Journal of Conservation Planning Vol 7 (2011) 61 - 68

## Topics in Conservation

# Identifying and selecting strategic mitigation opportunities: Criteria design and project evaluation using Logic Scoring of Preference and optimization

**William L. Allen, III; Ole M. Amundsen, III; Jozo Dujmović; Kent D. Messer**

**William L. Allen, III**
The Conservation Fund, Director of Strategic Conservation
Chapel Hill, NC, U.S.A.
Email: wallen@conservationfund.org
http://www.conservationfund.org/strategic_conservation

**Ole M. Amundsen, III**
The Conservation Fund
Strategic Conservation Program Manager
Ithaca, NY, U.S.A.
Email: oamundsen@conservationfund.org

**Jozo Dujmović**
Professor of Computer Science
San Francisco State University
San Francisco, CA, U.S.A.
Email: jozo@sfsu.edu
http://cs.sfsu.edu/People/jozo/jozo.html

**Kent D. Messer**
Associate Professor of Food & Resource Economics
Associate Professor of Economics
University of Delaware
Newark, DE, U.S.A.
Email: messer@udel.edu
http://ag.udel.edu/frec/faculty/messer.htm

**ABSTRACT:** State-of-the-art strategic mitigation efforts involve careful measurement of the likely benefits derived from a project and careful selection of the funded projects to ensure a cost-efficient outcome that delivers high quality results. This paper discusses how the Logic Scoring of Preference (LSP) and optimization can be integrated in a way that maximizes the benefits of mitigation outcomes. The strength of this approach is demonstrated by highlighting the results from several ongoing mitigation and conservation projects.

*Keywords: Logic Scoring of Preference, LSP, optimization, strategic mitigation, decision support*

## INTRODUCTION

Human activities that result in habitat alteration and conversion are responsible for negative impacts on ecological systems and the decline of many species (Wilson, 1992). Within infrastructure development in the United States, avoidance and minimization strategies are implemented first to reduce potential impacts (CEQ, 2000). When unavoidable impacts occur to species and their habitat, compensatory mitigation is required and has been traditionally addressed through regulatory requirements during project construction (Kiesecker et al., 2009). In the recent past, compensatory mitigation occurred on an incremental, project-by-project basis (Thorne, 2009), but is now beginning to be addressed before construction and from a regional perspective to improve conservation outcomes (Huber et al., 2009).

The next generation of mitigation will result in a more comprehensive approach to mitigation, use State Wildlife Action Plans and other plans to create an effective decision-making framework, and allocate compensatory funds in a manner that supports lasting and large scale ecological results (Wilkinson et al., 2009). For compensatory mitigation projects to deliver the greatest 'bang for the buck,' establishing a robust decision support framework that can be used to reliably and consistently evaluate and select potential opportunities is critical. The design and development of mitigation project selection criteria is an important step needed to take advantage of the state-of-the-art tools available to enhance environmental decision-making (Amundsen, 2011).

Project selection criteria should be based on a community's conservation needs and opportunities. These criteria should be rooted in adopted land use and conservation plans, and should do more than merely offset the negative impacts associated with the action requiring compensatory mitigation. A transparent process should be developed to design and refine criteria and ensure that they are applied in a logically consistent manner. Decision makers should have the tools to apply these criteria and quantify the benefits of project alternatives, while concurrently considering the cost of alternatives within realistic budget scenarios. Two cutting edge tools are being used in strategic mitigation projects by The Conservation Fund (the Fund) to help design criteria, evaluate project alternatives, and select projects that provide the greatest benefit at the lowest cost within constrained budgets: the Logic Scoring of Preference (LSP) method and optimization.

## USING LOGIC SCORING OF PREFERENCE TO MEASURE BENEFITS

Logic Scoring of Preference is a scientifically rigorous technique originally developed for computer science applications to design project selection criteria and weightings that reflect fundamental properties of human reasoning and ensure that the benefits calculated accurately reflect the desired intent of decision makers (Dujmović, 2007). The Fund has partnered with SEAS Co. (System Evaluation and Selection, www.seas.com), the world pioneer in the use of LSP for decision making, to design customized desktop and web-based software to support strategic mitigation projects. The desktop (ISEE V1.1) and web-based (LSPweb V1.0) software were first utilized in 2010 to support the compensatory mitigation needs of the NiSource Multi-Species Habitat Conservation Plan (MSHCP) project (The Conservation Fund, 2010).

