MEASURING RESILIENCE DERIVED FROM HABITAT CONNECTIVITY TO IMPROVE ESTIMATES OF RESTORATION BENEFITS

Kristen Hychka[1], *Lisa Wainger*[1], *Elizabeth Murray*[2], *and Elizabeth W. Price*[1]

[1]University of Maryland Center for Environmental Science, Solomons, MD, USA

[2]U.S. Army Corps of Engineers, Engineer Research and Development Center, San Francisco, CA, USA

Restoration and Landscape Setting

- Benefits to species from ecological restoration depend on site and landscape conditions that determine both
  - the likelihood of success and
  - the relative ecological impact of restoration

- Landscape condition can limit restoration benefits by:
  - constraining the types of restoration that are possible and
  - controlling the degree to which a site becomes part of a network of habitat that can sustain populations over the long term

Resilience and the Effectiveness of Restoration

- Connectivity
  - the degree to which the landscape facilitates or impedes movement (Taylor et al. 1993)
- Climate connectivity
  - whether the spatial configuration of natural lands allows species to track their current climatic conditions during projected climate change (McGuire et al. 2016)
- Resilience
  - An ecosystem's ability to resist, rebound, or adapt to environmental conditions (Gunderson 2000)

- Landscape resilience
  - The contribution of the restoration to population-scale biodiversity.
    - 'The capacity of the landscape-wide biota to recover from local species losses in individual patches through immigration at the landscape scale. (Rodrigues et al. 2009)'
  - The potential for self-sustaining effectiveness of the restoration

Project Goals

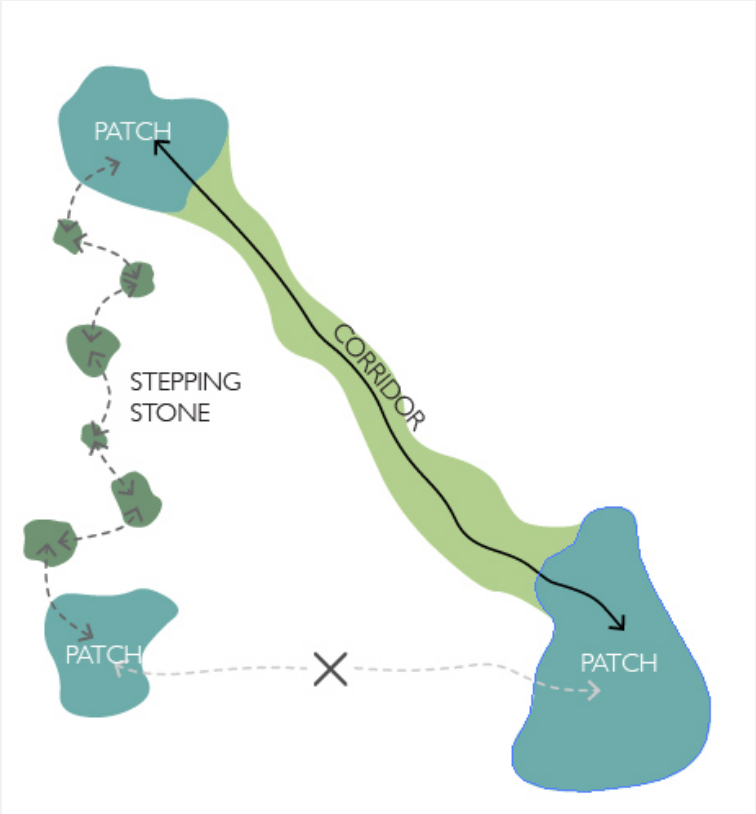
- Part of a larger Eco Scarcity Metrics effort capture benefits of restoration
  - In setting ecosystem and species priorities using an EGS framework, we suggest that landscape metrics can complement site information to evaluate eventual species use.
- Environmental restoration program of the U.S. Army Corps of Engineers
  - Identify metrics that enhance existing screening metrics by better capturing landscape setting and restorability to measure benefits generated by environmental restoration of freshwater wetlands and riparian systems
  - comparing potential effectiveness of a set of alternative available restoration sites to judge quality

