

Making better conservation decisions



Jeffrey Hanson



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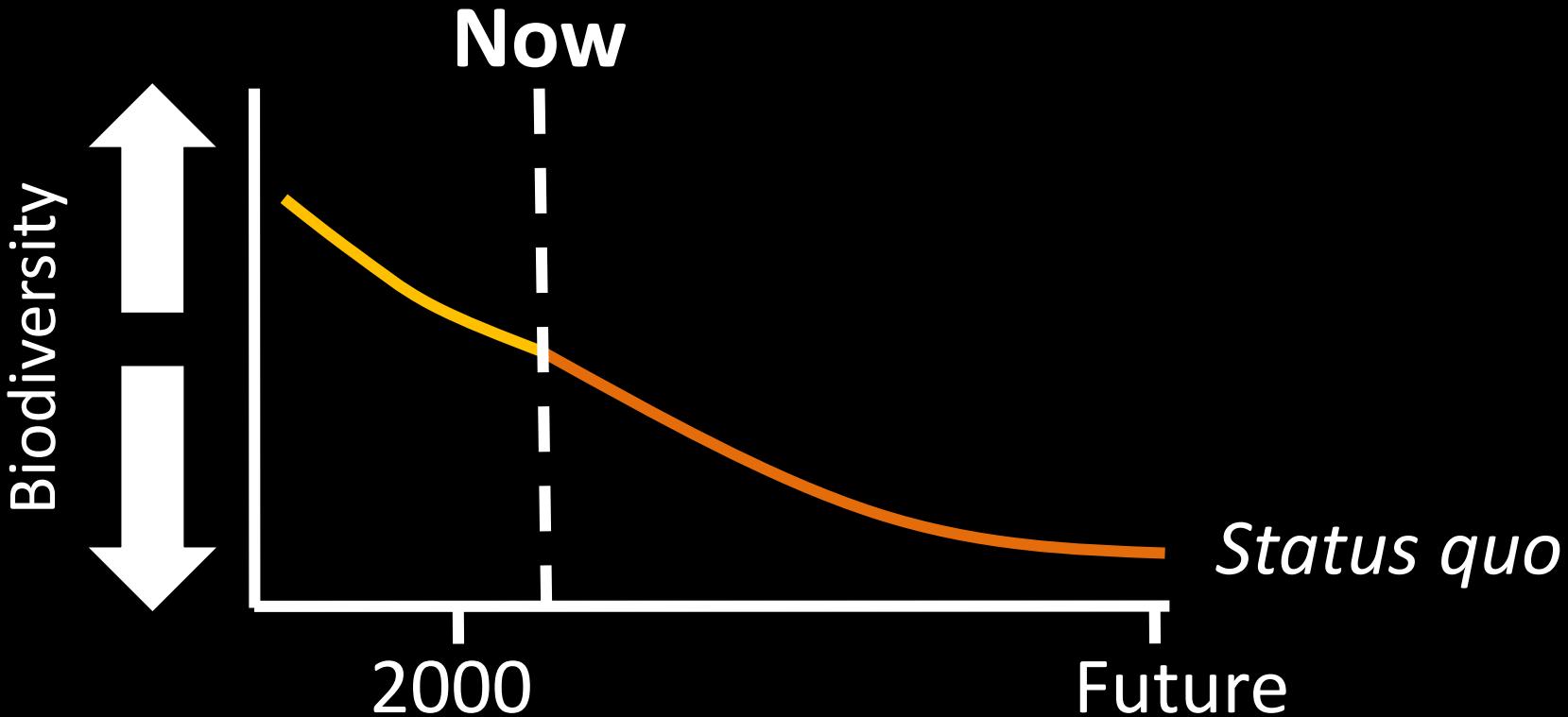


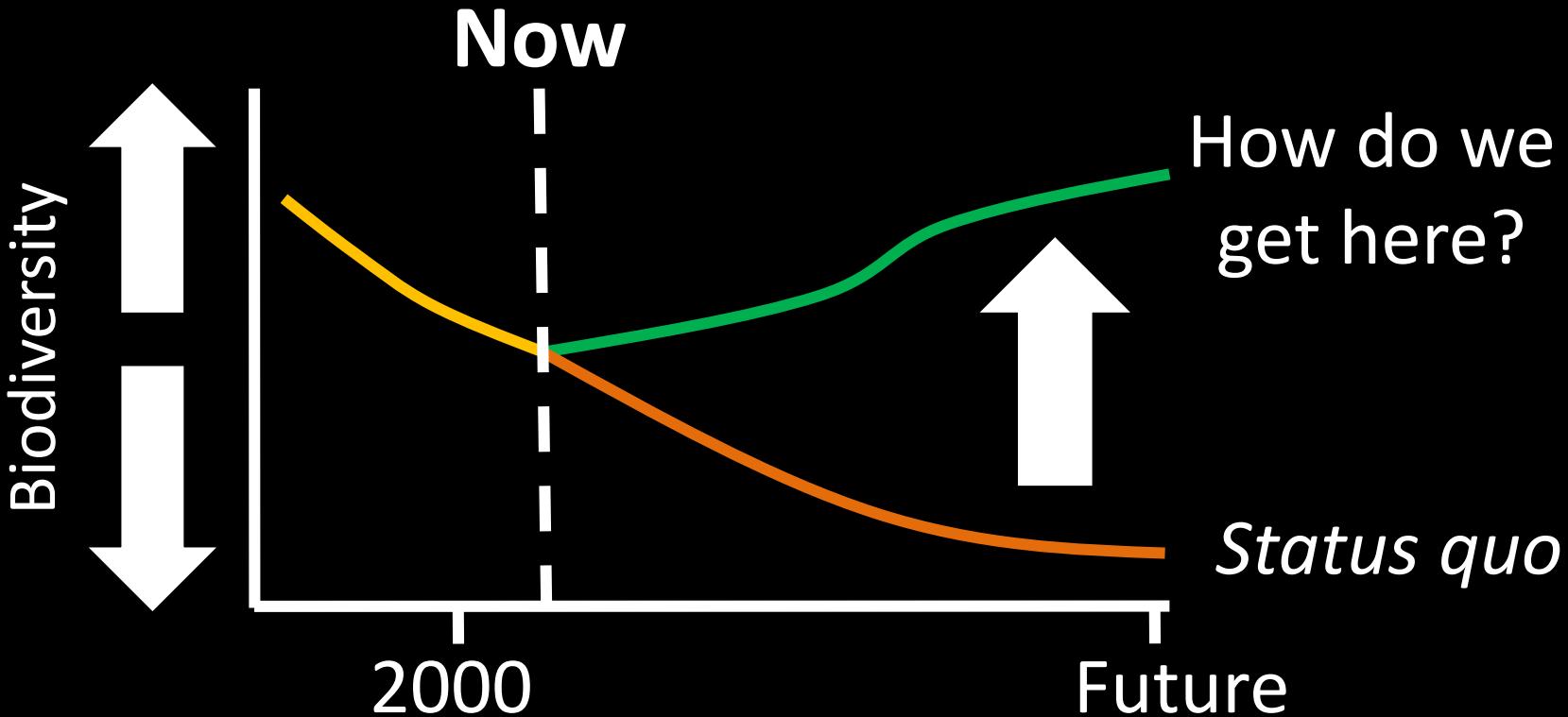
jeffrey-hanson.com

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Cynthia Riginos	Íñigo Martínez-Solano	Miguel Camacho-Sánchez	Stuart Butchart







How can we get a better conservation decision?

(1) Better algorithms

(2) Better data

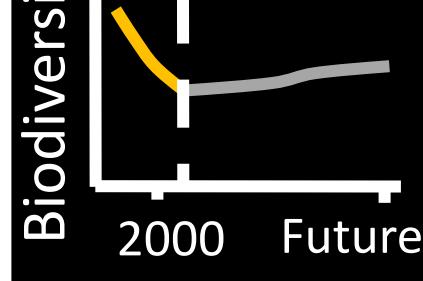
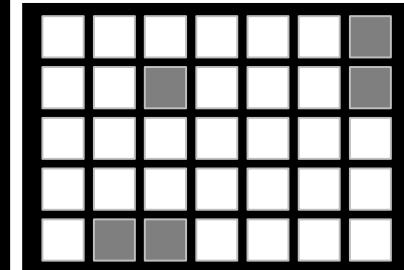
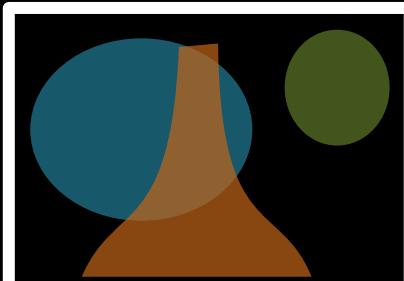
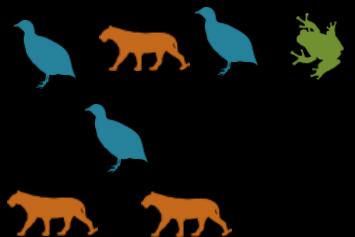
(3) Better surrogates

Ecological surveys

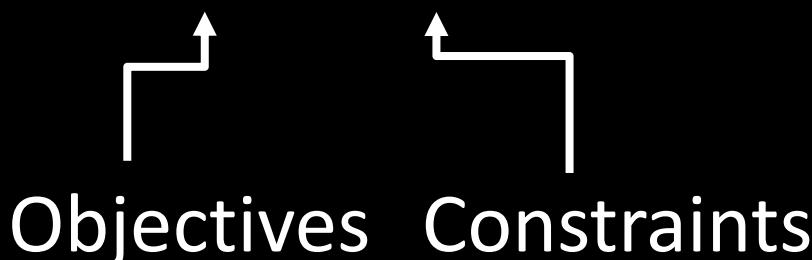
Distribution maps

Priority areas

Biodiversity



Data → Information → Plan → Outcome

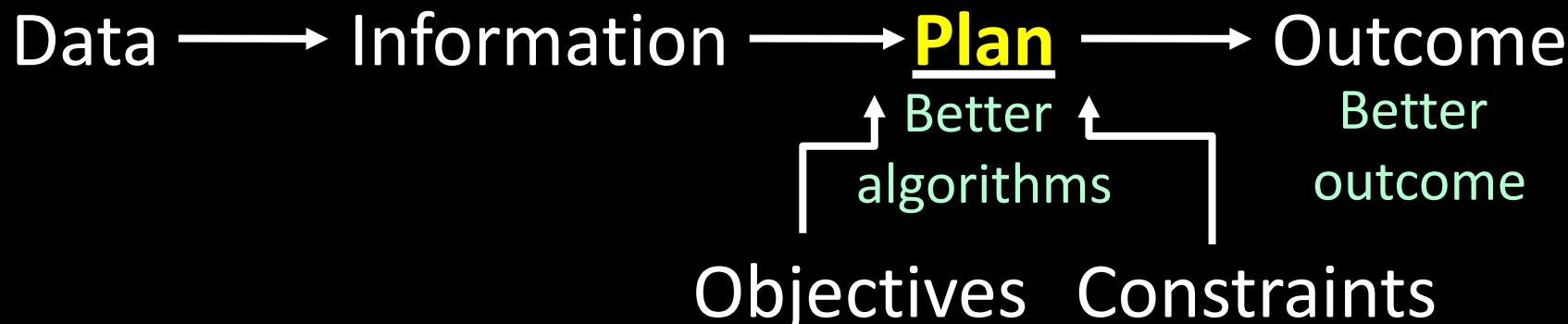
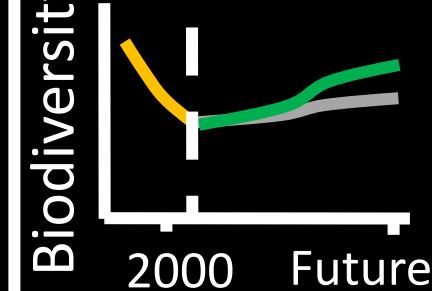
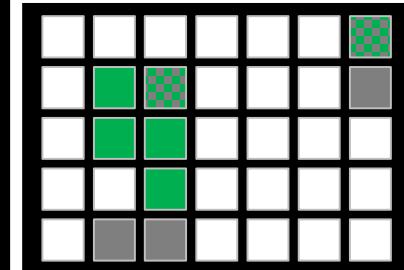
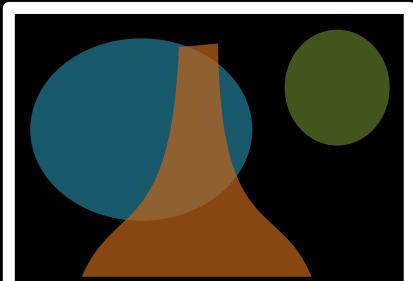
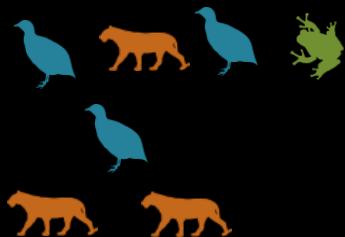


