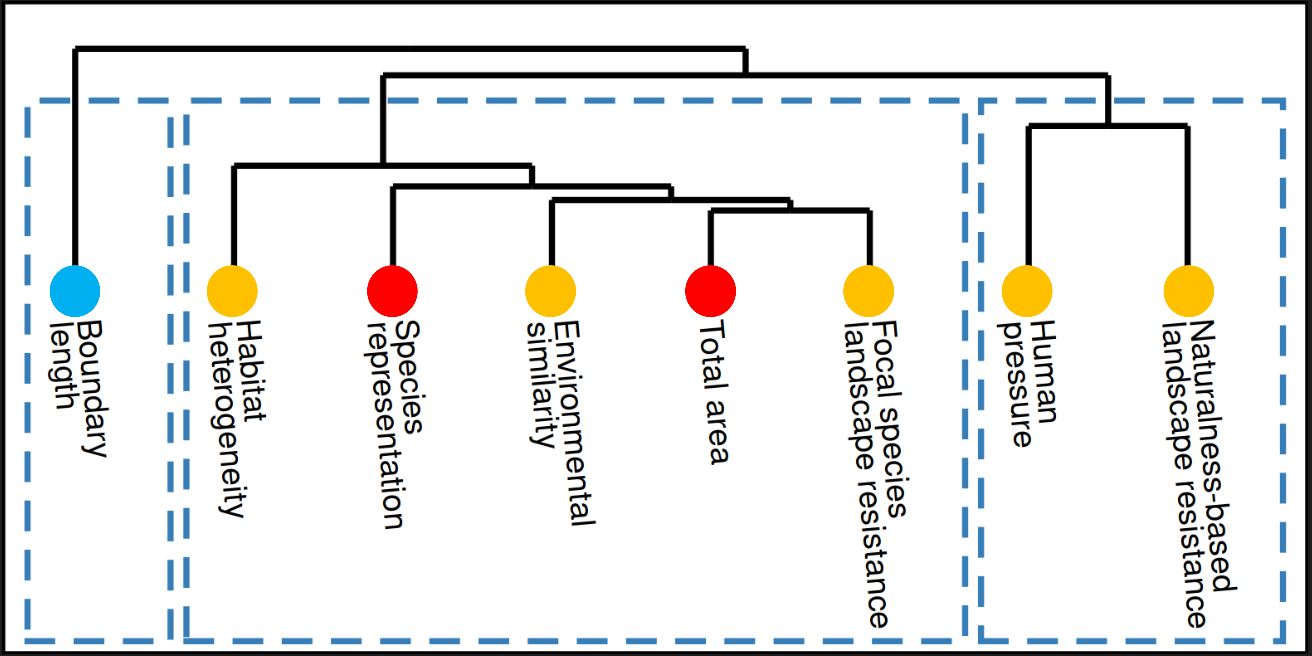
How do the prioritizations compare?



Approach
- Habitat-based
- Spatial clustering
- Resistance-based

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Make better conservation decisions by using…

1. Better algorithms
2. Cost-effective data
3. Reliable surrogates

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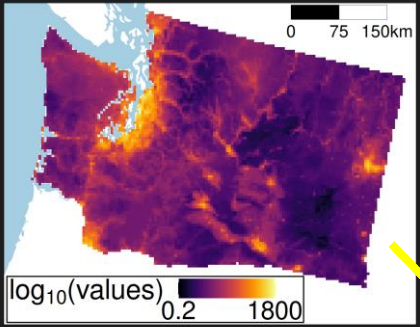
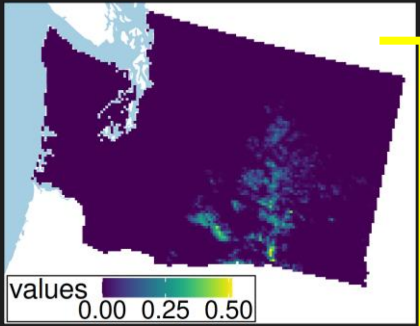
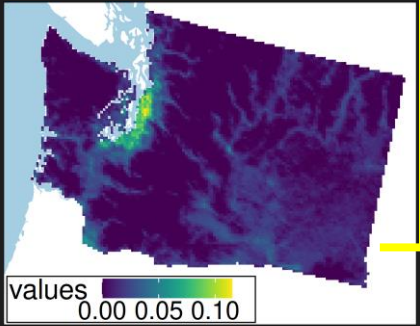
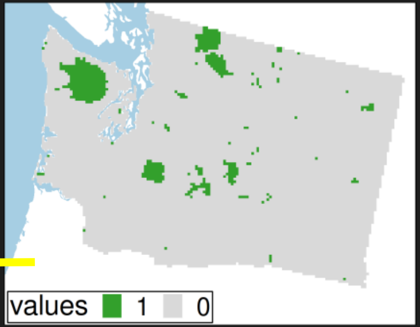
Worked example