In the LSP method, mitigation project criteria are developed through a collaborative process with stakeholders and subject matter experts to ensure all attributes that can be measured are included for evaluation and can represent an overall level of satisfaction of compensatory mitigation needs (Dujmović and Allen, 2011). Main steps of the LSP method are summarized in Figure 1. The first step is the development of an attribute tree, exemplified in Figure 2, for the NiSource MSHCP for potential freshwater mussel mitigation projects. The attribute tree is a set of n attributes used to evaluate quantitatively the benefits of potential mitigation opportunities on a consistent scale so that projects can be appropriately compared. Decision makers use the attribute tree to create all inputs needed to evaluate methodically each project, determining to what extent a potential mitigation project meets the particular mitigation needs and desires of the community. For each elementary attribute, the LSP method requires an elementary attribute criterion used for evaluating the value of attribute and computing the degree of attribute suitability. In the next step, which is a unique feature of the LSP method, soft computing evaluation logic is used to aggregate all attribute suitability degrees and determine an overall suitability of the evaluated project. This process includes all necessary logic relationships between attributes and their groups. At the same time, we identify all components that affect the overall cost of the project and create an overall cost indicator. The overall suitability and the overall cost are inputs for an appropriate Cost/Suitability Analysis that generates an indicator of the overall value of each project. The overall value is used for ranking competitive projects and selecting the most appropriate project.

Each criterion in the decision tree spans a range of characteristics from most to least suitable in terms of meeting mitigation requirements, known as an elementary (attribute) criterion. Where each project falls within this range is represented numerically on a standard suitability scale from 0 to 100% that represents how well it satisfies that particular criterion (100% being the most suitable or ideal). In addition, criteria in a decision tree have logic properties that designate them as mandatory, sufficient, or desired, based on their contribution to fulfilling mitigation requirements. An example of an elementary criterion for branch #11122 – Intact Buffer Sites is shown in Figure 3.

Relative weights for criteria within a single node of the suitability aggregation tree are assigned by stakeholders and subject matter experts since some factors are more important than others in evaluating a potential mitigation project. A variety of techniques help assign weights; one being the Analytic Hierarchy Process (AHP) (Saaty, 1990; Duke and Aull-Hyde, 2002; Carr and Zwick, 2007; Messer and Allen, 2010). Below is an example of the weighting and logic structure for the branch of the tree with the Intact Buffer Sites criterion:

1112 Project Site Assessment [Logic structure: simultaneity]

- 11121 Buffer Size & Shape – 40%
- 11122 Intact Buffer Sites – 30%
- 11123 Mussell Distribution – 30%

Percentages correspond to the relative weights of each criterion within this branch of the tree. All parameters of the decision model (the elementary criteria, weights, and logic aggregators) are initially selected by the LSP designers (in this case The Conservation Fund and SEAS). With a simultaneity logic structure, all criteria should be, to some extent, simultaneously satisfied. For some criteria, a replaceability logic structure is more appropriate, where all inputs need to be simultaneously satisfied to some extent. In either case, a zero value for one criterion does not necessarily yield a zero output for the entire branch of the tree unless it is determined that is appropriate. It is important to emphasize that all parameters of LSP models can be finally edited and adjusted by stakeholders and experts using LSPweb V1.0, an Internet tool developed as a decision support system for the LSP method.

