A Tool for Decision Support in Dynamic Conservation Management

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Ecological Reserve Design

Reserve Design

How should we select land for conservation to protect rare and endangered species?

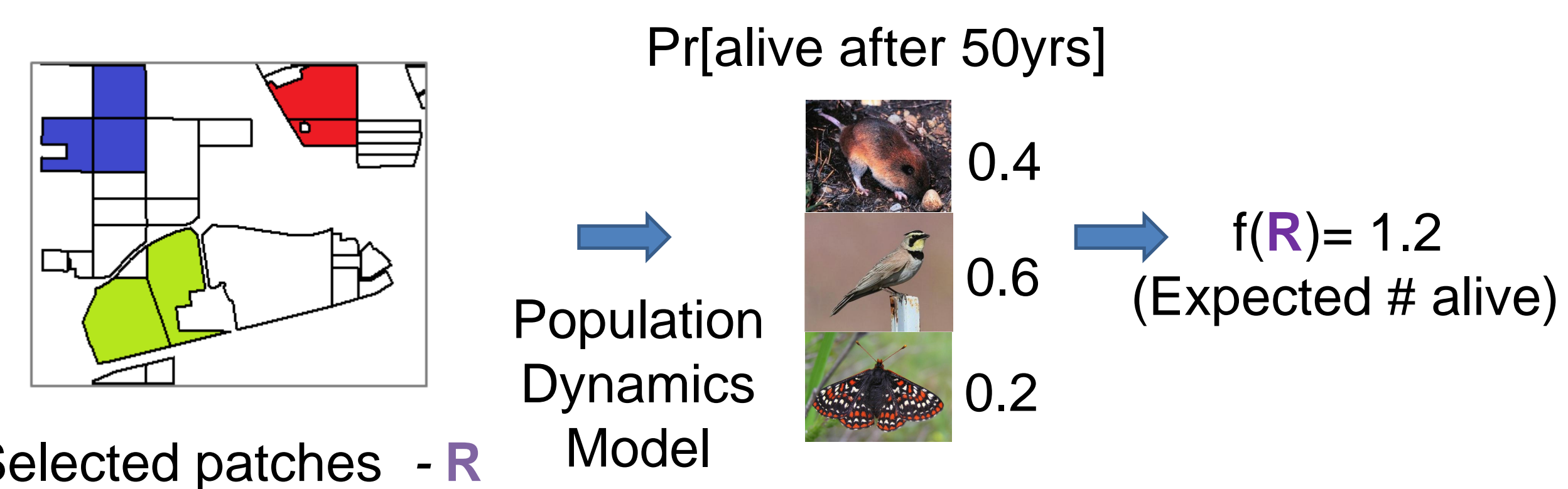**Case Study:** Planned Reserve in Washington State

How to Design an Optimal Reserve?

"Dynamic resource allocation in conservation planning"
D. Golovin, A. Krause, B. Gardner, S. J. Converse, and S. Morey

Goal: Choose R to maximize species persistence.

Pr[alive after 50yrs]

0.4
0.6
0.2

Population Dynamics Model

$f(R) = 1.2$
(Expected # alive)

Selected patches - **R**

Previous Study [Golovin et al. '11]

Select a reserve of maximum persistence probability, subject to a budget constraint:

$$\max_R f(R) \text{ s.t. } c(R) \leq B \qquad (1)$$

f is **submodular** => We can find a **near-optimal solution**.

Theorem [Sviridenko '04]:
We can efficiently obtain reserve R such that
$$f(R) \geq (1 - 1/e) \max_{R': c(R') \leq B} f(R')$$

Reserve Recommendation Problem

How to Recommend Different Near-Optimal Reserves?

The previous approach produces **a single near-optimal** solution.

Finding only one solution leaves the conservation management community without possibility to explore alternatives!

The Best-K algorithm - A randomized variant of the greedy algorithm that allows users to explore a diverse set of alternatives. Solves (1).