Approach

- Review Literature
- Present example tools and case studies
- Present a suite of landscape resilience metrics

Literature Review

- Population-level effects
  - barriers or pinchpoints,
  - contribute to regional connectivity, and
  - provide stepping stones
- Site-level restorability metrics
  - capture local landscape connectivity and
  - identify intermediate resilience sites that may be more restorable

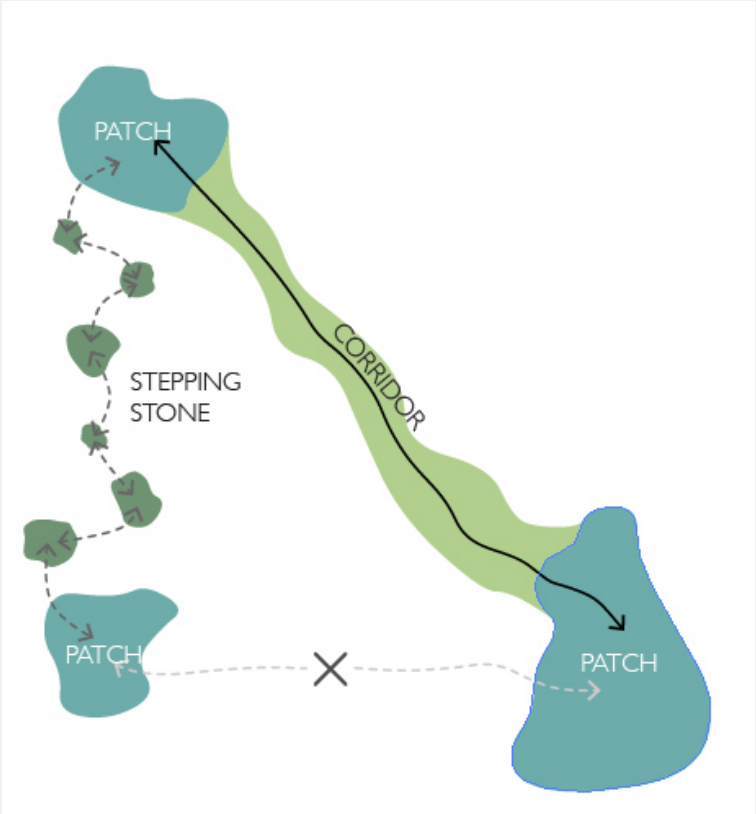


http://content.yardmap.org/learn/habitat-connection/

Literature Review

Metric Types

- Population-level effects
  - **barriers** or pinchpoints,
  - contribute to regional connectivity, and
  - provide stepping stones
- Site-level restorability metrics
  - capture local landscape connectivity and
  - **identify intermediate resilience sites that may be more restorable**