**Figure 1. Main components of the LSP method.**

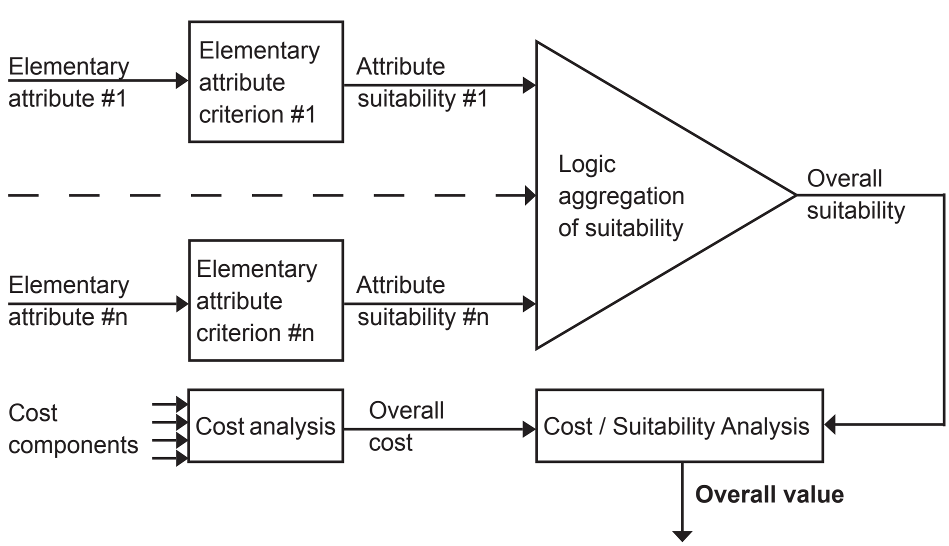

**Figure 2. An attribute tree for the NiSource MSHCP for potential freshwater mussel mitigation projects.**

- **1 Freshwater Mussel Mitigation**
  - **11 Take Species Habitat Mitigation Requirements**
    - **111 Mandatory Habitat Requirements**
      - 1111 Mitigation Units
      - 1112 Project Site Assessment
        - 11121 Buffer Size & Shape
        - 11122 Intact Buffer Sites
        - 11123 Mussel Distribution
      - 1113 Project Physical Conditions
        - 11131 Substratum
        - 11132 Water Quality
        - 11133 Bed Stability
        - 11134 Barriers to Fish Passage
      - 1114 Project Species Occurrence
        - 11141 Known & Potential Host Fish
        - 11142 Mussel Population Viability
        - 11143 Mussel Diversity
        - 11144 Mussel Density
        - 11145 Detrimental Invasive Species
      - 1115 Project Location
    - **112 Desired and Optional Habitat Requirements**
      - 1121 Likely Protection in Perpetuity
        - 11211 Point & Nonpoint Pollution Risks
        - 11212 Sedimentation & Substrate Removal Risk
        - 11213 Stream Impoundment Risk
        - 11214 Stream Buffer Clearing Potential
        - 11215 Project Monitoring Program
      - 1122 Protection of Other Listed Species
        - 11221 NiSource MSHCP Take Species
        - 11222 Other Federal and State Listed Species
  - **12 Other Conservation Goals and Benefits**
    - **121 Support for Green Infrastructure Goals**
    - **122 Planning Goals and Leverage Opportunities**
      - 1221 State Wildlife Action Plans
      - 1222 Other State and Regional Plans
      - 1223 Collaboration and Other Ecosystem Benefits
    - **123 Human Benefits**
      - 1231 State Trail, Greenway, and Bikeway Plan Support
      - 1232 Stimulation of Nature-Based Economic Development

**Figure 3. An elementary criterion for the attribute #11122 – Intact Buffer Sites.**

| **11122** | | **Intact Buffer Sites [0,3]** |
|---|---|---|
| *Value* | *%* | The US Fish and Wildlife Service, NiSource, and the States have determined suitability based upon four potential buffer configurations that may result from a compensatory mitigation project for Endangered and Threatened freshwater mussels.<br><br>The values from 0-3 correspond to a particular percent suitability that described the desired end state of the compensatory mitigation project for mussel species of interest.<br><br>3 = Project includes one site that is internally intact (i.e. there can be no unprotected or unrestored gaps greater than 100 feet on each bank at the conclusion of the project). This is the most suitable.<br><br>2 = Two sites internally intact, but sites less than one mile upstream (as measured from the bottom of the first site to the bottom of the second).<br><br>1 = Three sites internally intact, but sites more than one mile upstream.<br><br>0 = Greater than 3 sites. This is considered unsuitable.<br><br>This criterion represents a mandatory requirement. |
| 0<br>1<br>2<br>3 | 0<br>20<br>80<br>100 | |

Some of the decision tree criteria are designated as mandatory while others are designated as desired. A desired criterion *cannot compensate* for the absence of a mandatory criterion, but the mandatory criterion *can significantly compensate* the absence or low value of the desired criterion. The LSP method allows decision tree designers to establish a percent penalty for a low desired value and a percent reward for a high desired value. Branch #121 – Support for Green Infrastructure Goals – represents how well a mitigation project contributes to the protection of the green infrastructure network, the "strategically planned and managed network of natural lands, working landscapes, and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations" (Benedict and McMahon, 2006).

Green infrastructure networks are helping transportation agencies meet federal guidelines for consultation, use of natural resource inventories, and consideration of environmental mitigation as specified in section 6001 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) legislation enacted in 2005 (Amundsen, Allen, and Hoellen, 2009). The NiSource MSHCP stakeholders believed that although a project's ability to enhance the protected green infrastructure network was a desired characteristic of a mitigation project, it should not entirely compensate for a low value of meeting specific endangered and threatened species mitigation needs. This logic structure seems appropriate for an array of compensatory mitigation applications, including transportation, where multiple benefits are desired but specific mitigation needs are legally required to be the priority.