The Best-K Algorithm

In every step, the algorithm efficiently finds *K* patches which have the highest marginal benefit.
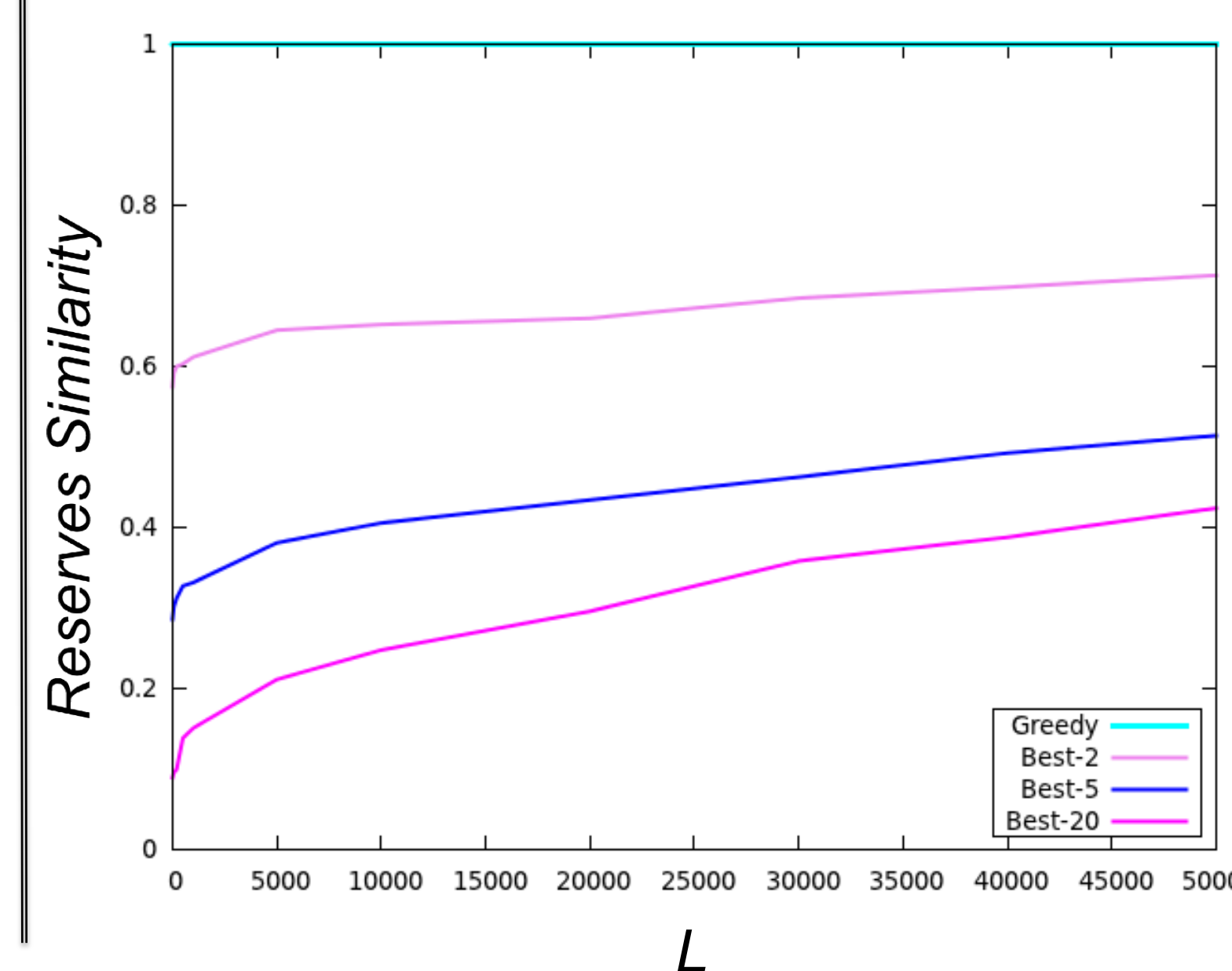
$$\Delta(p|R) = \frac{f(R \cup \{p\}) - f(R)}{c(p)}$$
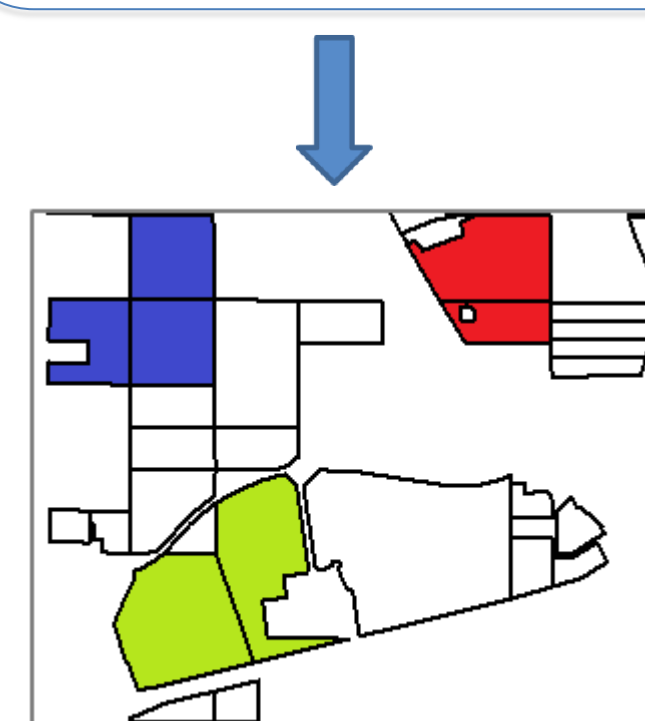
Pick one patch at random