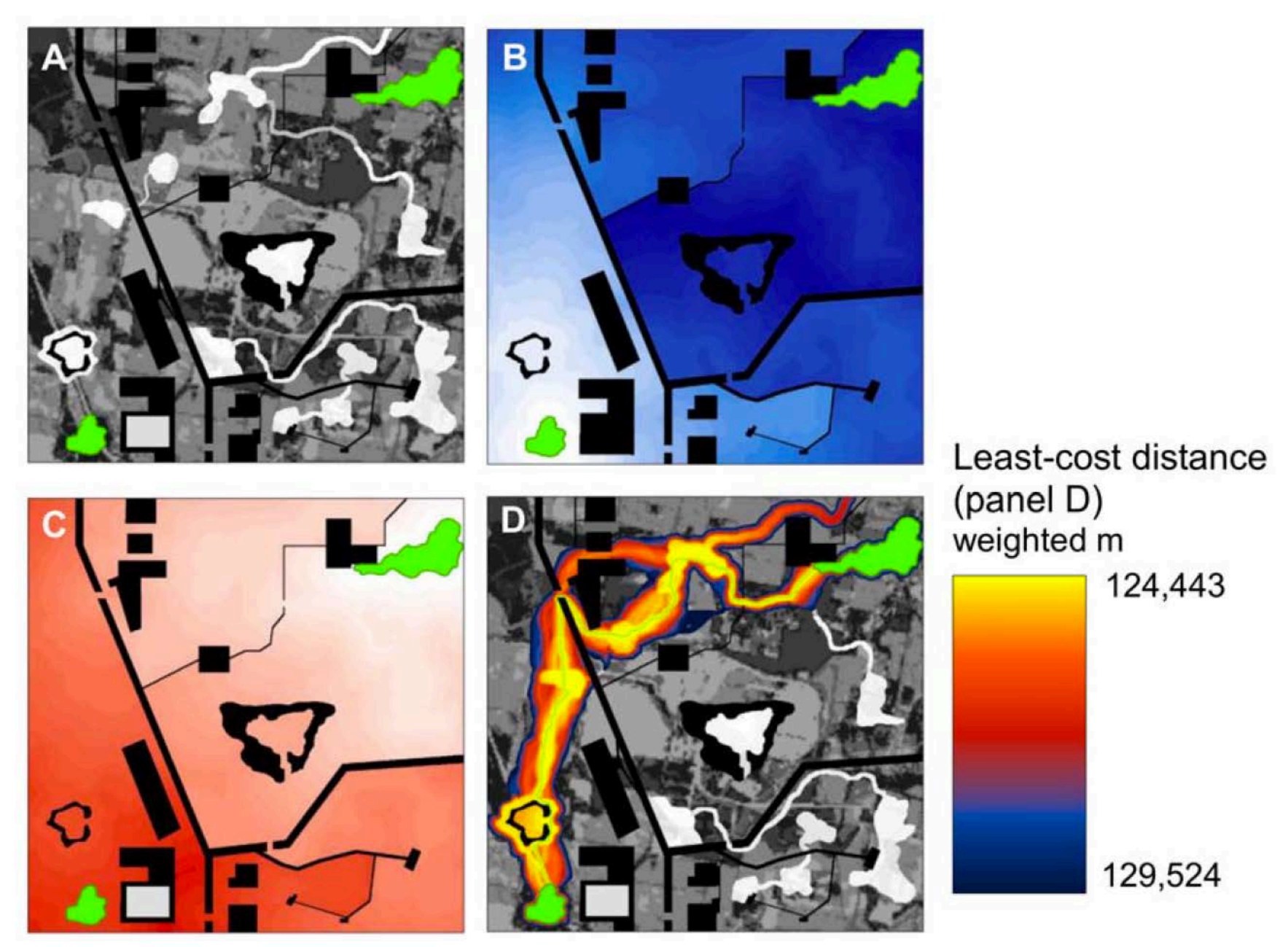


http://content.yardmap.org/learn/habitat-connection/

Barriers

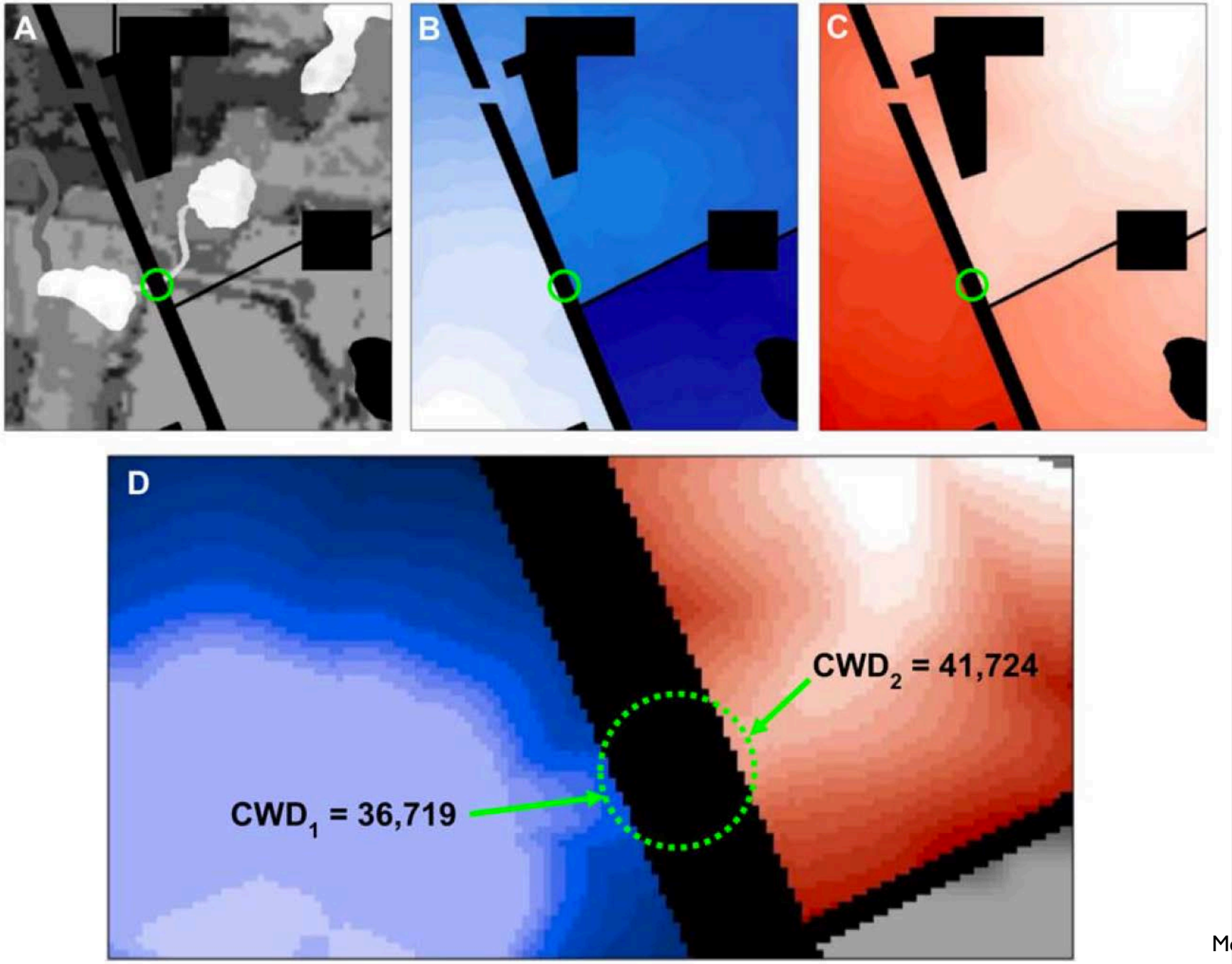
- Maps corridors from core areas using least cost path analysis with a resistance surface between adjacent core areas
- Shows the relative value of each grid cell in providing connectivity between core areas
- Identify which routes encounter more or fewer features that facilitate or impede movement between core areas
- Barrier Mapper (Circuitscape) (McRae et al. 2012)
  - **Lots of effort has been put into mapping corridors or connectivity (opportunities for protection) with less effort put into mapping barriers (opportunities for restoration)**
  - Uses neighborhood analysis with effective distance analyses
  - Detects both complete barriers and those that just impede movement