Ecological surveys

Distribution maps

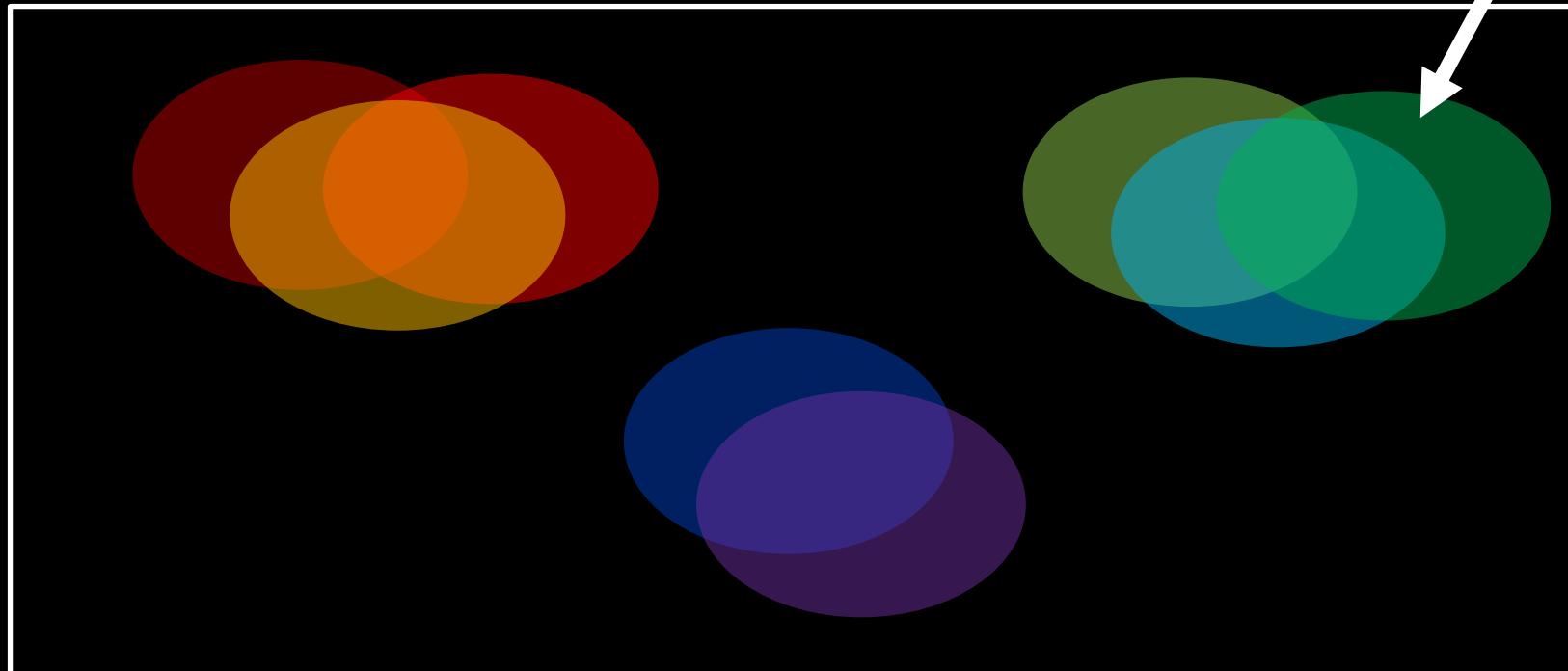
Priority areas

Biodiversity



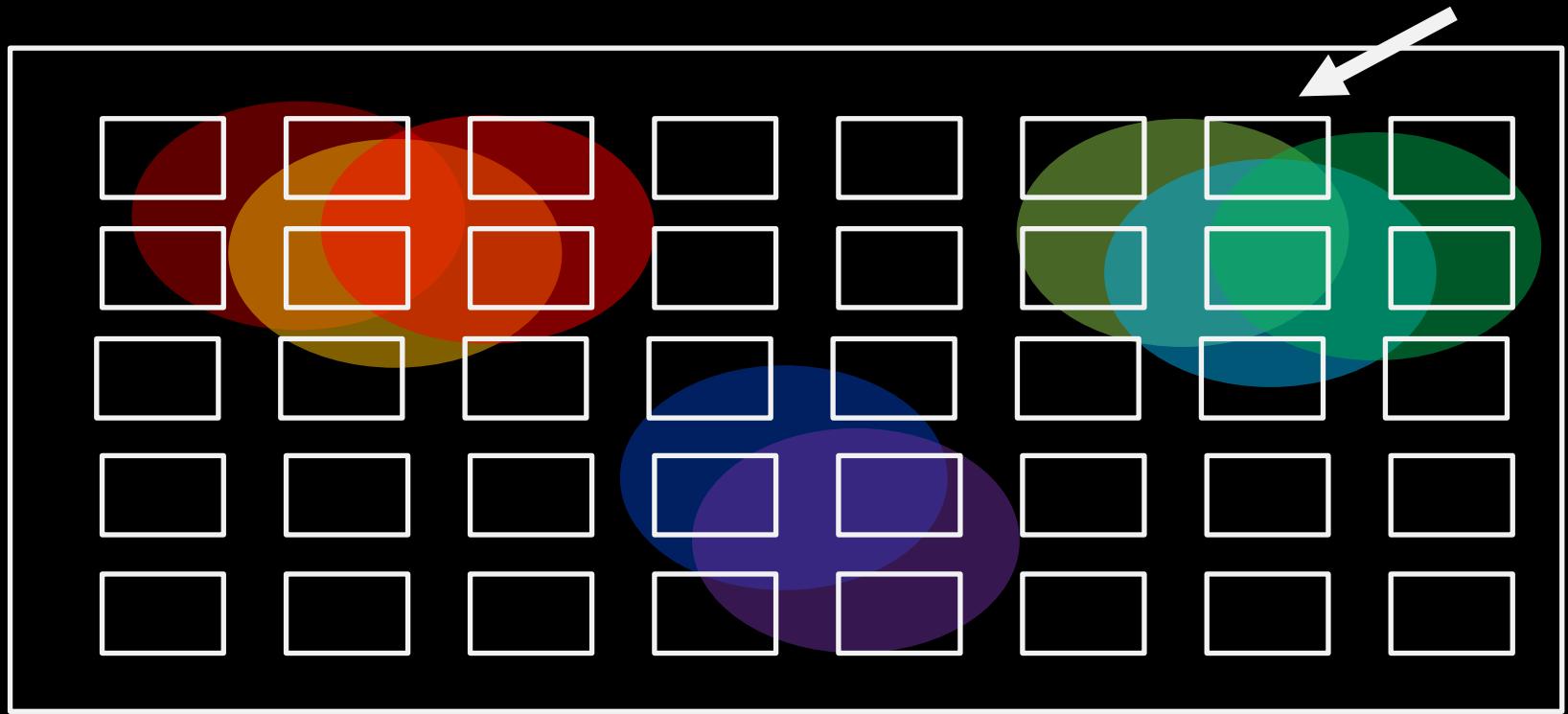
Reserve selection

Features

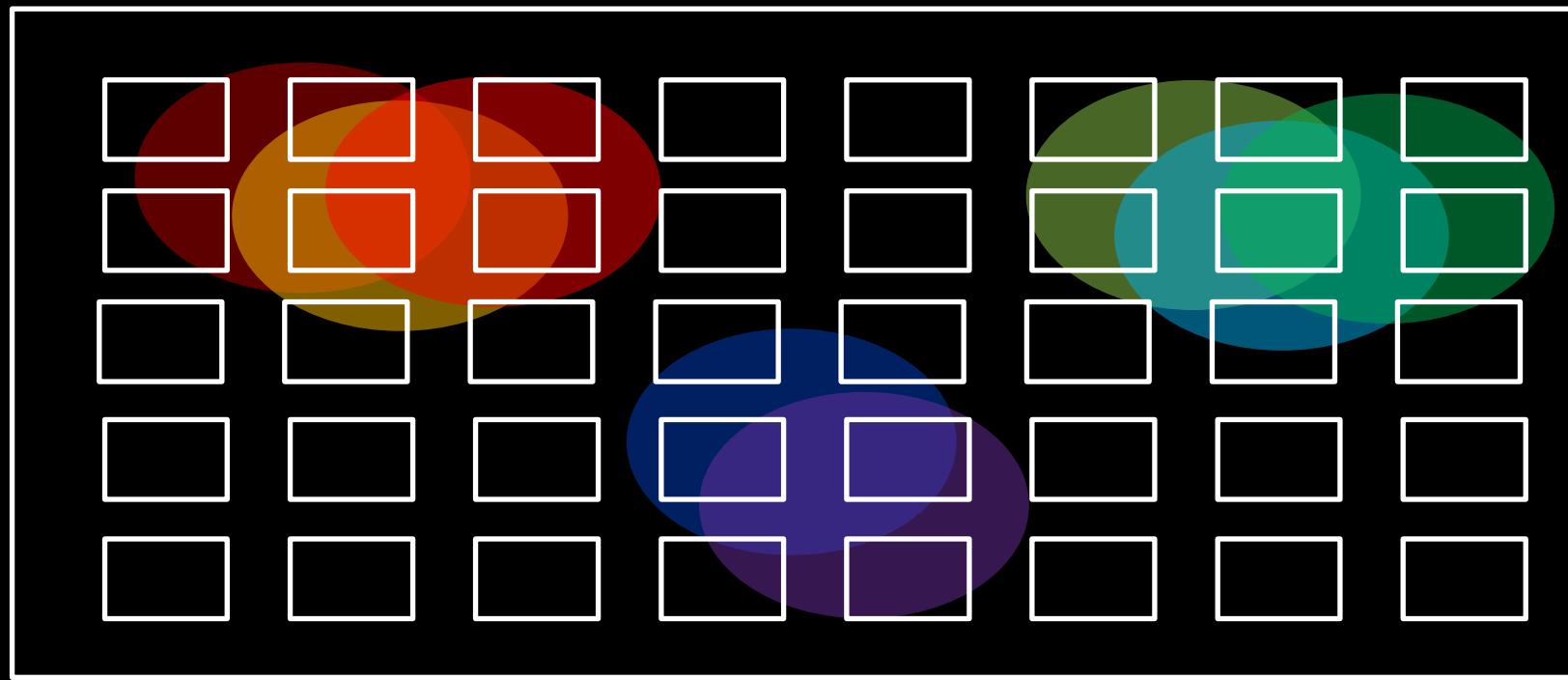


Reserve selection

Planning units



Reserve selection



?

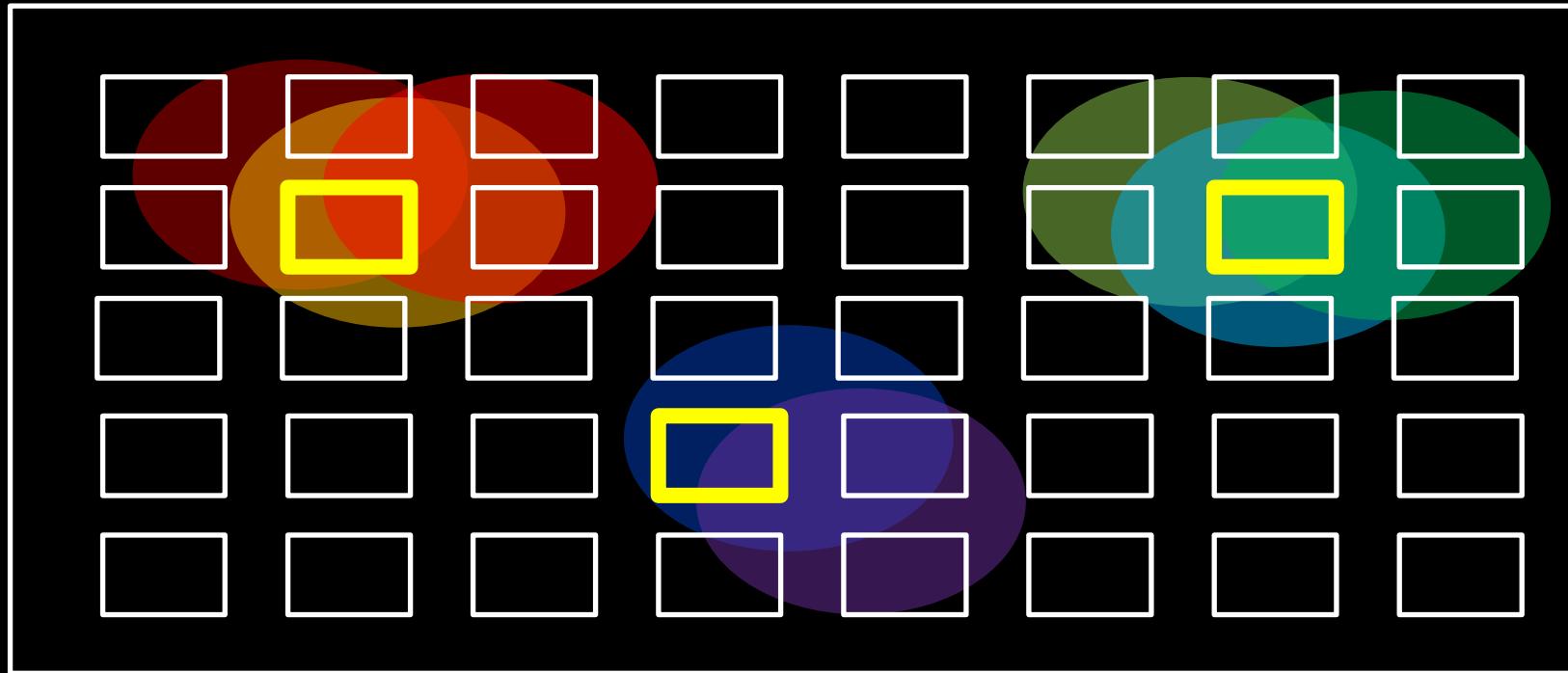
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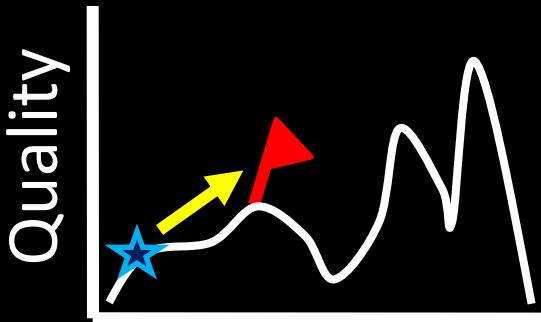
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Reserve selection



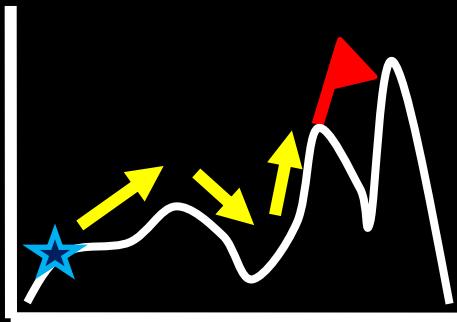
Heuristic algorithm



Different solutions



Meta-heuristic algorithms



Different solutions



Exact algorithms



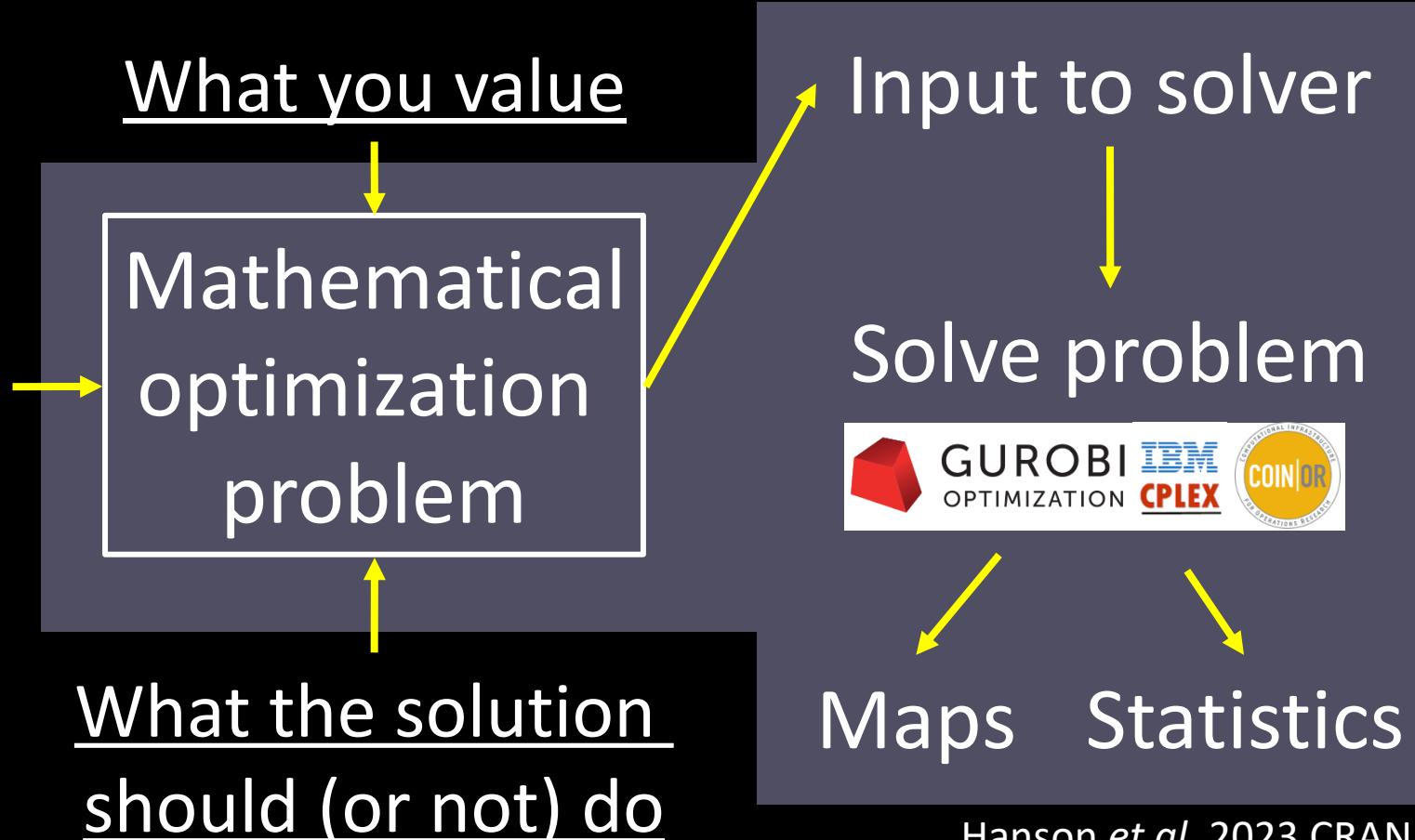
Different solutions



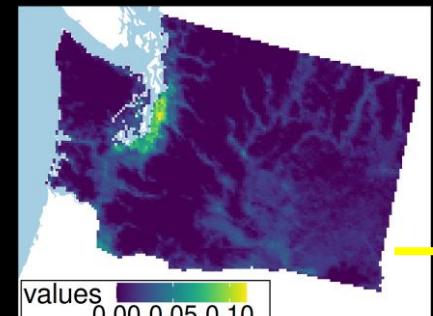
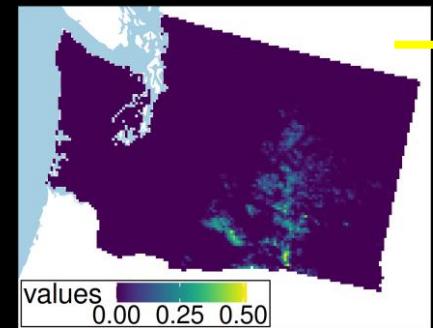
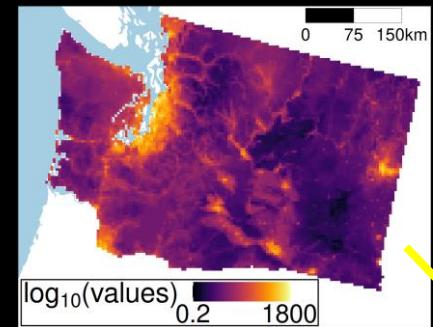