$$Pr[p] \propto \exp(L \cdot \Delta(p|R))$$ $R = R \cup \{p\}$
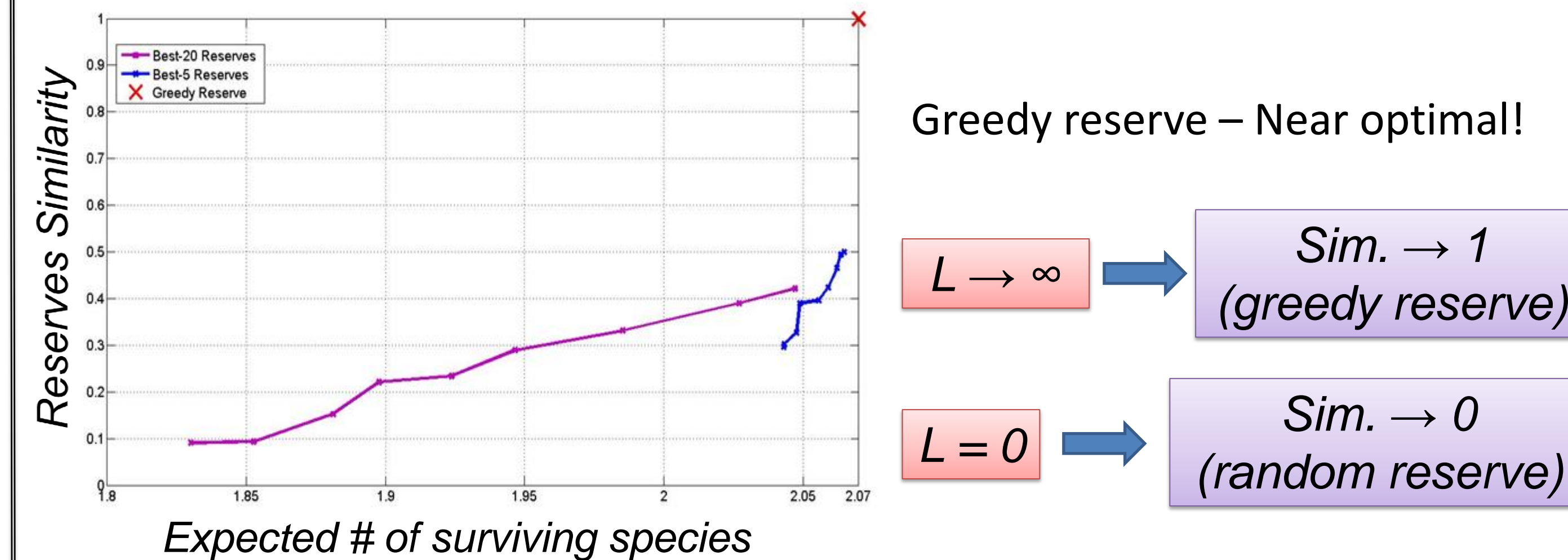
How diverse are our recommendations?