In summary, decision trees were developed for all of the endangered and threatened species in need of compensatory mitigation in the NiSource MSHCP. Once all criteria values are calculated and weights and logic structures applied, each mitigation project alternative will receive a numerical score from 0-100 based upon its overall level of satisfaction in meeting compensatory mitigation needs. These quantitative suitability scores will then be considered along with the implementation costs (e.g. acquisition, management, and monitoring) of potential mitigation projects for further evaluation.

## USING OPTIMIZATION TO ACHIEVE HIGHER EFFICIENCIES WITH PROJECT SELECTION

Integrating economic costs into conservation planning is a key to ensuring better conservation outcomes (Naidoo et al., 2006). When trying to select the most cost-effective mix of strategic mitigation projects, it is more efficient to determine overall quality based on benefit and costs rather than with an analysis strictly of either cost or benefit (Babcock et al., 1997; Hughey and Cullen, 2003; Perhans et al., 2008).

Optimization is a branch of economics and operations research studies that in recent years has shown conservation professionals how to get more land conserved within constrained budgets or achieve the same level of environmental benefits from land conservation projects with a smaller budget. The Fund has partnered with Innovative Conservation Solutions to develop desktop and web-based software that allows users to identify a suitable portfolio of mitigation projects based on one of three techniques: (1) identifying an optimal set of mitigation projects within a fixed budget constraint, (2) exploring the relative cost effectiveness of mitigation projects and selecting the portfolio with the highest benefit-cost ratio, or (3) identifying the minimum cost required to achieve a defined benefit level. The Optimization Decision Support Tool (ODST) has been utilized in strategic conservation and mitigation projects since 2005 (Messer, 2006; Allen et al., 2006; Messer and Allen, 2009, 2010). The Fund and Innovative Conservation Solutions have demonstrated that utilizing optimization in conservation programs yields significantly more acreage with higher overall conservation benefits than does applying more traditional project selection approaches.

Effective conservation and mitigation efforts require both sound science and sound economics, yet the most common technique used to select conservation projects can be quite inefficient. This selection technique, a "rank-based model," selects the projects with the highest benefit scores with little consideration of the relative project costs. In situations where numerous high quality projects go unfunded due to budget constraints, the rank-based approach ensures only that the available resources are spent on the highest ranked projects. However, the model frequently misses opportunities to spend the money in a cost-effective way by funding lower-cost, high-benefit alternatives that would extend limited financial resources and maximize overall conservation benefits (Allen, Weber, and Hoellen, 2010).

In contrast, an optimization model uses a mathematical programming technique called binary linear programming to identify the set of cost-effective projects that maximizes aggregate benefits (Kaiser and Messer, 2011). The optimization model uses data describing the resource benefits of the potential projects and relative priority weights that an organization assigns to each benefit measure, as well as estimated project costs and budget constraints. The optimization model evaluates each of the possible sets of available projects and selects the set that maximizes the aggregate conservation benefits given a specified budget. The optimization model can help distinguish between the high-cost "Cadillac" projects, which can rapidly deplete available funds while making relatively small contributions to overall conservation goals, and the "best buy" projects, which individually may not appear as valuable, but when combined, provide greater aggregate benefits. An alternative optimization approach is known as Cost-Effective Analysis, which ranks benefit-cost ratios for each project from highest to lowest and then selects the highest ranked benefit-cost ratio until the budget is exhausted. Identifying the cost-efficient set of projects not only helps organizations maximize financial resources, but can also provide a science-based, economic rationale for identifying and prioritizing projects.

Optimization models enable the user to select the set of projects that maximizes the total conservation benefits. An important distinction must be underscored: "total benefits" are defined as the sum the benefits from each of the selected individual projects. Optimization focuses on the total benefits of the pool of potential projects, whereas a traditional rank-based selection process examines projects and determines individual worth in isolation, without actually looking at the broader portfolio of potential projects.

Optimization can readily build upon the benefit criteria from the LSP method to provide a project's overall conservation benefit to the community. Optimization offers a way for those in need of mitigation to increase public confidence that taxpayer funds are being well managed, are consistent with federal funding guidelines, and that a scientific, objective, merit-based decision-making process is being used. In addition, optimization can help decision makers distinguish between high-cost projects that can rapidly deplete available funds while making relatively small contributions to overall conservation goals and "good value" projects that ensure that conservation benefits are maximized given the available budget (Amundsen, Messer and Allen, 2010).