Least Cost Path Distance



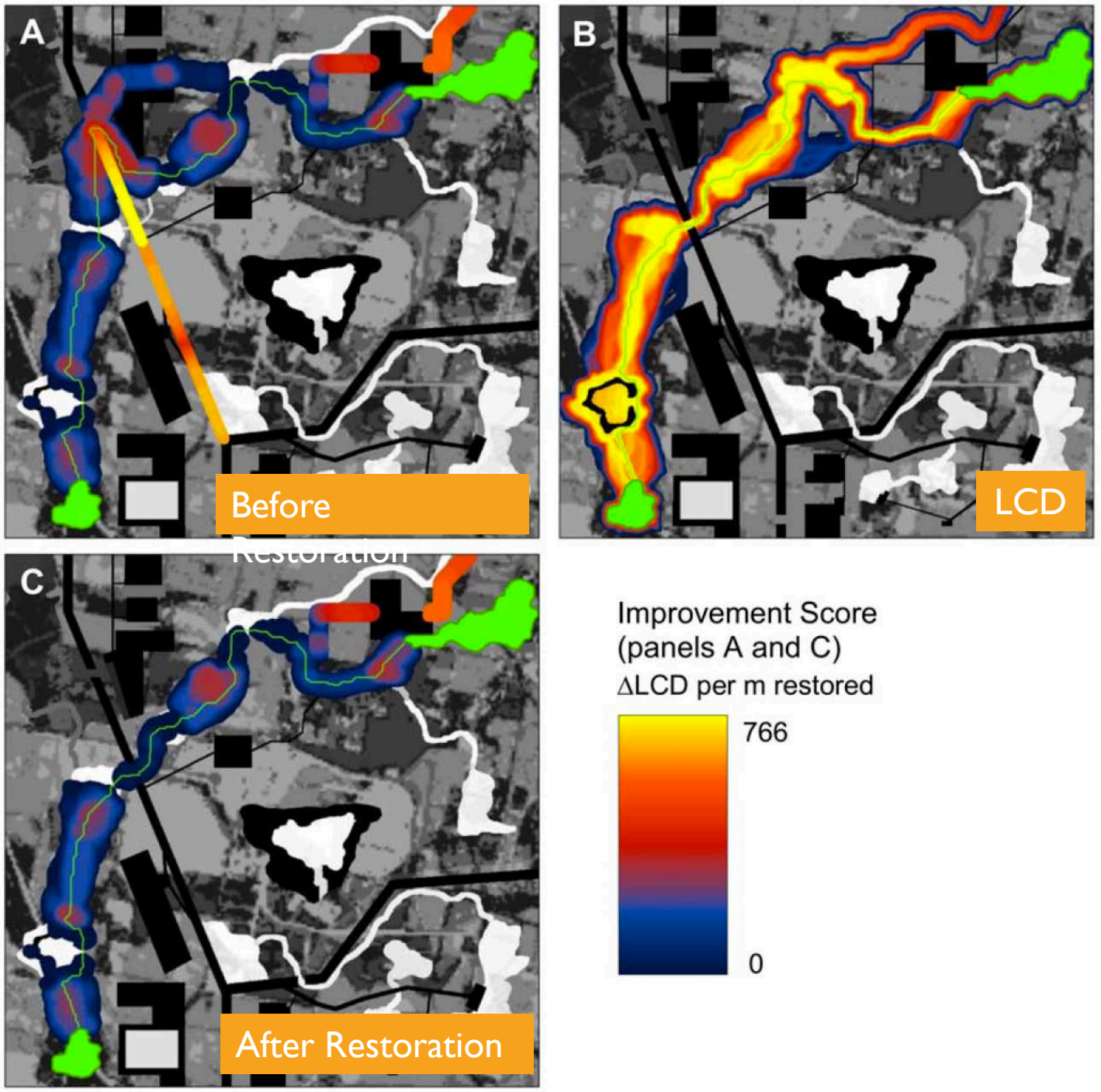
McRae et al. 2012

Barrier Mapper



McRae et al. 2012

Barrier Mapper



McRae et al. 2012

Intermediate Resilience Sites

- Landscape setting to inform restorability
- Landscapes with intermediate amounts of remaining habitat and that still maintain certain levels of connectivity should be the highest priority for restoration actions (Holl & Aide 2011)
  - high potential to maintain biodiversity and to
  - recover by autogenic processes
- Multiscale prioritization of sites
  - At the local scale **habitat amount and connectivity**
  - On a broader scale rank these intermediate resilient landscapes in terms of their importance as **corridors or bottlenecks for biological flows**