$$Similarity = \sum_{i,j} \frac{|R_i \cap R_j|}{|R_i \cup R_j|}$$

The diversity parameter *L*:

$$Pr[p] \propto \exp(L \cdot \Delta(p|R))$$

Decision Support Tool

Expected Number of Surviving Species / Reserve Similarity

Greedy reserve – Near optimal!

$L \to \infty$ → Sim. → 1 (greedy reserve)

$L = 0$ → Sim. → 0 (random reserve)
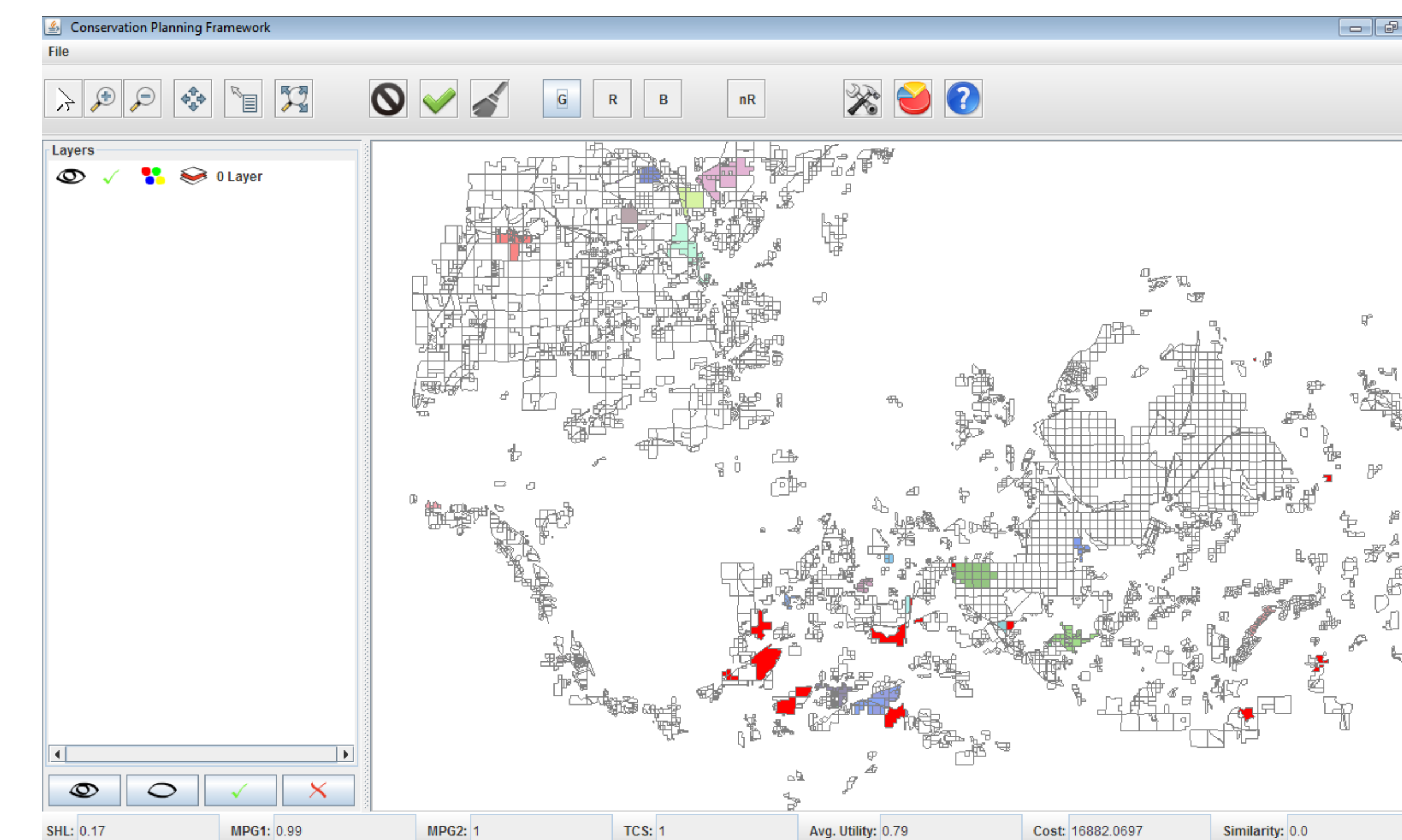
Expected # of surviving species