prioritizr R package

Data
Biodiversity
Land use
Economic



Worked example



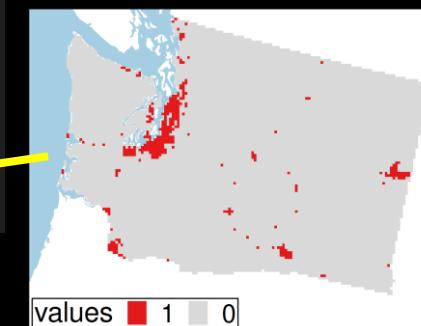
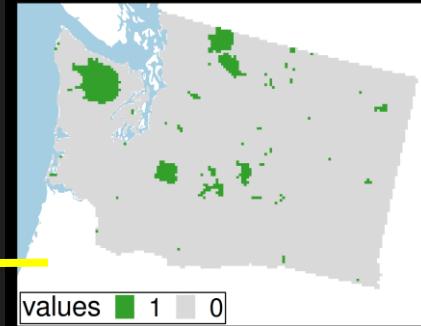
```
# load packages
library(prioritizr) # package for conservation planning
library(terra)        # package for raster data

# 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") ←
```

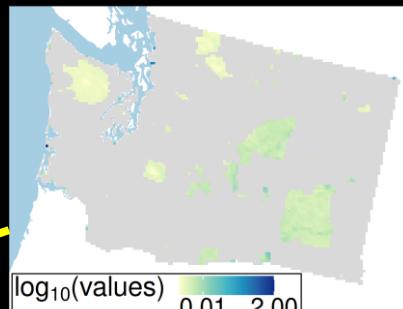
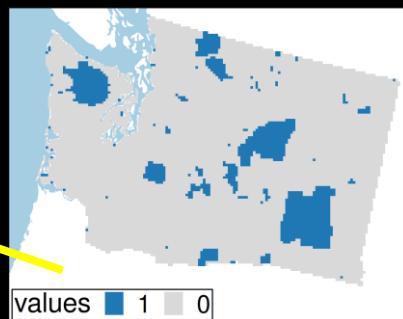


```
# build problem
## specify the data, formulation, and solver
conservation_planning_problem <-
  ### initialize with planning unit and feature data
problem(planning_unit_data, feature_data) %>%
  ### add minimum shortfall function with budget
add_min_shortfall_objective(3917.631) %>%
  ### add representation 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)
```

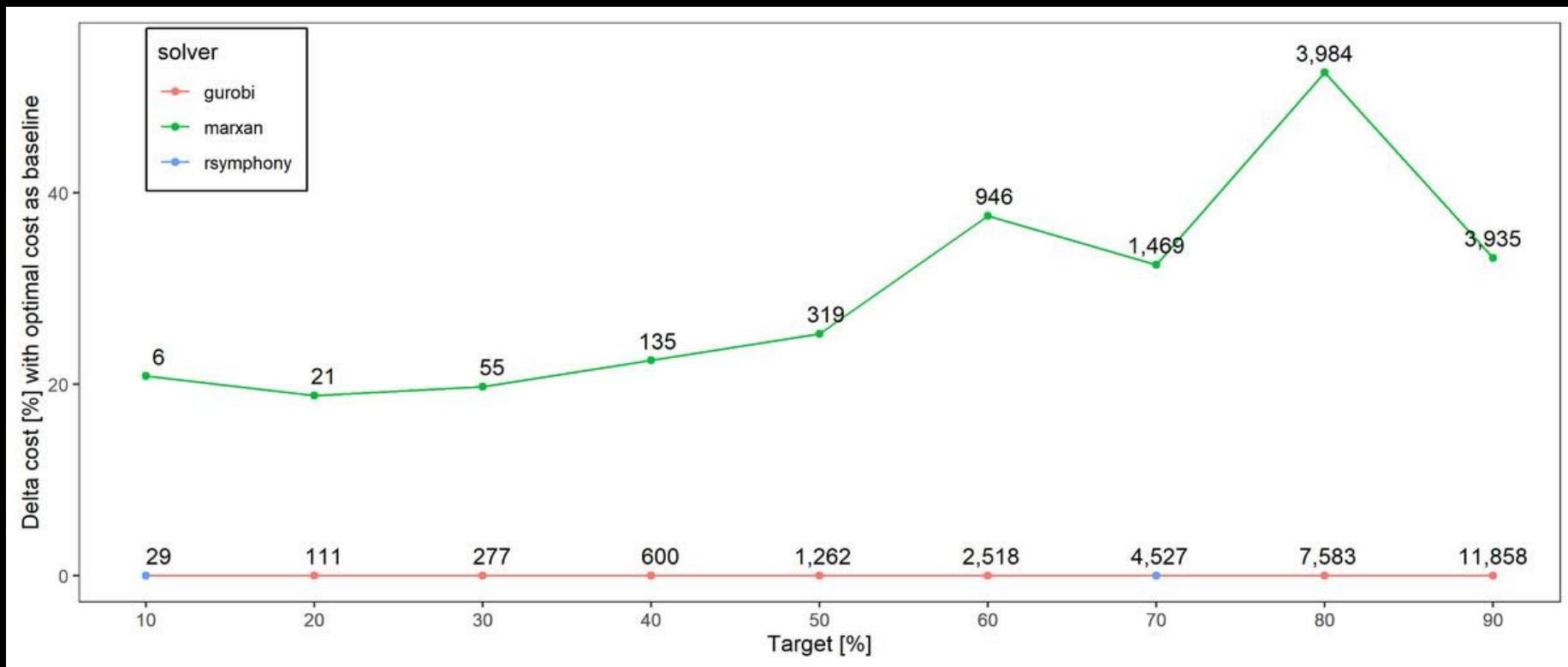
```
# solve problem
## output raster has binary values indicating if
## each planning unit is (1) selected or (0) not
prioritization <- solve(conservation_planning_problem)

# 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

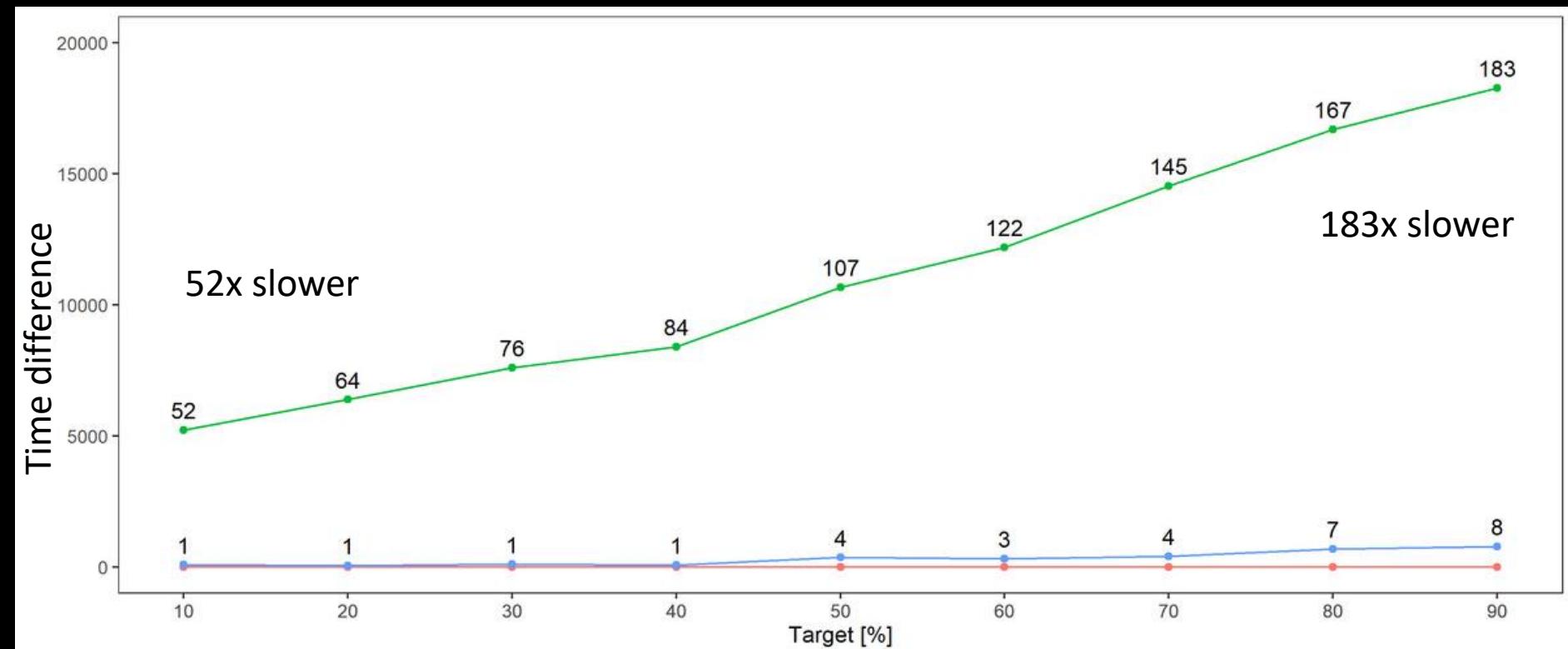
## calculate relative importance of selected planning units
### output raster has continuous importance values
relative_importance <-
  eval_ferrier_importance(
    conservation_planning_problem, prioritization)
```



Better solutions



...and faster too!



How can we get a better conservation decision?

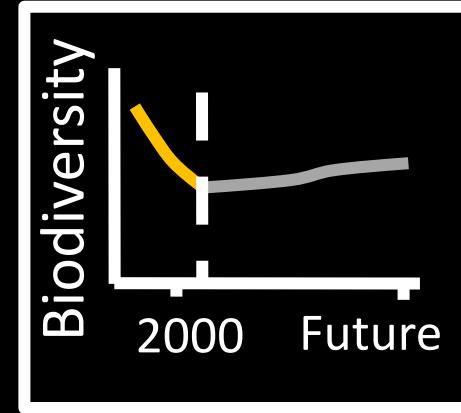
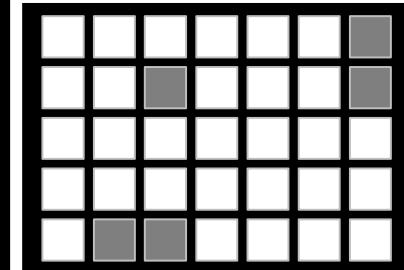
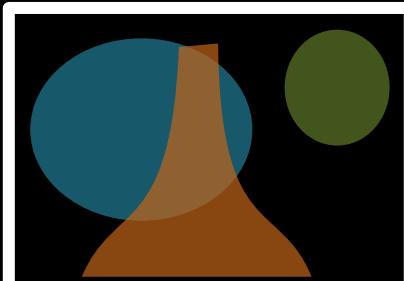
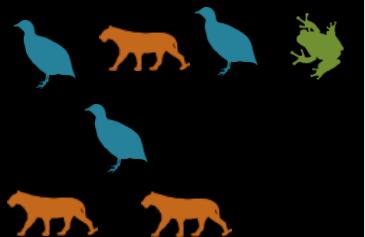
- (1) Better algorithms
- (2) Better data
- (3) Better surrogates

Ecological surveys

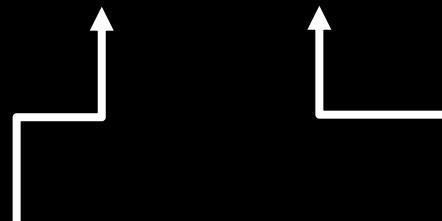
Distribution maps

Priority areas

Biodiversity

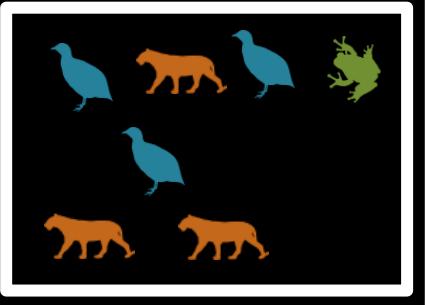


Data → Information → Plan → Outcome

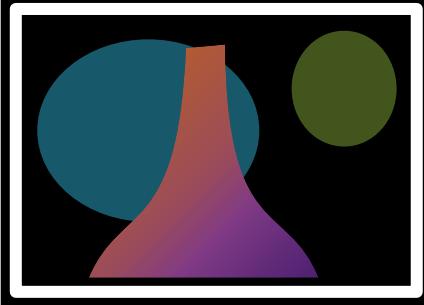


Objectives Constraints

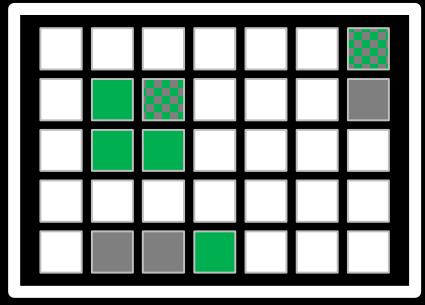
Ecological surveys



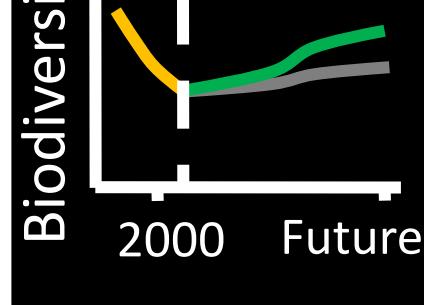
Distribution maps



Priority areas



Biodiversity



Data → Information → Plan → Outcome

Genetic samples



Better
understanding
of biodiversity

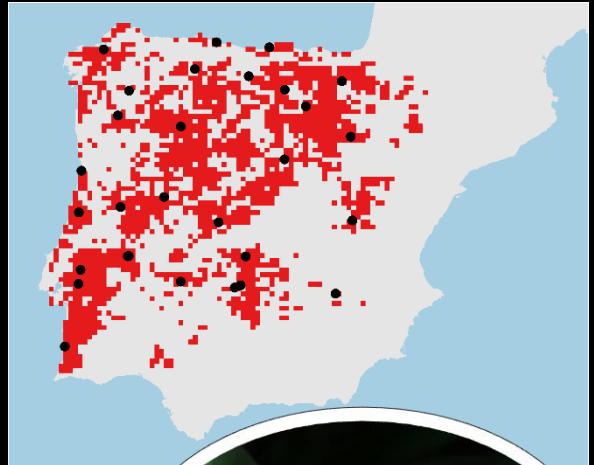
Objectives Constraints

Better
plan

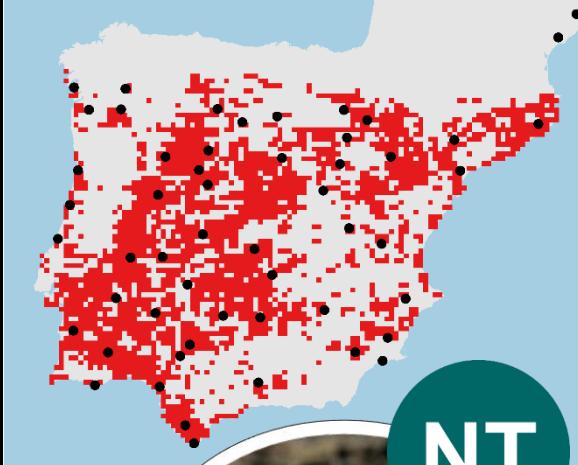
Better
outcome

Conservation planning for adaptive and neutral evolutionary processes

Hyla molleri



Pelobates cultripes



Rana iberica



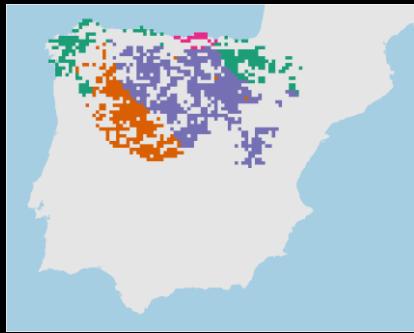
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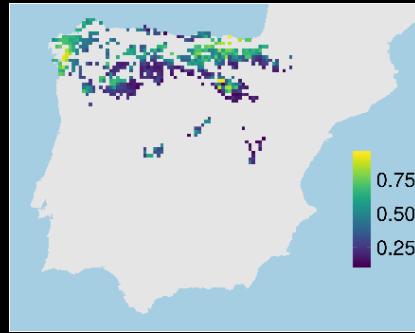