Tambosi, L. R., Martensen, A. C., Ribeiro, M. C., & Metzger, J. P. (2014). A framework to optimize biodiversity restoration efforts based on habitat amount and landscape connectivity. *Restoration Ecology*, *22*(2), 169-177.

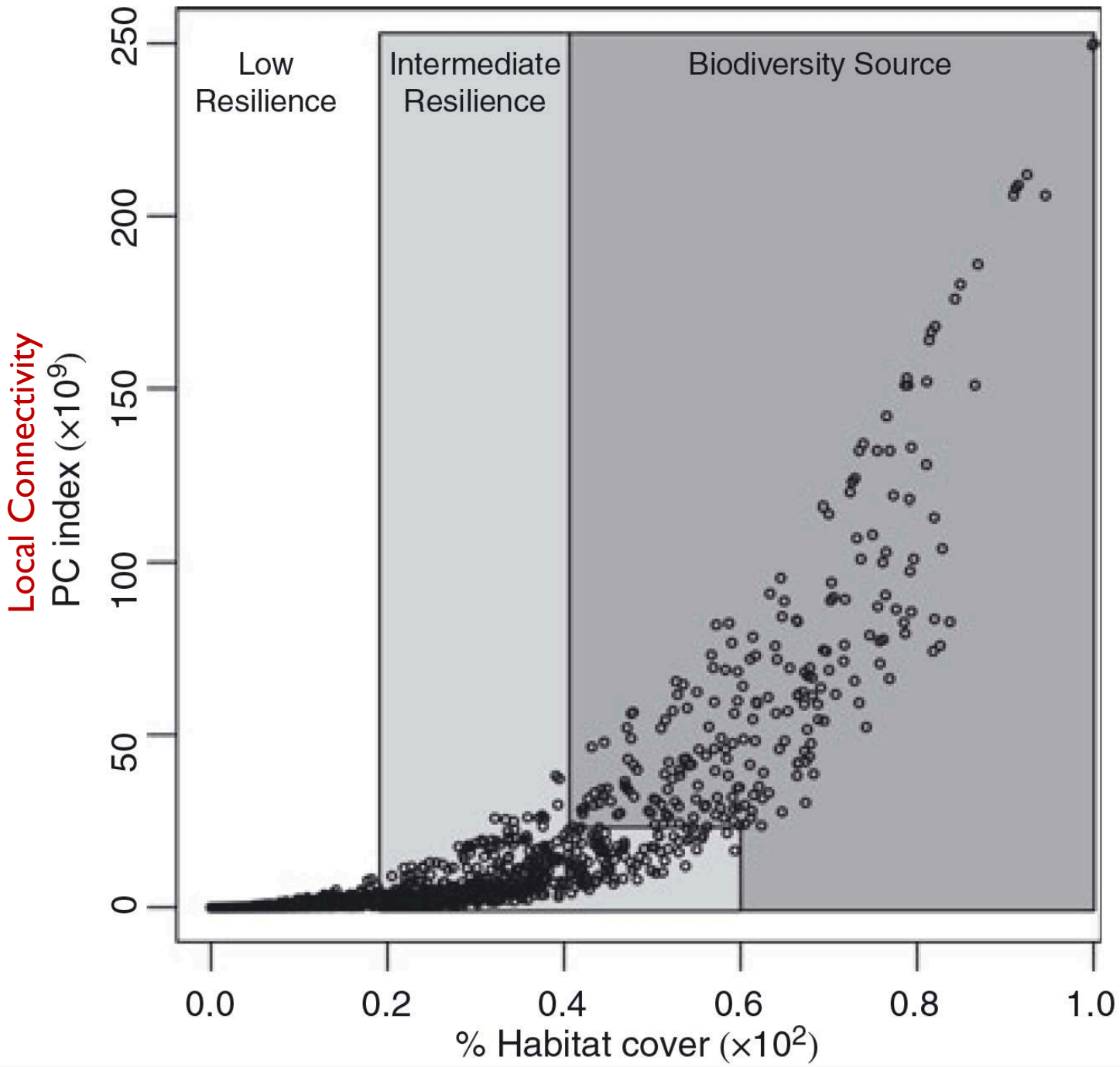


Figure 3. Distribution of focal landscapes (circles) according to the habitat cover and connectivity (PC index) in one of the BSRs of the Brazilian Atlantic Forest (Bahia). Dark gray polygon represents limits of *biodiversity source* landscapes; light gray polygon represents limits of *intermediate resilience* landscapes. *Low resilience landscapes* are those with less than 20% of habitat cover.

- Target sites with intermediate resilience
  - Moderate level of habitat coverage
  - Lower connectivity scores

Tambosi, L. R., Martensen, A. C., Ribeiro, M. C., & Metzger, J. P. (2014). A framework to optimize biodiversity restoration efforts based on habitat amount and landscape connectivity. *Restoration Ecology*, *22*(2), 169-177.