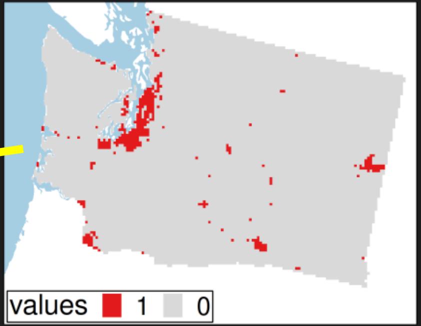







```
# load packages
library(prioritizr) # package for conservation planning
library(terra)      # package for raster data

# input data
## raster with continuous values indicating costs
planning_unit_data <- rast("pu.tif")

## multi-layer raster with relative abundance data
### feature_data[[1]] is the first feature,
### feature_data[[2]] is the second feature,
### and so on, with 396 features in total
feature_data <- rast("features.tif")

## raster with binary values indicating if each planning
## unit is covered by (1) protected areas or (0) not
protected_area_data <- rast("protected-areas.tif")

## raster with binary values indicating if each planning
## unit covered by (1) urban areas or (0) not
urban_area_data <- rast("urban-areas.tif")
```





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```r
# build problem
## specify the data, formulation, and solver
conservation_planning_problem <-
  ### initialize with planning unit and feature data
  problem(planning_unit_data, feature_data) %>%
  ### add minimum shortfall function with budget
  add_min_shortfall_objective(3917.631) %>%
  ### add representation targets for 20% coverage of each feature
  add_relative_targets(targets = 0.2) %>%
  ### add penalties to reduce spatial fragmentation
  add_boundary_penalties(penalty = 0.00001) %>%
  ### add constraints to ensure existing protected areas are selected
  add_locked_in_constraints(protected_area_data) %>%
  ### add constraints to ensure urban areas are not selected
  add_locked_out_constraints(urban_area_data) %>%
  ### specify that decision variables are binary (0 or 1 values)
  add_binary_decisions() %>%
  ### specify software to perform optimization,
  ### and set gap parameter for near-optimal solution
  add_gurobi_solver(gap = 0.1)
```

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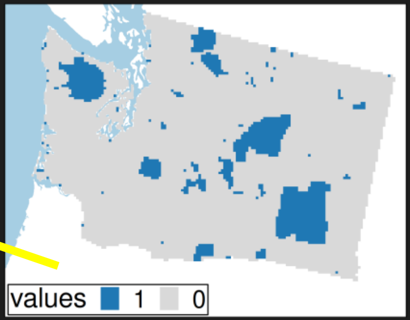
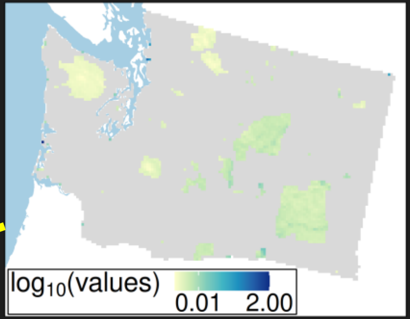
```r
# solve problem
## output raster has binary values indicating if
## each planning unit is (1) selected or (0) not
prioritization <- solve(conservation_planning_problem)

# evaluate prioritization
## calculate overall cost of prioritization
eval_cost_summary(
  conservation_planning_problem, prioritization)
#> # A tibble: 1 × 2
#>   summary     cost
#>   <chr>      <dbl>
#> 1 overall 3911.832

## calculate relative importance of selected planning units
### output raster has continuous importance values
relative_importance <-
  eval_ferrier_importance(
    conservation_planning_problem, prioritization)
```





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