Adaptive processes

Adaptive
clusters

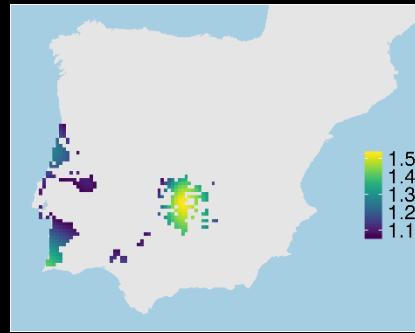


Climate
refugia

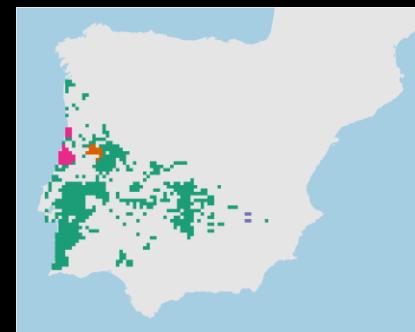
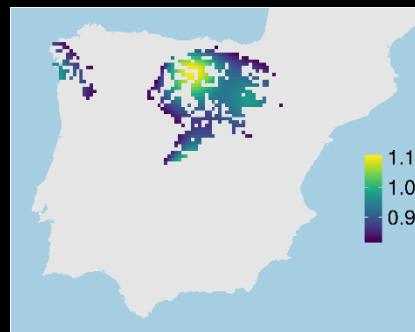
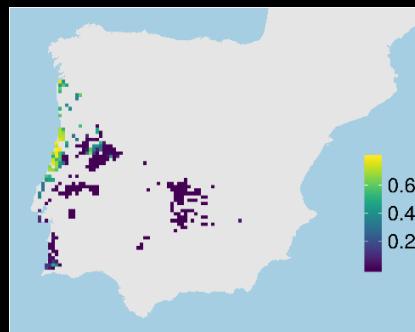
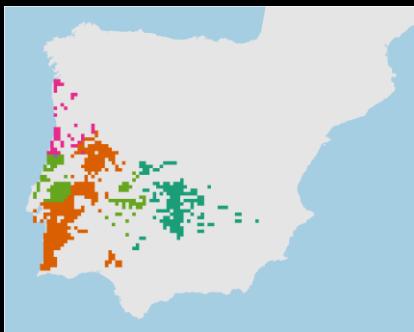
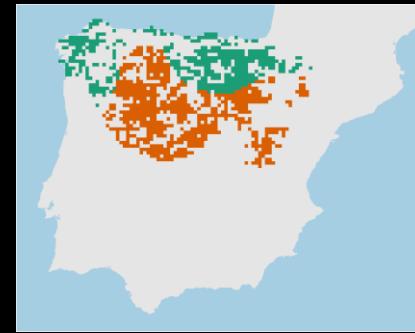