The best on-the-ground illustration of the value of using optimization is the Baltimore County Agricultural Land Preservation Program in Maryland. This program has used the ODST to save 22% more farmland than it would have otherwise over the past three years. Every year since 2007, Baltimore County has used the ODST to choose which agricultural lands to save. Optimization has helped the county protect an additional 680 acres of high-quality agricultural land, at a cost savings of roughly $5.4 million—a return on investment over three years of more than 60 to 1. In other words, for every $1 that Baltimore County spent using the ODST, it has gained more than $60 in conservation benefits (Amundsen, Messer and Allen, 2010). When combined with the results from previous studies on the potential cost savings, efficiency gains and increased benefits and acreage, it makes for a compelling case for the expanded use of this tool.

The Maryland State Highway Administration (SHA) has been examining transportation improvement options for US 301 near the Town of Waldorf, including the construction of a bypass or upgrading the existing road. SHA adopted environmental stewardship into its US 301 transportation planning, with the goal of creating a net benefit to the environment. This approach is innovative among transportation agencies in that it goes above and beyond compensatory mitigation required by the National Environmental Policy Act (NEPA) to offset impacts from construction and related activities (Weber and Allen, 2010). One of the methods by which SHA aims to achieve this ambitious goal is through the use of optimization to identify the set of stewardship projects that will maximize natural resource benefits within given budget constraints (Allen, Weber, and Hoellen, 2010). The Fund identified portfolios of environmental stewardship projects at different budget levels and then maximized the ecological benefits at each given cost. Optimization outperformed rank-based selection under all scenarios, with 69% more green infrastructure area, 68% more aggregate ecological benefits, and 1,641 more acres protected under a hypothetical $15 million environmental stewardship budget scenario (Dillaway, 2010).

## CONCLUSION

State-of-the-art strategic mitigation efforts involve careful measurement of the likely benefits derived from a project and careful selection of the funded projects to ensure a cost-efficient outcome that delivers high quality results. This paper outlines the approach of two tools—the Logic Scoring of Preference (LSP) and optimization—and describes how they can be integrated in a way that delivers dramatically improved mitigation outcomes by maximizing the effectiveness of limited financial resources. A key strength of this approach is the inherent flexibility of these tools, which makes them applicable to a large array of mitigation and conservation settings.

## LITERATURE CITED

Allen, W.L., Weber, T.C. and Hoellen, K.A. 2010. Green Infrastructure Design and Benefit-Cost Optimization in Transportation Planning: Maximizing Conservation and Restoration Opportunities in Four Southern Maryland Watersheds. Chapter in Burke, David G. and Joel E. Dunn (eds.). A Sustainable Chesapeake: Better Models for Conservation. The Conservation Fund. Arlington, VA.

Allen, W.L., Weber, T.C., Messer, K.D., Amundsen, O.M. and Phillips, B.T. 2006. Kent County Rapid Assessment of Green Infrastructure. The Conservation Fund. Arlington, VA.

Amundsen, O.M. 2011. Guide to Strategic Conservation Planning. Land Trust Alliance. Washington D.C.

Amundsen, O.M., Messer, K.D. and Allen, W.L. 2010. Integrating Optimization and Strategic Conservation to Achieve Higher Efficiencies in Land Protection. University of Delaware Working Papers series, (http://www.lerner.udel.edu/departments/economics/research-scholarship/workingpaperseries).

Amundsen, O.M., Allen, W.L. and Hoellen, K.A. 2009. Green Infrastructure Planning: Recent Advances and Applications, American Planning Association, *PAS Memo*, May/June 2009.

Babcock, B.A., Lakshminarayan, P.G., Wu, J. and Zilberman, D. 1997. Targeting Tools for the Purchase of Environmental Amenities. *Land Economics*, 73: 325-339.

Benedict, M.A. and McMahon, E.T. 2006. Green Infrastructure: Linking Landscapes and Communities. Island Press, Washington, DC.

Carr, M.H. and Zwick, P.D. 2007. Smart Land-Use Analysis – The LUCIS Model. ESRI Press, Redlands, CA.

CEQ (Council on Environmental Quality). 2000. Protection of the environment (under the National Environment Policy Act). Washington, DC: Council on Environmental Quality. Report No 40 CFR 1500-1517.