Decision Support Tool

Conservation managers can explore their decision in the space of possible recommendations.

Allows interactive optimization in (near-) **real-time.**

Recommendations in just **a few seconds** per optimization problem instance.

Incorporates the **Greedy** and the **Best-K** algorithm.
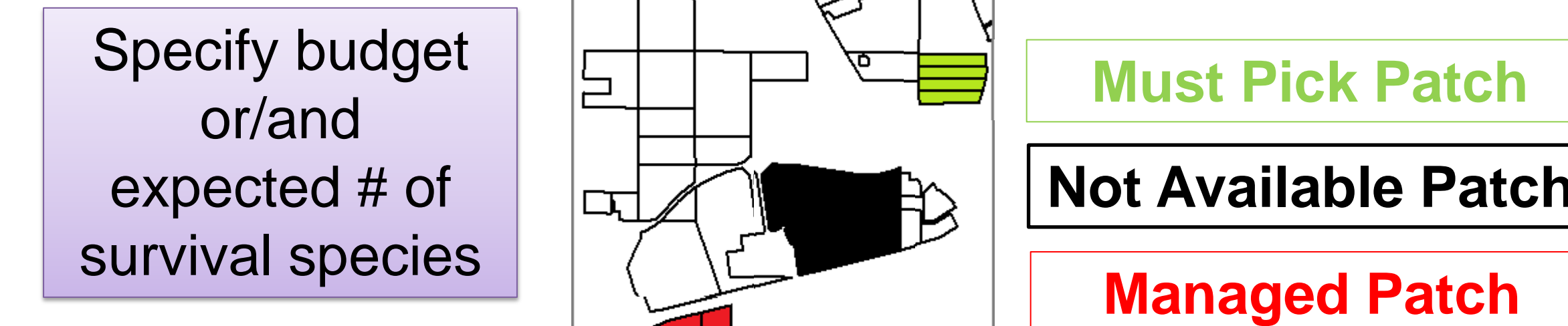

Tool GUI: One possible reserve consisting of recommended patches

Resources Dynamics

Patch Availability

Recommend different reserves when the budget has changed, patch availability has changed etc.

Patch availability over time:

Specify budget or/and expected # of survival species

Must Pick Patch
Not Available Patch
Managed Patch

Recommend a new reserve

Related Work

Existing software
- Marxan [Ball, Possingham & Watts '09]
- Zonation [Moilanen and Kujala '08]
- General purpose software
- No population dynamics modeling, no guarantees

Sheldon et al. '10
- Models non-submodular population dynamics

Conclusions

Reserve design: prototypical optimization problem in Computational Sustainability.

Reserve Recommendation Problem: How to recommend different near-optimal reserves?

The Best-K algorithm
- Produces diverse reserve recommendations which are near – optimal

Decision Support Tool
- Allows mangers to choose between different conservation strategies
- Better utilization of available resources