Neutral processes

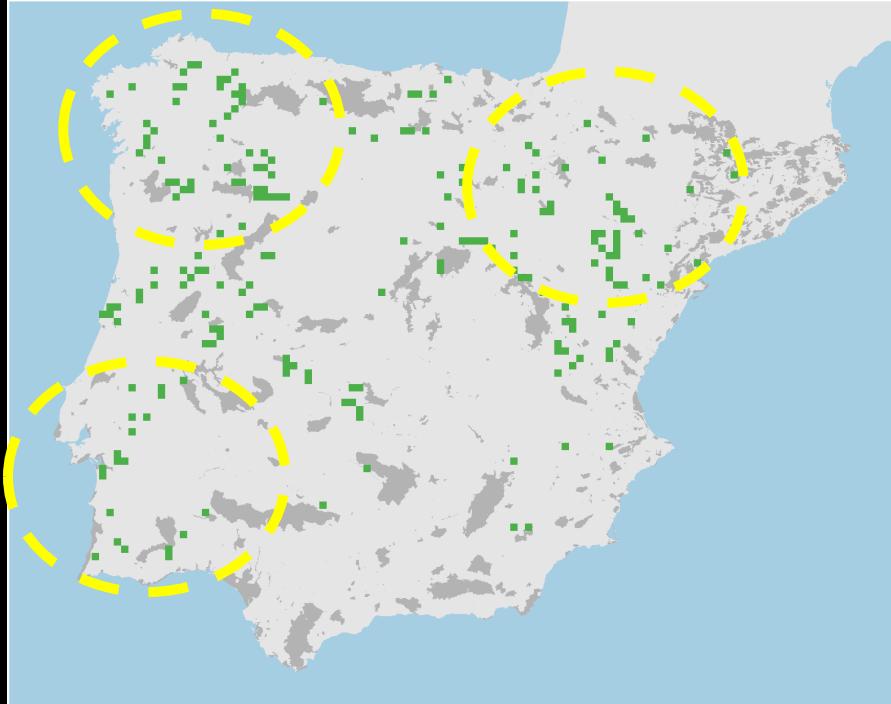
Individual
heterozygosity



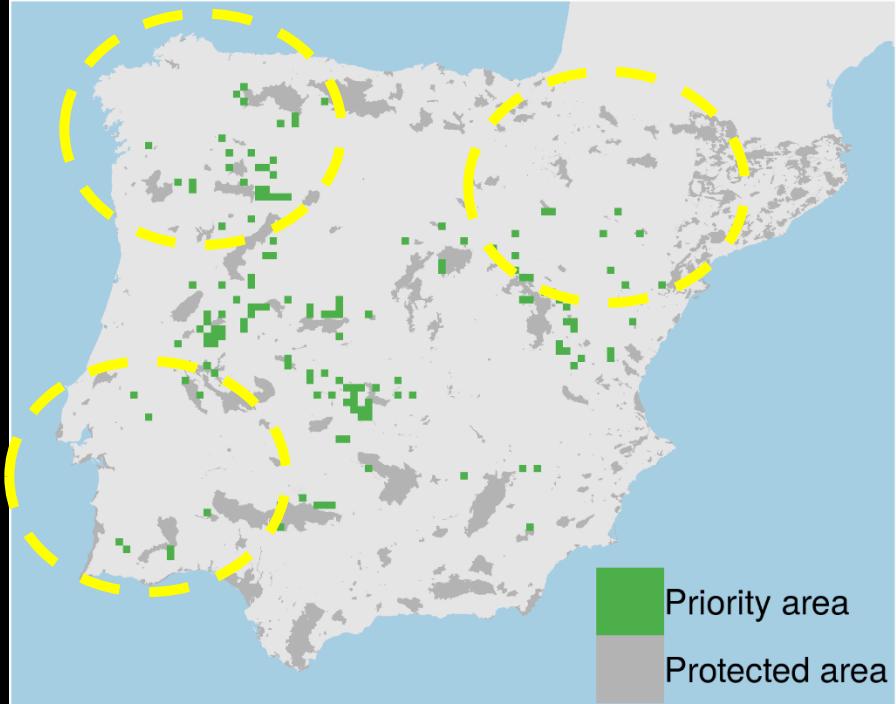
Neutral
clusters



Prioritizations

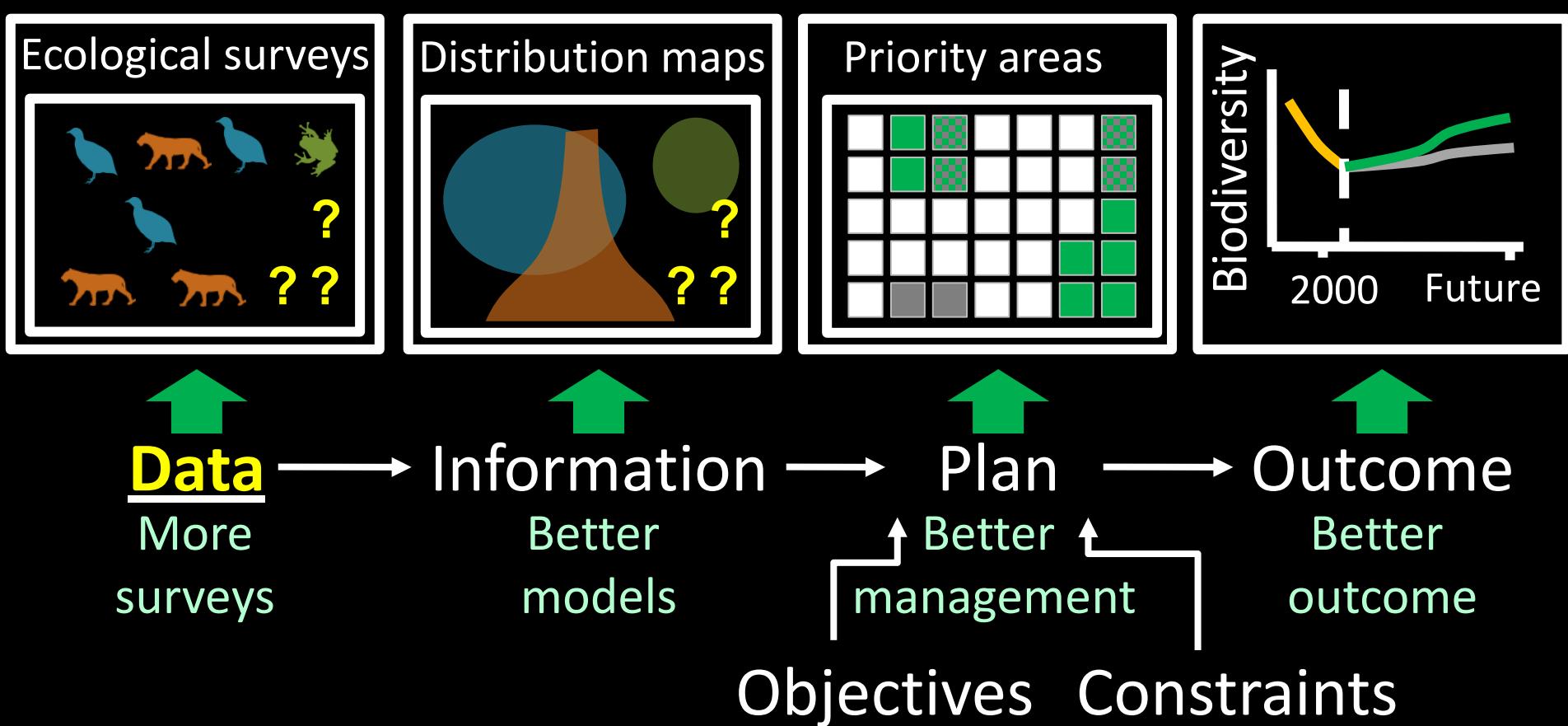


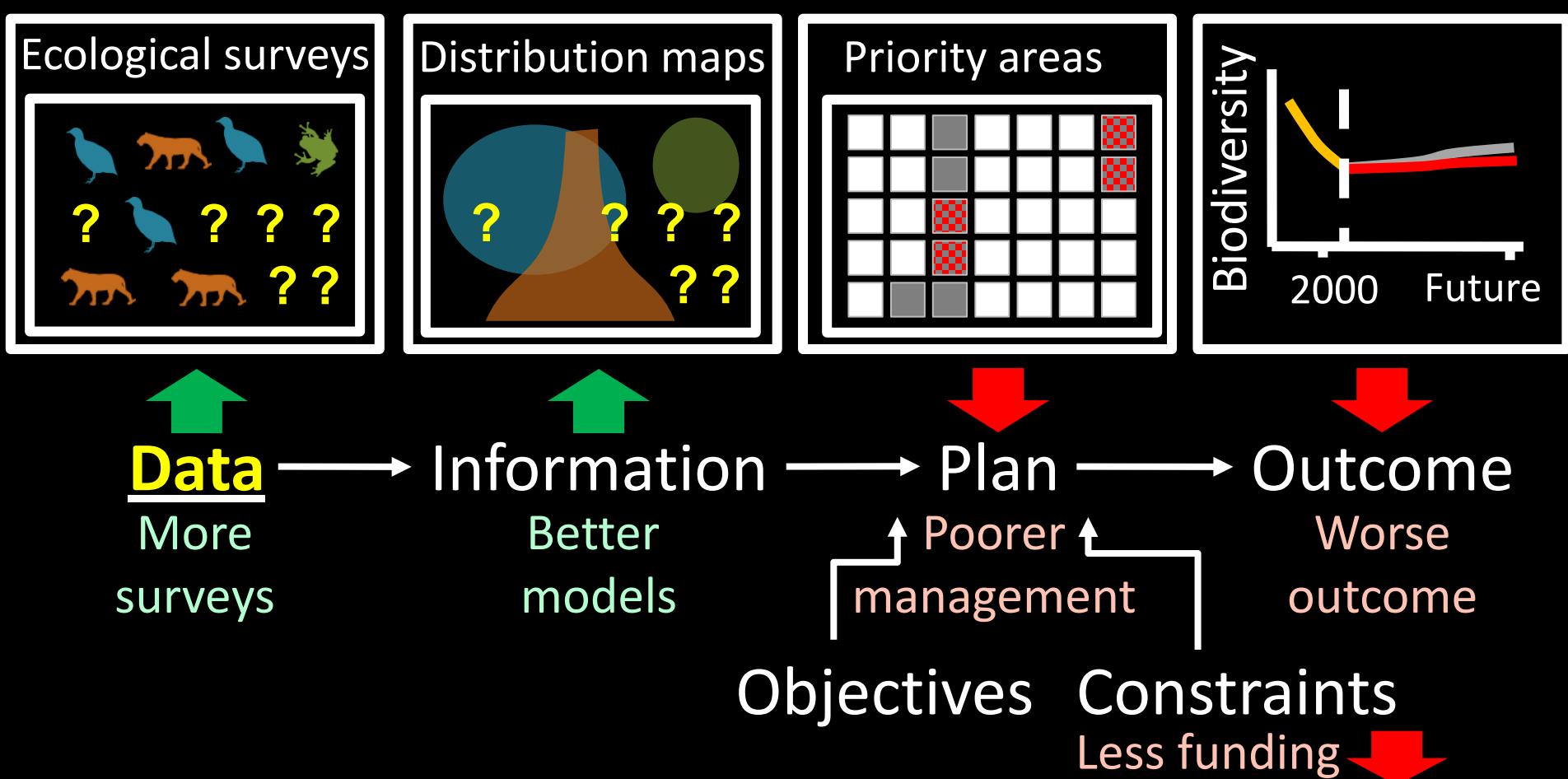
Plan with evolutionary
attributes



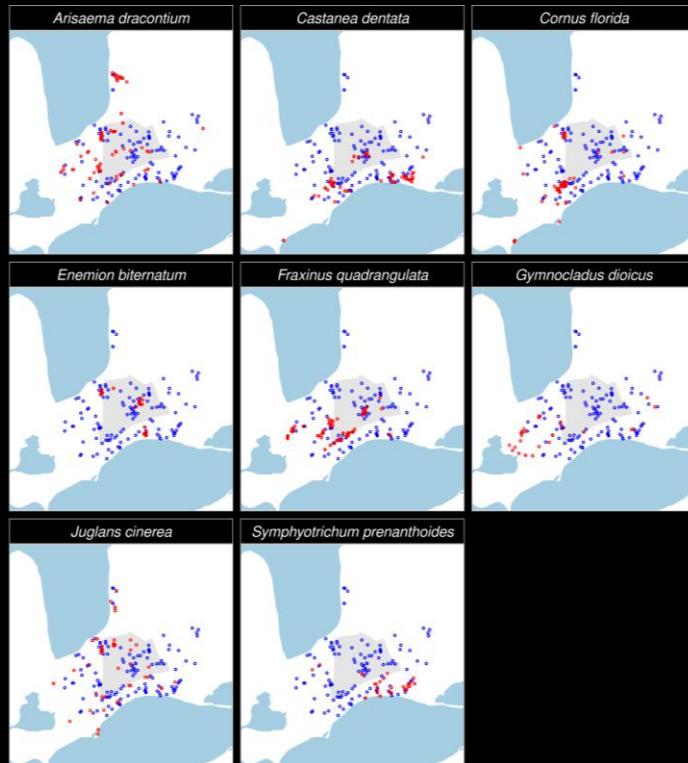
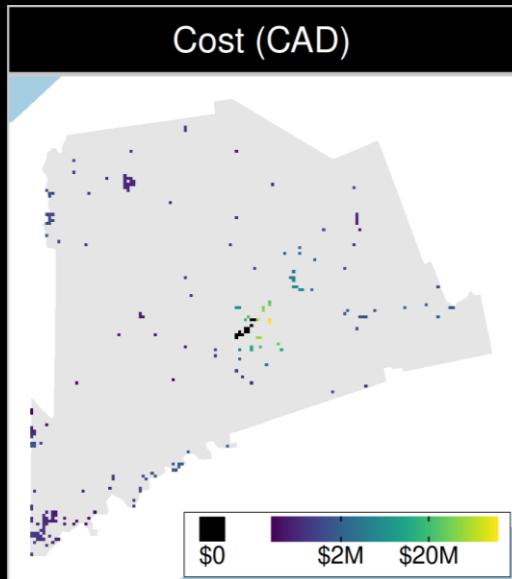
Conventional plan
Only costs 9% less

However, more data
isn't always better...



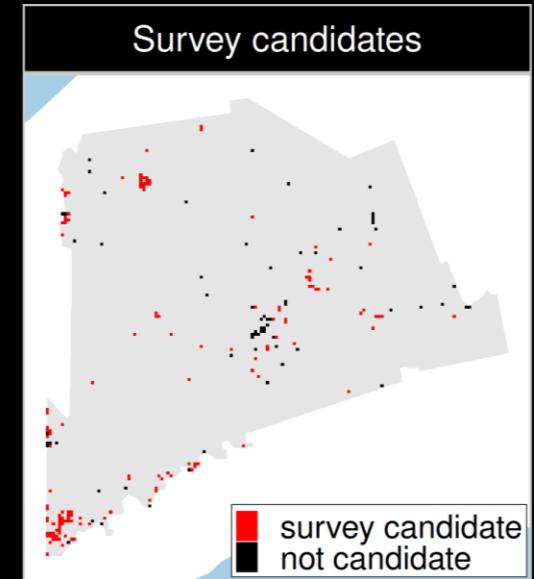


Study system: Middlesex county, Canada



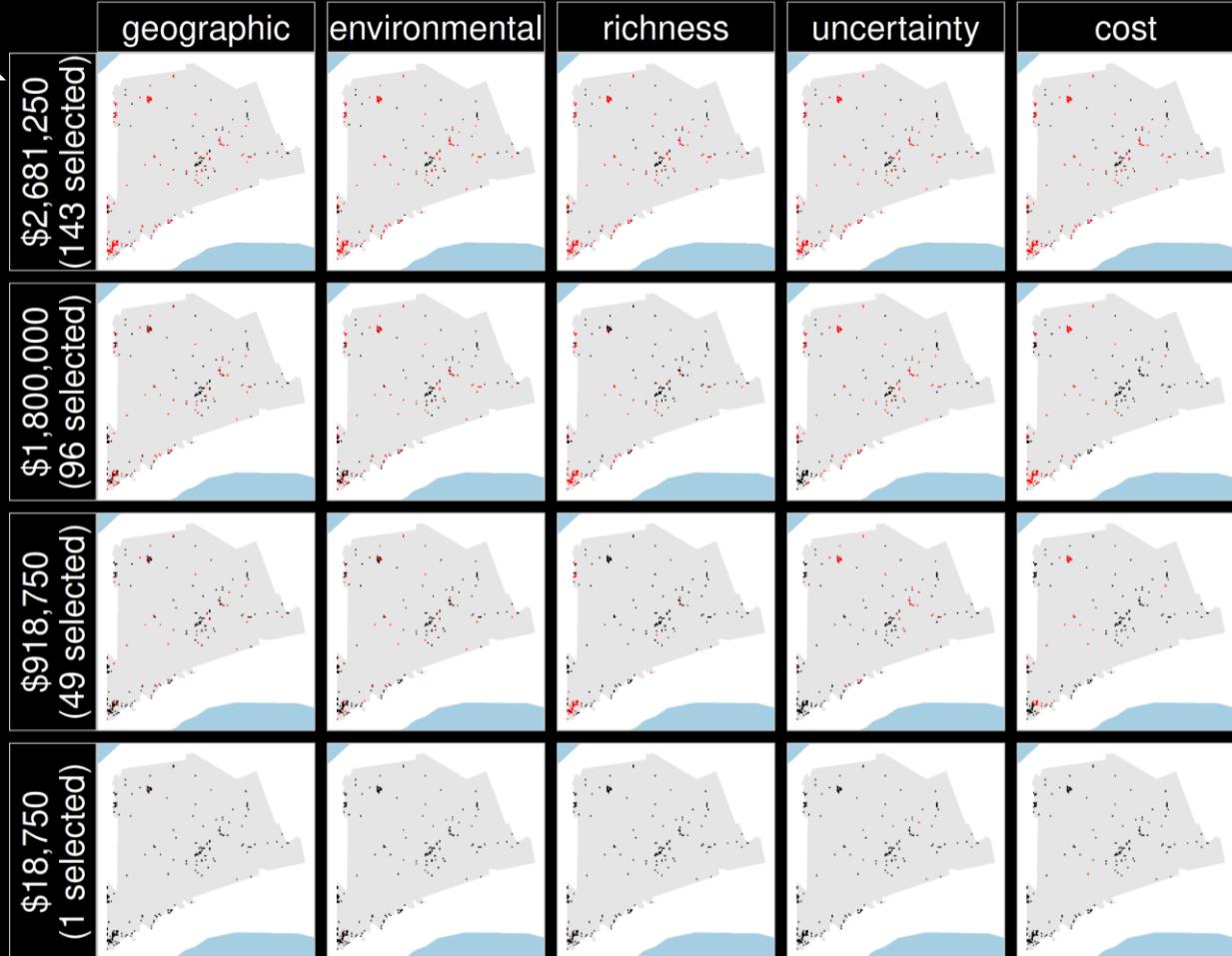
8 imperiled plant species

199 places that could potentially be acquired for protected area establishment



143 places that could potentially be surveyed to improve existing data

Number of places selected for surveys
(amount of funds allocated for collecting extra data)