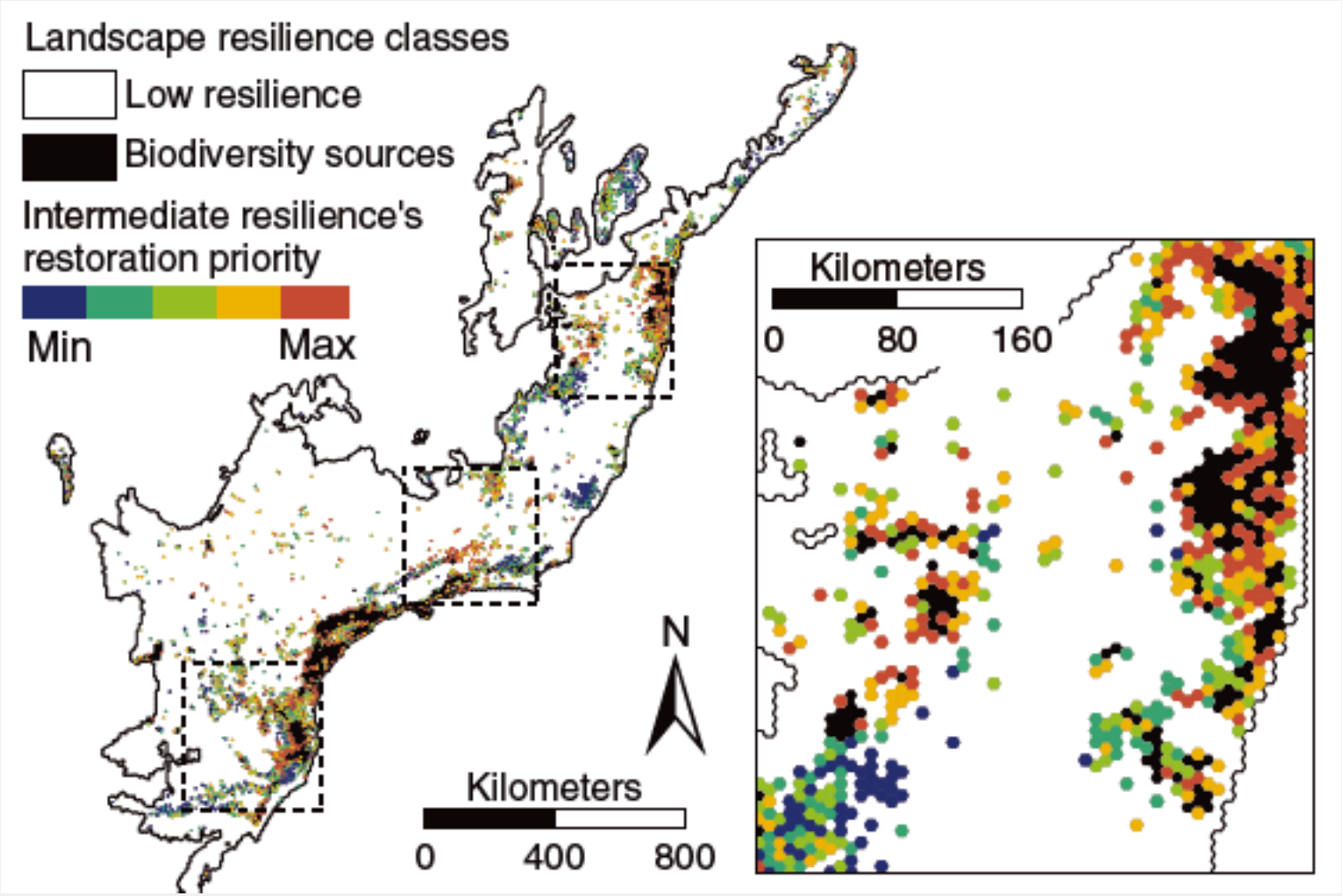


Figure 4. Spatial distribution of the three resilience classes of the Atlantic Forest focal landscapes (top left) and restoration priorities for the *intermediate resilience* landscapes. This figure appears in color in the online version of the article (doi: 10.1111/rec.12049).

Measures of resilience derived from habitat connectivity

Landscape Effect	Landscape Characterization	Metric	Data Requirements
Population-level	Barriers	Improvement Score (change in least cost distance per meter)[1]	Mapped core areas; Movement resistance surface
Population-level	Pinchpoints	Corridors with strong current[1]	Mapped core areas; Movement resistance surface
Population-level	Pinchpoints	Integral Index of Connectivity Connector (IICconnector))[2]	Habitat map; Focal areas
Population-level	Regional landscape connectivity	Integral Index of Connectivity Flux (IICflux))[2]	Habitat map; Focal areas
Population-level	Stepping stones	Traversability[3,4]	Habitat suitability map
Site-level	Local landscape connectivity	Probability of connectivity (PC index) measured at a local scale (5,000 ha)[2]	Habitat map; Focal areas
Site-level	Identifying intermediate resilience sites	Combining PC Index and Percent habitat[2]	Habitat map; Focal areas

McRae et al. 2012[1], Tambosi et al. 2014[2], Rudnick et al. 2012[3], and Urban and Keitt 2000[4]

Summary

- Goal is to create indices that enhance existing restoration screening metrics for non-tidal wetland, stream/floodplain, and riparian buffer projects:
  - Site's contribution to sustaining populations
  - Site's restorability
- Compare potential effectiveness amongst proposed projects by looking at the landscape scale to judge quality
- In setting ecosystem and species priorities using an EGS framework, we suggest that landscape metrics can complement site information to evaluate eventual species use
- Opportunities to identify restoration sites based on barriers
- Multi-scale approach to identify sites with intermediate disturbance

Future Directions

- Develop specific measurement methods for potential use by planners or other decision makers
  - Making measurements consistent,
  - Combining and scoring indicators,
  - Identifying appropriate data sources, and
  - Developing data sets
- Functional vs. Structural Connectivity

Thank you

***Kristen Hychka*[1]*, Lisa Wainger*[1]*, Elizabeth Murray*[2]*, and Elizabeth W. Price*[1]

[1]University of Maryland Center for Environmental Science, Solomons, MD, USA

[2]U.S. Army Corps of Engineers, Engineer Research and Development Center, San Francisco, CA, USA

khychka@umces.edu