Conservation Fund, The. 2010. Determining Mitigation Needs for NiSource Natural Gas Transmission Facilities – Implementation of the Multi-Species Habitat Conservation Plan. Unpublished report.

Dillaway, R. 2010. Achieving Cost Effective Conservation: ORES801 Case Studies of Applying Optimization to Wetland Mitigation from Highway Expansions in Maryland, Improve Water Quality from the Impact of Dirt and Gravel Roads in Pennsylvania, Increase Cost-Sharing for Forest Protection, and Preserving Agricultural Lands in Delaware and Baltimore County, Maryland. editor K.D. Messer, *Food and Resource Economics Working Paper RR10-01*, University of Delaware, July.

Dujmović, J.J., Continuous Preference Logic for System Evaluation. 2007. IEEE Transactions on Fuzzy Systems, 15(6): 1082-1099, December.

Dujmović, J.J. and Allen, W.L. 2011. A Family of Soft Computing Decision Models for Selecting Multi-Species Habitat Mitigation Projects. Proceedings of the World Conference on Soft Computing, San Francisco, 2011.

Duke, J. M. and Aull-Hyde, R. A. 2002. Identifying Public Preferences for Land Preservation Using the Analytic Hierarchy Process. *Ecological Economics*, 42: 131–145.

Huber, P.R., D.R. Cameron, Thorne, J.H. and Frink, T.M. 2009. Regional Advance Mitigation Planning: A Pilot Study Integrating Multi-Agency Mitigation Needs and Actions Within a Comprehensive Ecological Framework. The 2009 International Conference on Ecology & Transportation, Duluth, MN, September.

Hughey, K.F.D., Cullen, R. and Moran, E. 2003. Integrating Economic Approaches into the Evaluation of Conservation Management Initiatives. *Conservation Biology*, 17(1): 1-12.

Kaiser, H.M. and Messer, K.D.. 2011. Mathematical Programming Models for Agricultural, Environmental, and Resource Economics. John Wiley & Sons.

Kiesecker, J.M., Copeland, H., Pocewicz, A., Nibbelink, N., McKenney, B., Dahlke, J., Holloran, M. and Stroud, D. 2009. A framework for implementing biodiversity offsets: selecting sites and determining scale. *BioScience*, 59: 77-84.

Messer, K.D. 2006. The Conservation Benefits of Cost Effective Land Acquisition: A Case Study in Maryland. *Journal of Environmental Management*, 79: 305–315.

Messer, K.D. and Allen, W.L. 2010. Applying Optimization and the Analytic Hierarchy Process to Enhance Agricultural Preservation Strategies in the State of Delaware. *Agricultural and Resource Economics Review*. 39(3): 442-456.

Messer, K.D. and Allen, W.L. 2009. Optimizing Project Selection for the U.S. Army Compatible Use Buffer Program. White paper prepared for US Army Environmental Center and LMI Government Consulting.

Naidoo, R., Balmford, A., Ferraro, P. J., Polasky, S., Ricketts, T. H. and Rouget, M. 2006. Integrating economic costs into conservation planning. *Trends in Ecology & Evolution*, 21(12): 681-687.

Perhans K, Kindstrand C, Boman M, Djupström LB, Gustafsson L, Mattsson L, Schroeder LM, Weslien J, Wikberg S. 2008. Conservation goals and the relative importance of costs and benefits in reserve selection. *Conservation Biology*, 22(5): 1331-9.

Saaty, T. L. 1990. How to Make a Decision: The Analytic Hierarchy Process. *European Journal of Operational Research*, 48(1): 9–26.

Thorne J.T., Girvetz, E.H. and McCoy, M.C. 2009. Evaluating aggregate terrestrial impacts of road construction projects for advanced regional mitigation. *Environmental Management*, 43: 936-948.

Weber, T.C. and Allen, W.L. 2010. Beyond on-site mitigation: An integrated, multi-scale approach to environmental mitigation and stewardship for transportation projects. *Landscape and Urban Planning*. 96: 240-256.

Wilkinson, J.B., McElfish, J.M. Jr., Kihslinger, R., Bendick, R. and McKenney, B.A. 2009. The Next Generation of Mitigation: Linking Current and Future Mitigation Programs with State Wildlife Action Plans and Other State and Regional Plans. Whitepaper from the Environmental Law Institute and The Nature Conservancy.

Wilson, E.O. 1992. The Diversity of Life. Harvard University Press. Cambridge, MA.

*This Topics in Conservation manuscript was accepted by the editors, but it did not go through a double blind peer review process.*