Selected
for survey

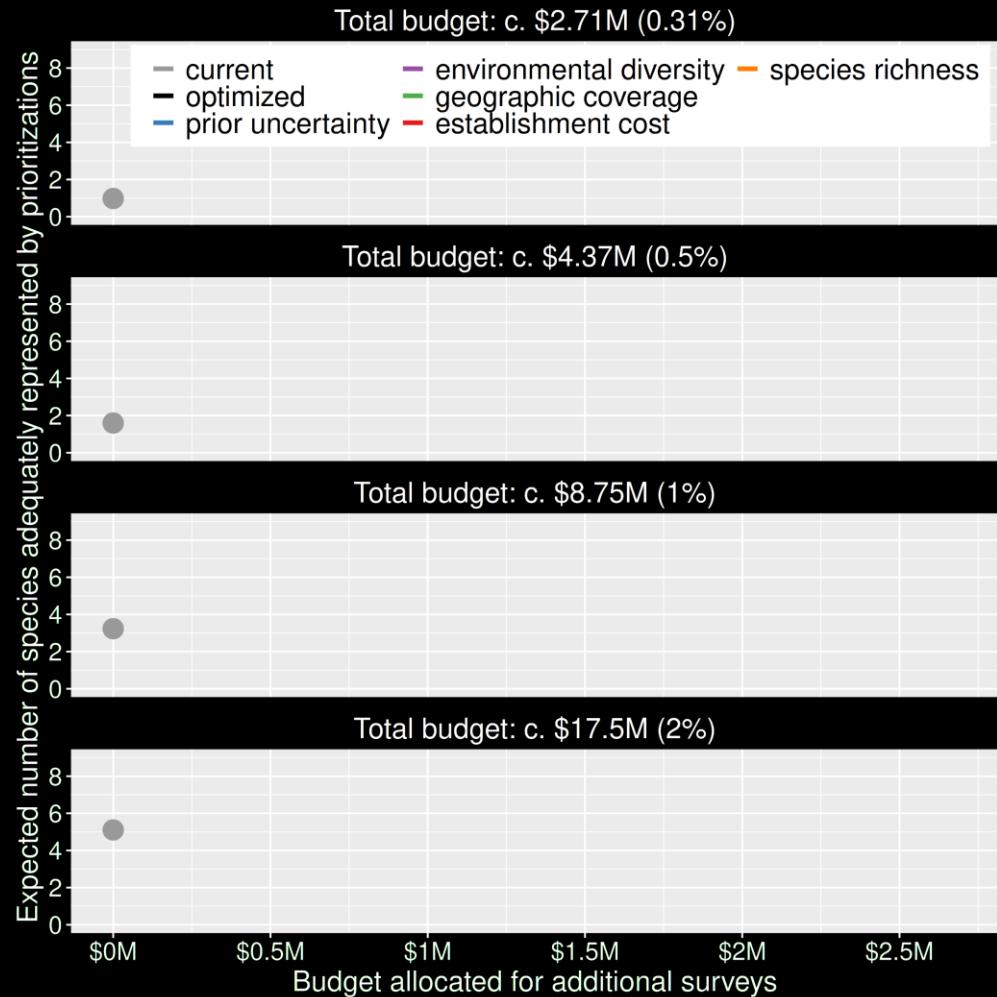


NOT selected
for survey

Different approaches for designing survey schemes

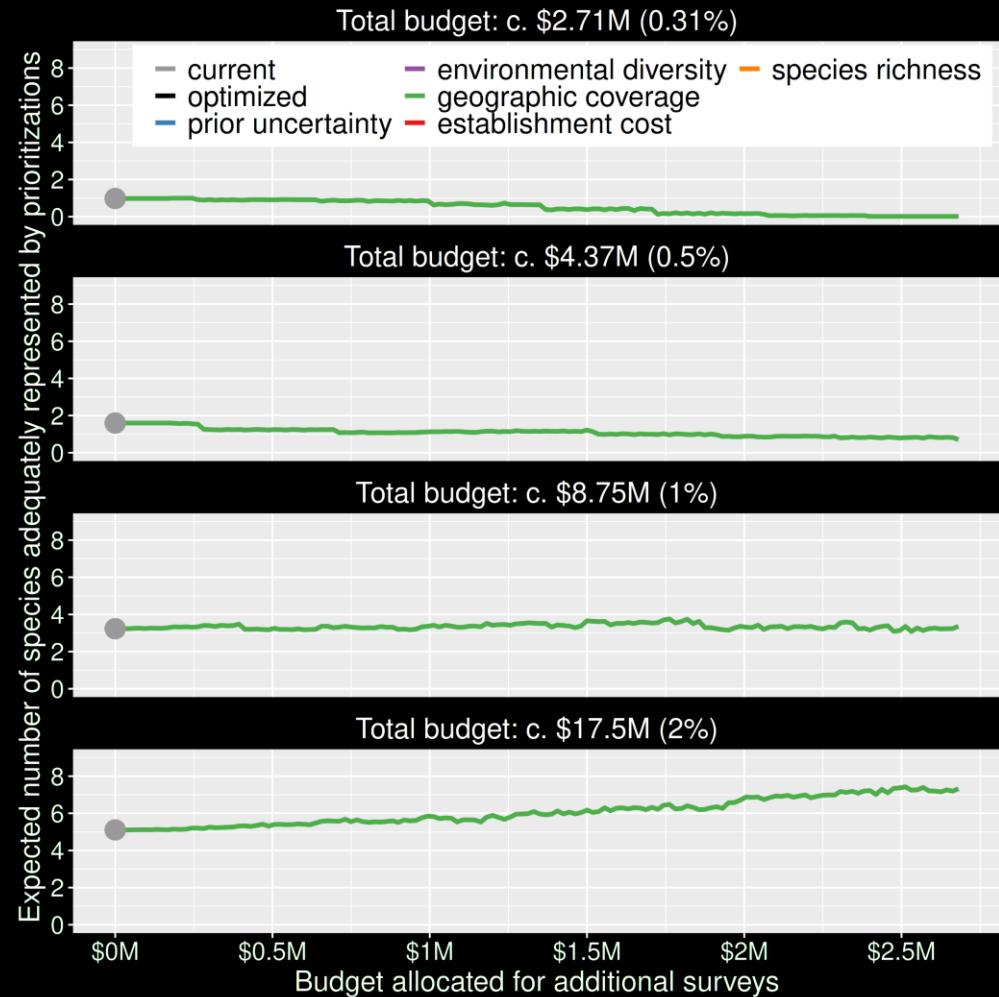
Value of information

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



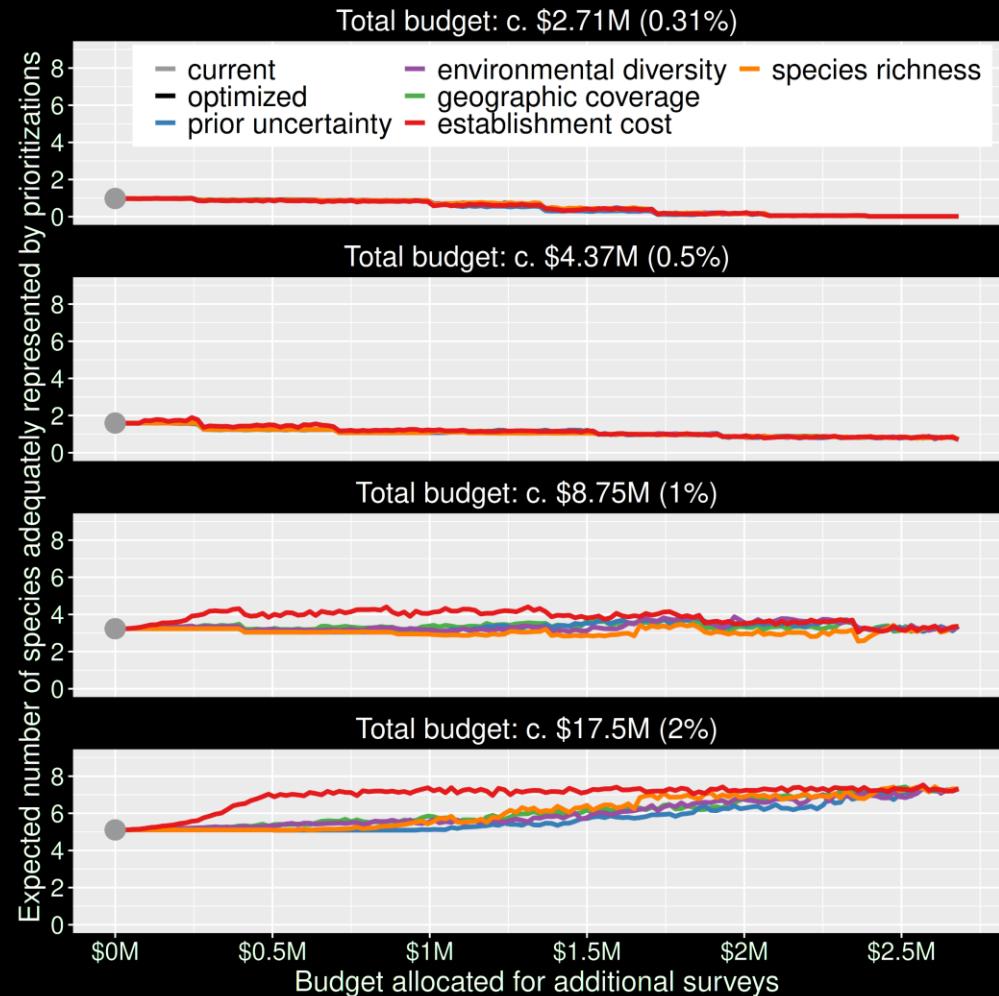
Value of information

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



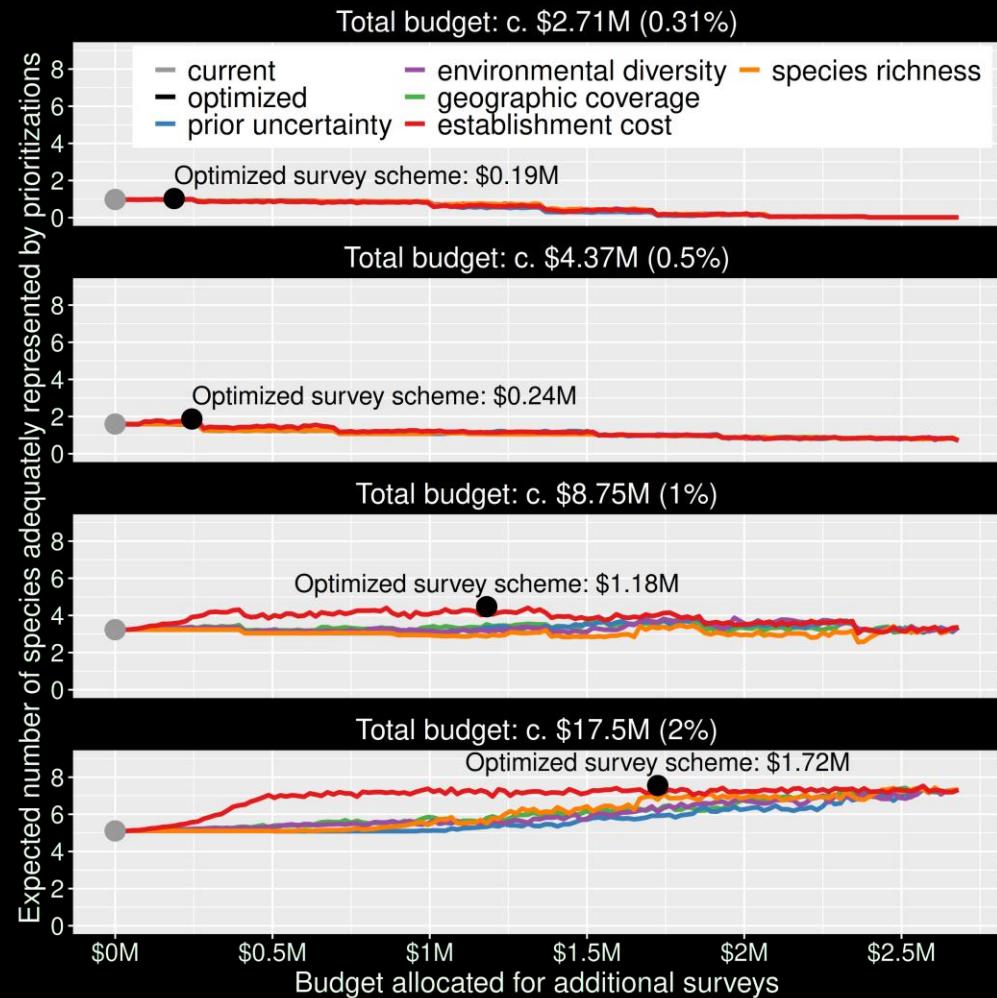
Value of information

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



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



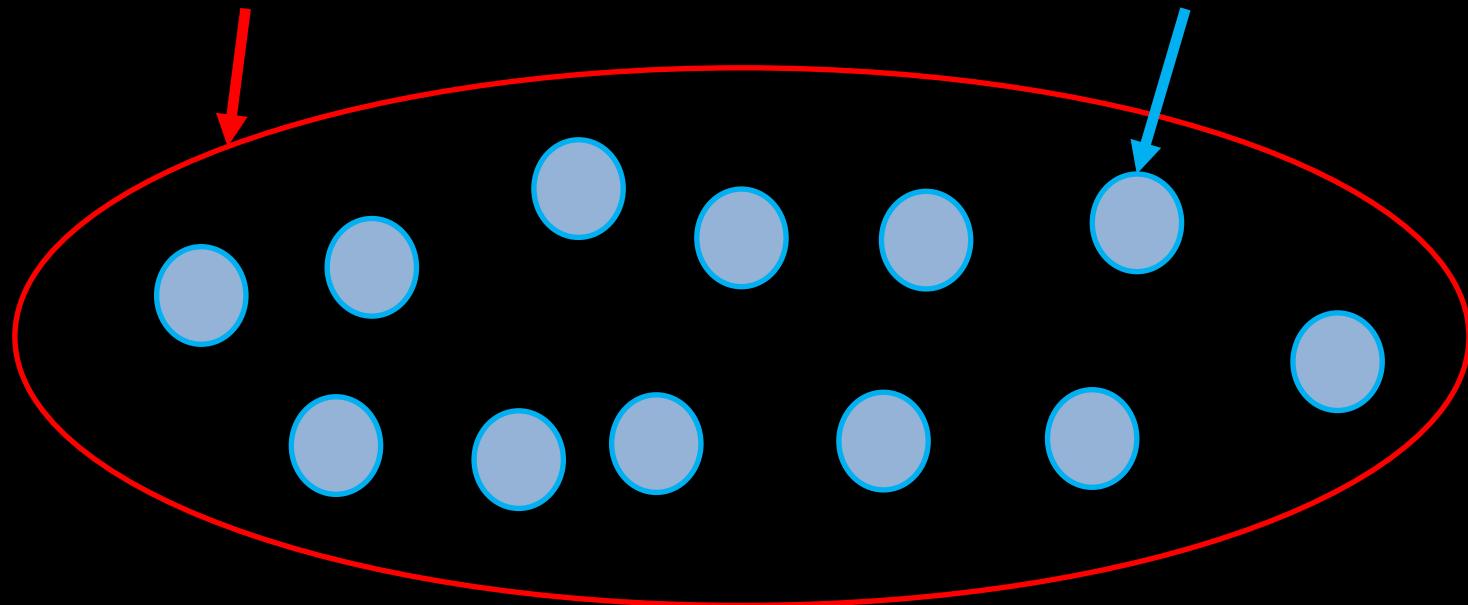
How can we get a better conservation decision?

- (1) Better algorithms
- (2) Better data
- (3) Better surrogates

Evolutionary processes

Species range

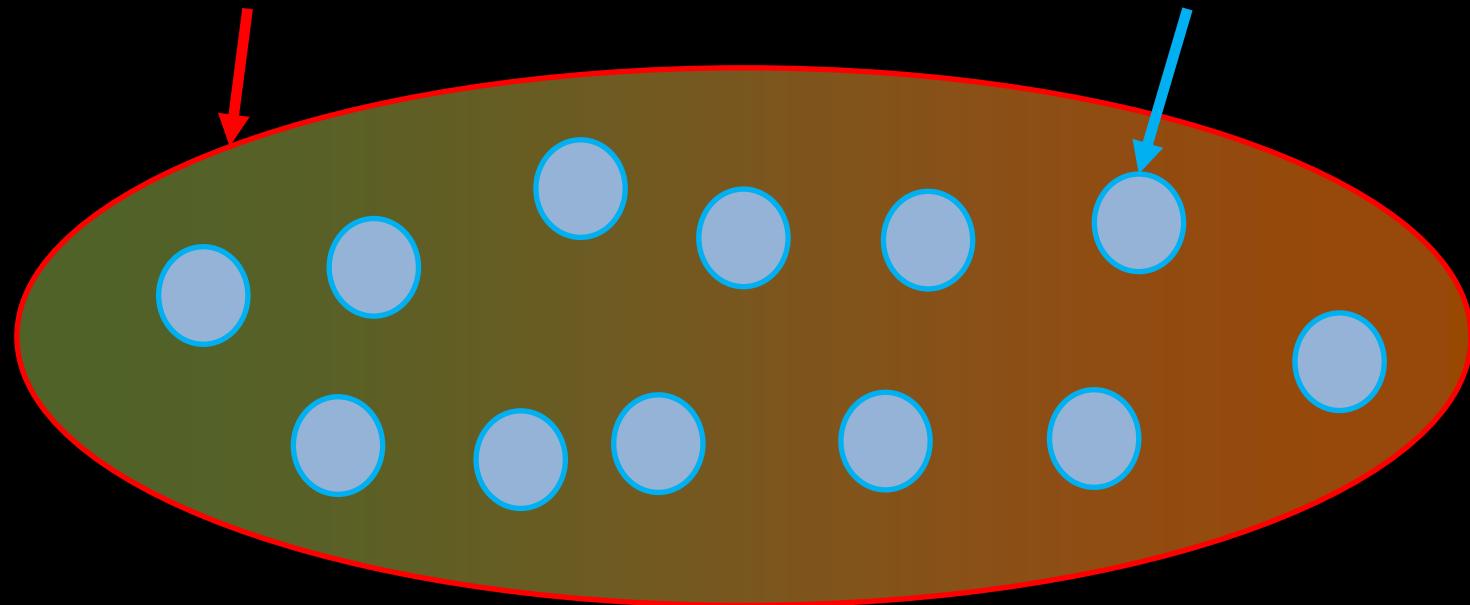
Population



Evolutionary processes

Species range

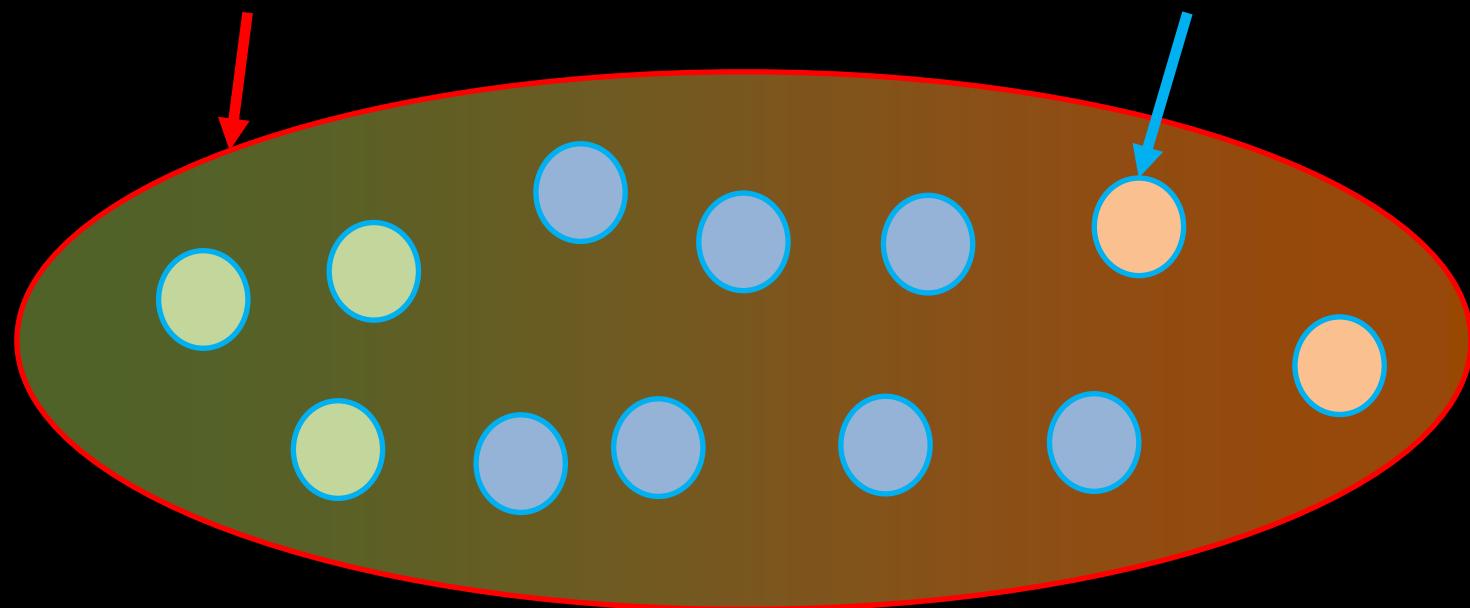
Population



Evolutionary processes

Species range

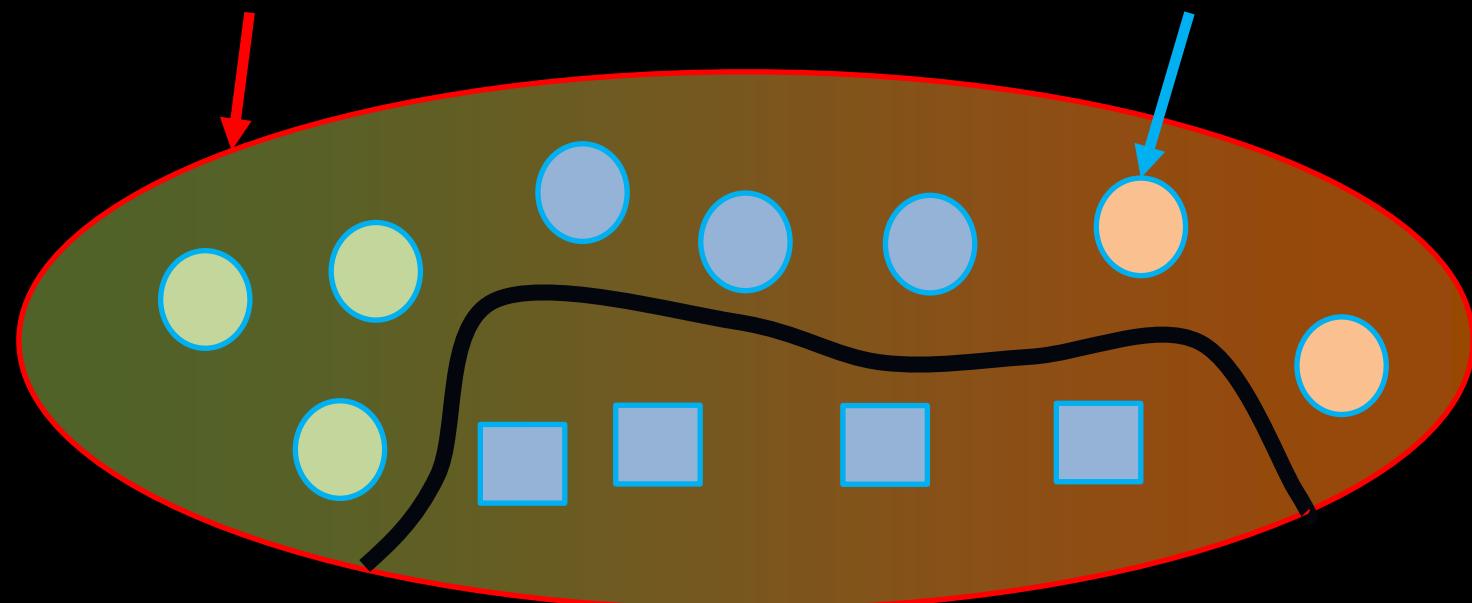
Population



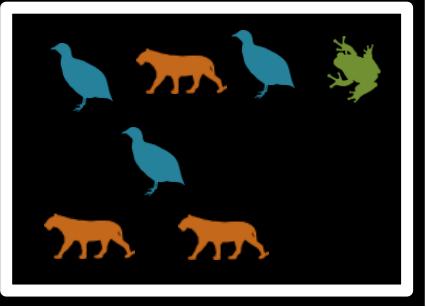
Evolutionary processes

Species range

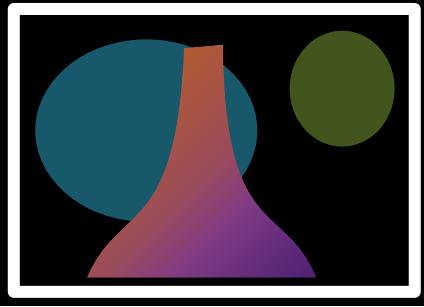
Population



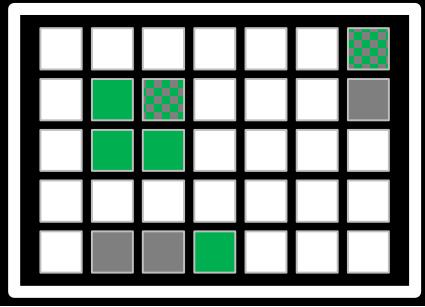
Ecological surveys



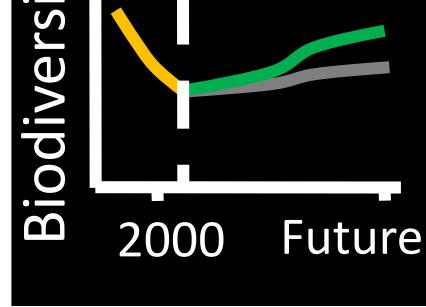
Distribution maps



Priority areas



Biodiversity



Data → Information → Plan → Outcome

Genetic samples



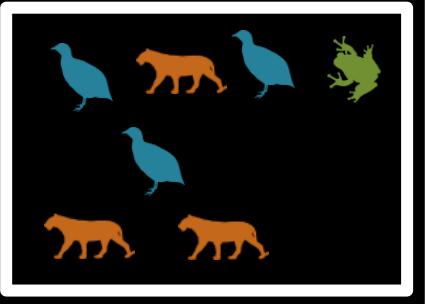
Better
understanding
of biodiversity

Objectives Constraints

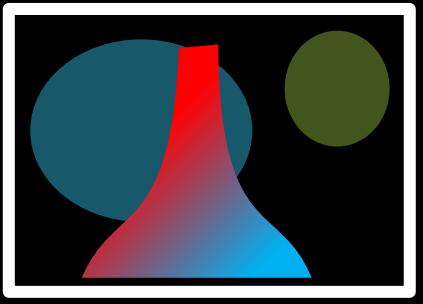


Better
outcome

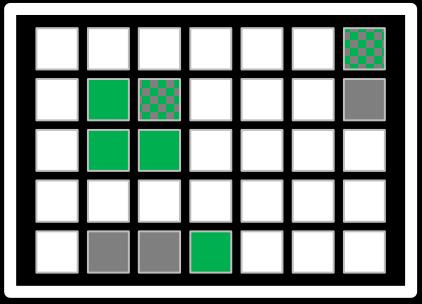
Ecological surveys



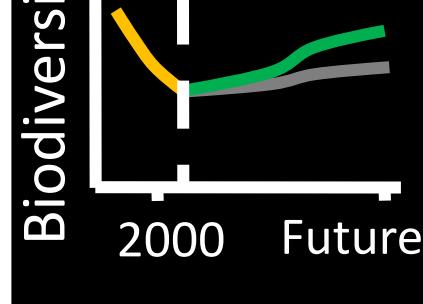
Distribution maps



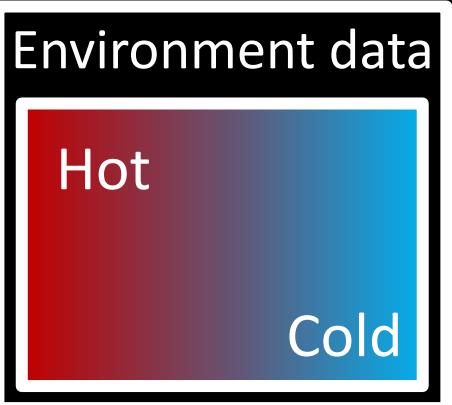
Priority areas



Biodiversity



Data → Information → Plan → Outcome



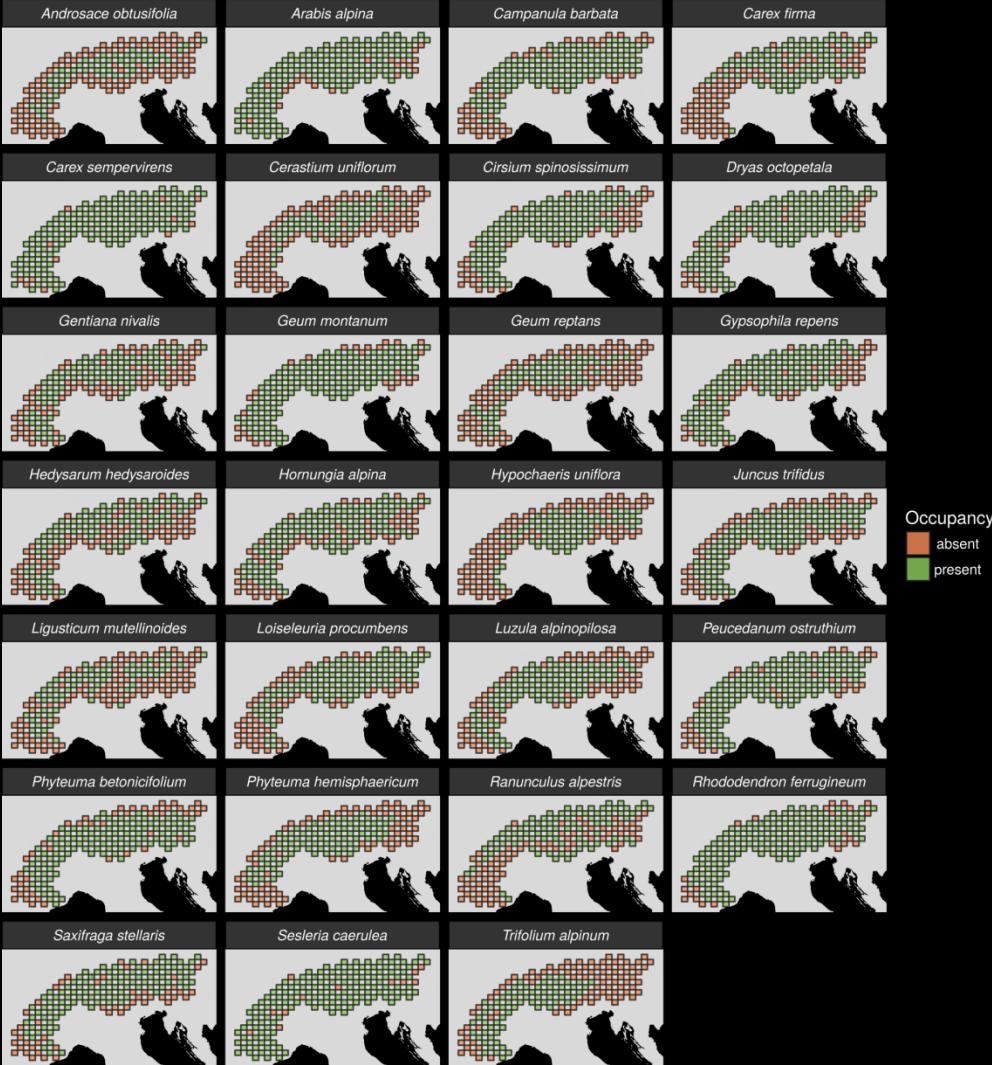
Good enough
understanding
of biodiversity

Objectives Constraints



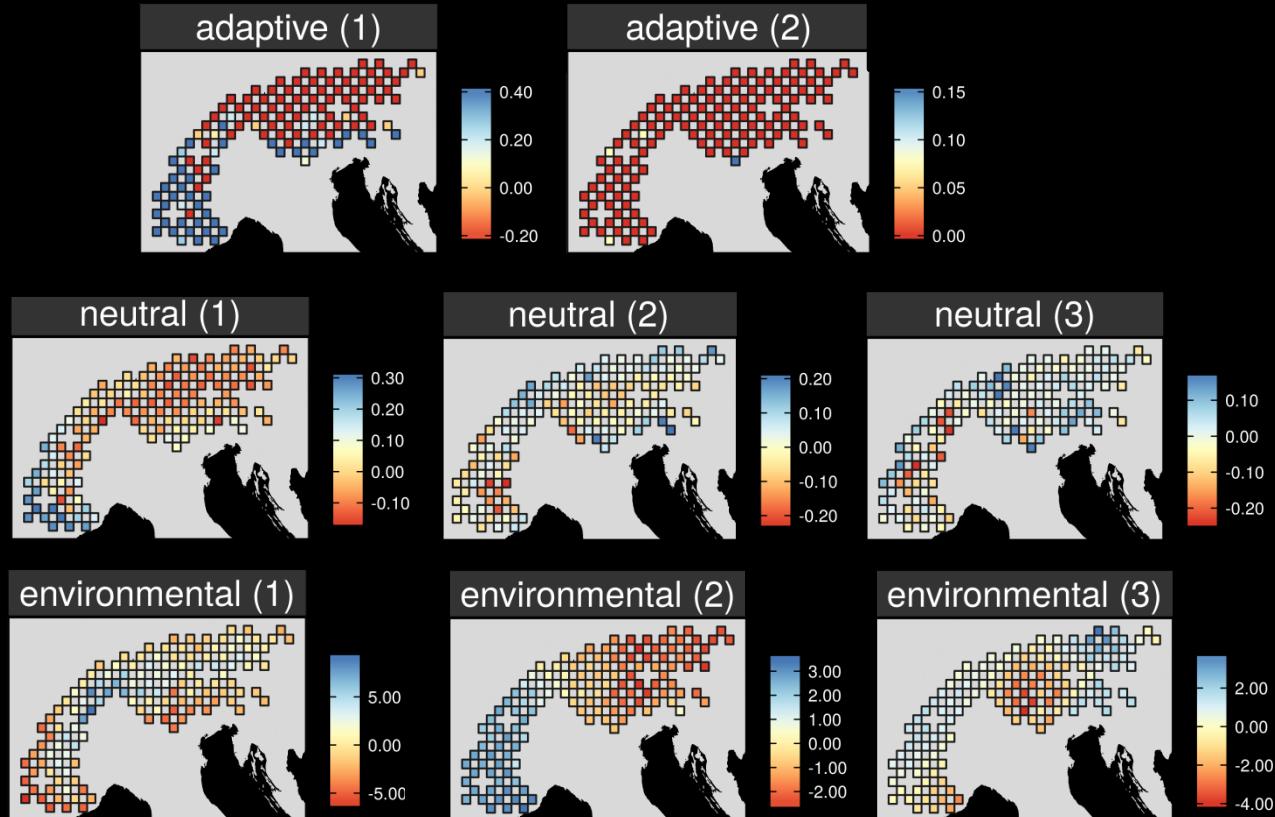
27 plant species

- Different dispersal
- Different life-histories
- Different niches
- AFLP markers

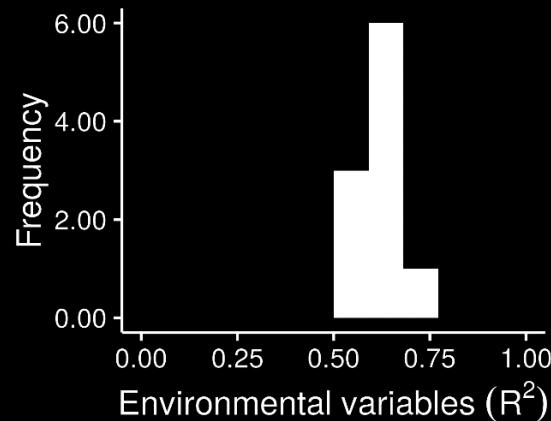
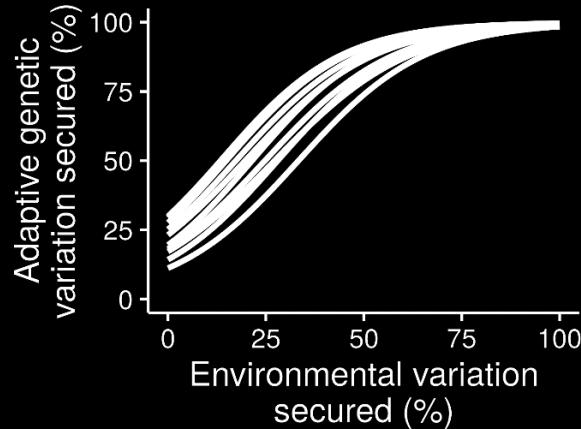


Map intra-specific variation

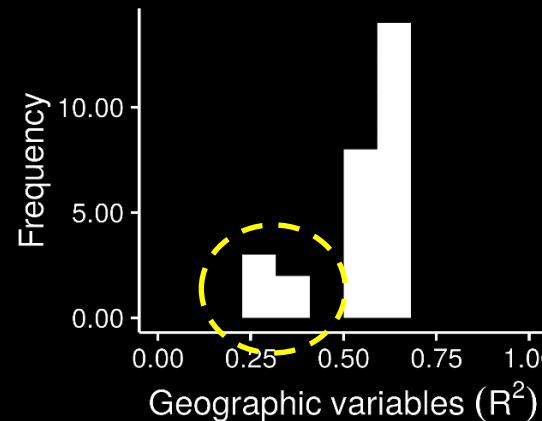
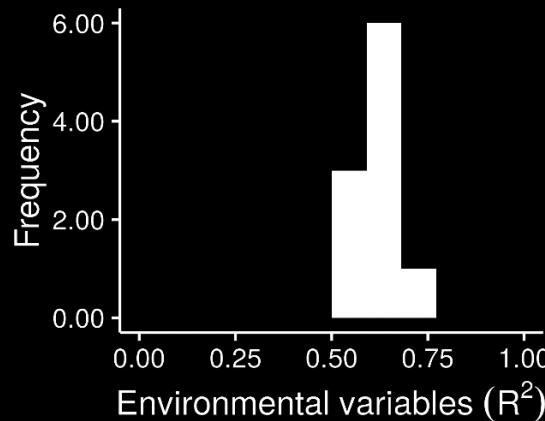
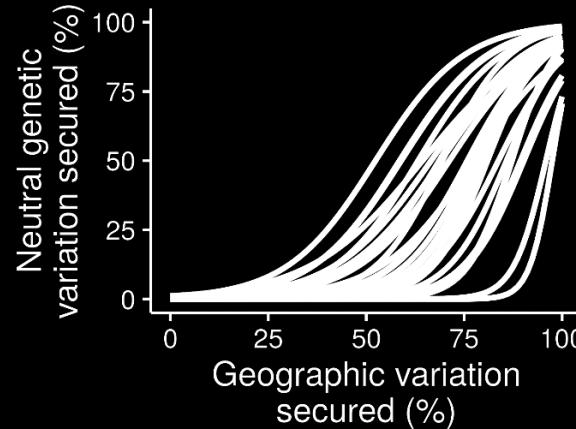
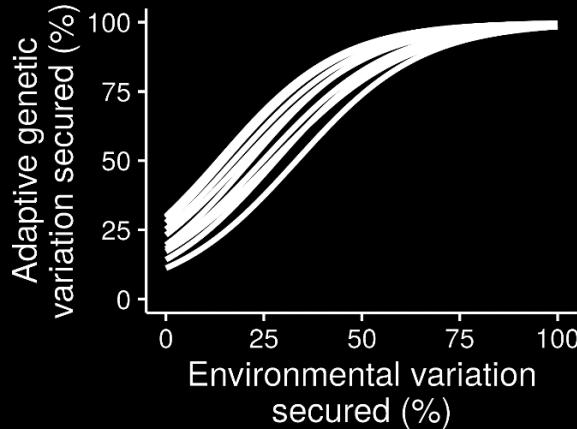
Arabis alpina



What is the relationship?



What is the relationship?

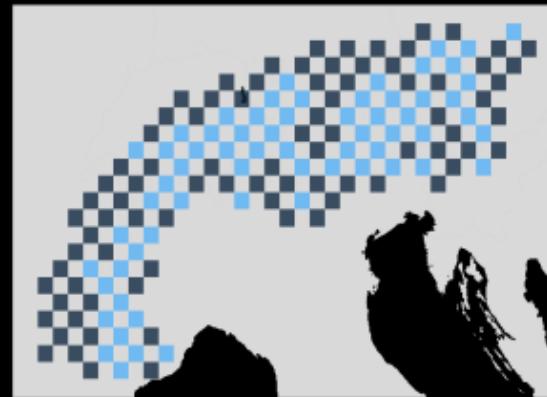
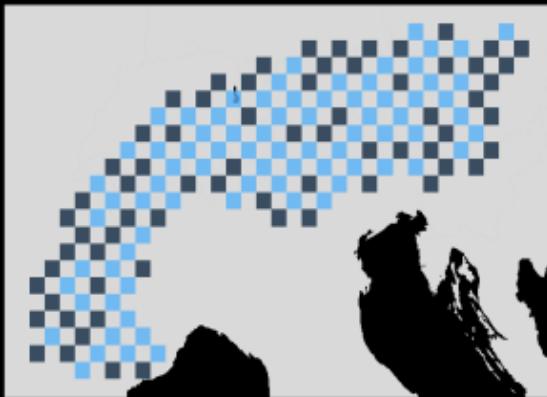
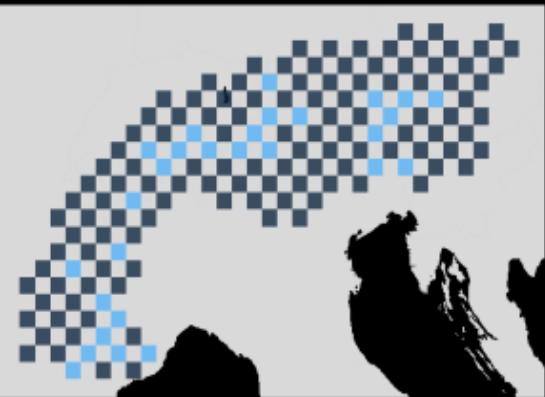


Can surrogates inform our decisions?

Amount targets

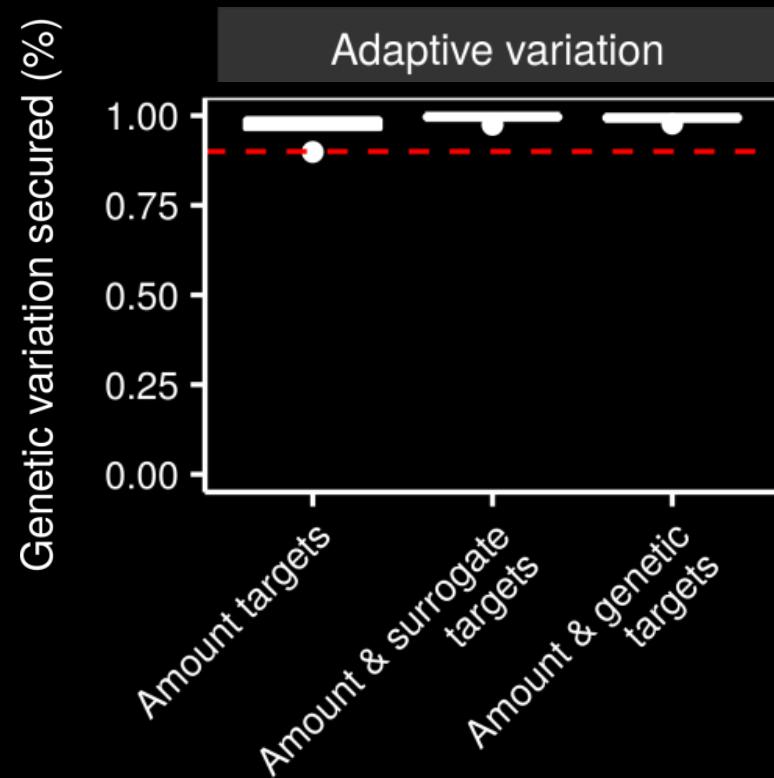
Amount & surrogate
targets

Amount & genetic
targets

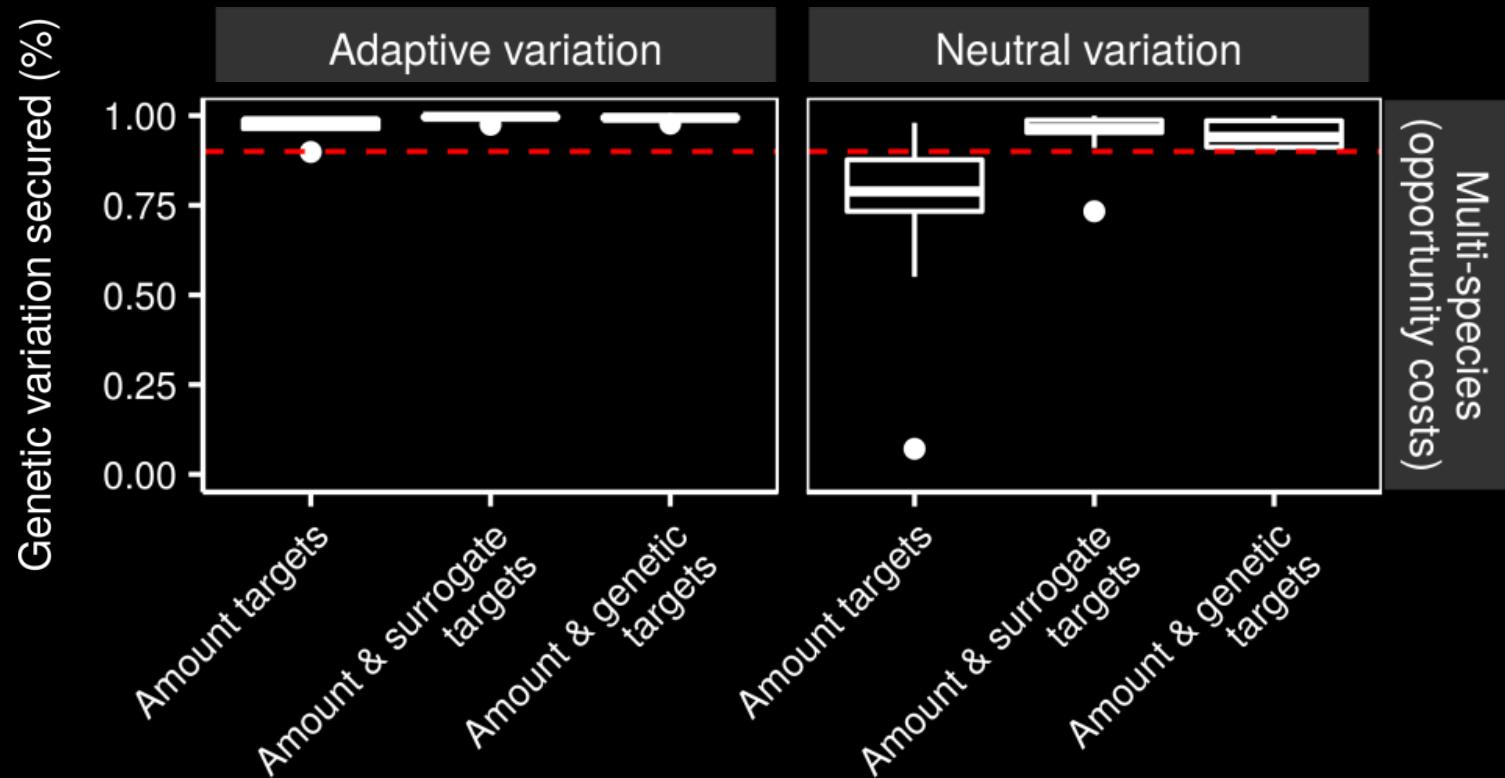


Multi-species
(opportunity costs)

Can we make better decisions using surrogates?



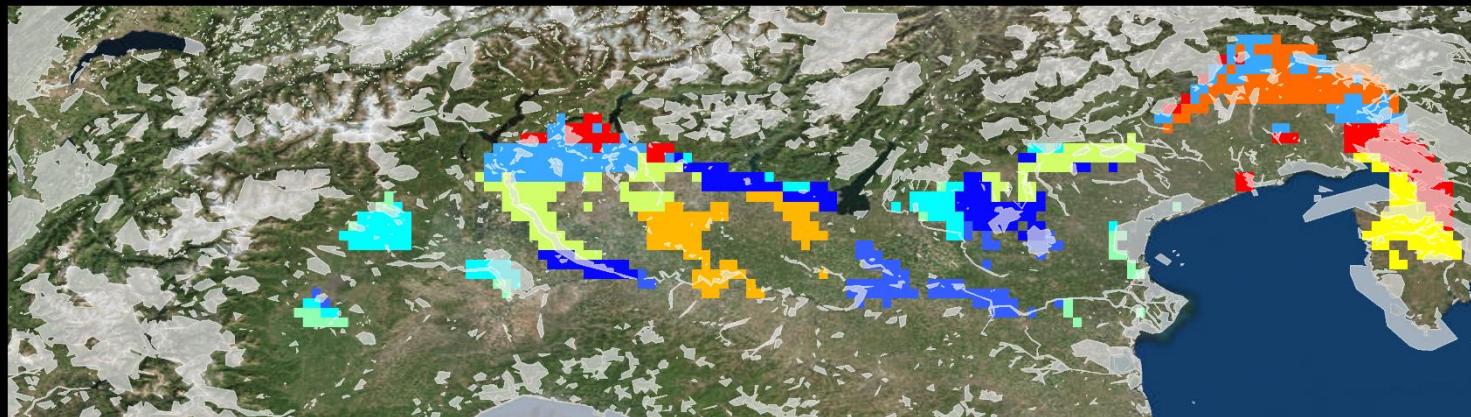
Can we make better decisions using surrogates?



Global conservation of species niches

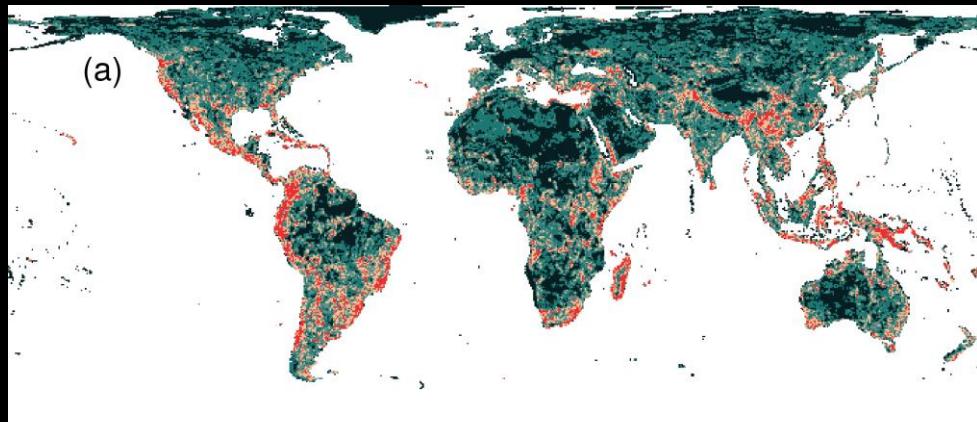
- 9,670 bird, 5,070 mammal, 5,197 amphibian species
- 5×5 km maps delineating suitable habitat
- Split each species' distribution into 10 “environmental” partitions
- Habitat targets set following standard approaches

Italian Agile Frog



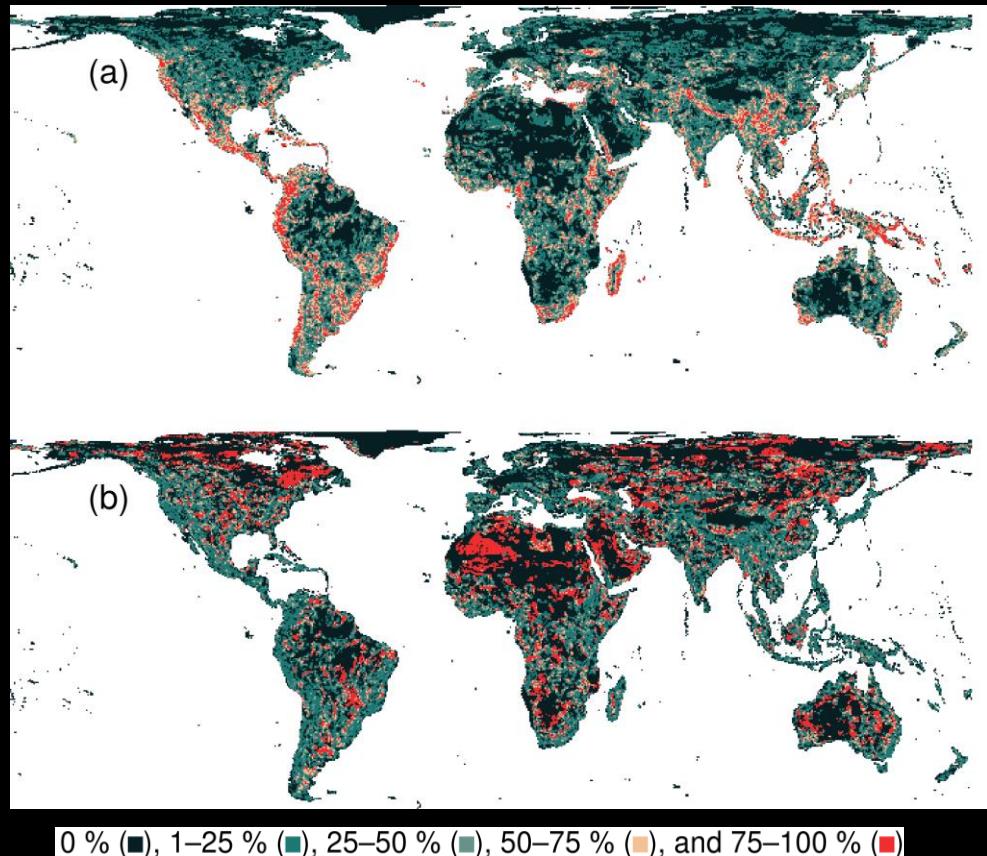
Prioritization for realized niches

- 35.9 % of the Earth's land needed to complement existing protected areas
- Biodiversity hotspots are critically important
- Conservation efforts needed across the planet



What if we ignore species' niches?

- Only 3.7% less of the Earth's land than prioritization which considers niches
- Fails to adequately represent 7,989 (40%) species



Make better conservation decisions by using...

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



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