Appalachian LLC Data Needs Assessment Report

Task Three – List of conservation planning tools, their functions, and relevance to AppLCC conservation planning goals

The number of conservation planning tools and approaches is a growing and dynamic field of research. Here, we present description and evaluation of 21 conservation planning tools. To reduce the complexity of the conservation planning tools we decided to take a functional-grouping approach. These six groups are: reserve planning, habitat connectivity, species distribution modeling and viability, planning process integration, threats and climate change. To do the review, we used our own knowledge of conservation planning software and approaches, surveyed the literature for references to published programs, and searched the internet for emerging programs. We have condensed this information into a table (Table 1) and used it as a springboard for further exploration and discussion.

In our discussion we first give an overview of conservation planning tools in general and explore how they work and how they don't work. Second, we discuss the workings of representative program from each group with details about what they do including their working environment, inputs, and outputs. In addition we discuss how they might be used to assist decision making in the Appalachian LCC project area. Some of these tools are coarse filter approaches (based on ecological integrity), and some are fine filter approaches (species based). Based on our experience with the tools, we have provided recommendations about its applicability to the AppLCC.

The ultimate purpose of our review is to list and describe existing programs that might be useful at different levels and/or at different stages of conservation planning in the Appalachian LCC region. Making a decision about which approach to use may require additional comparisons in which new approaches (e.g., LCAD) are evaluated in the App LCC along with existing and previous approaches.

Table 1.Overview of conservation planning tools. Most are software; four are data models representing scenarios that are used in conservation planning.

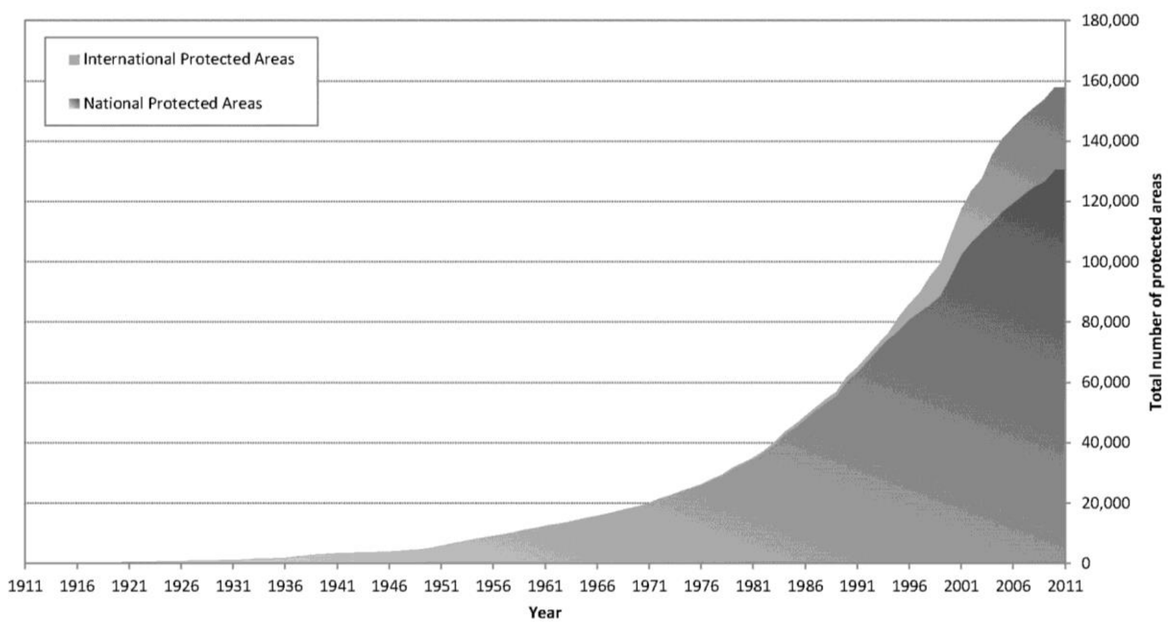
Software purpose	**Software name**	**Computing environment**	**Programming language**	**Difficulty** (1 = easy, 5 = lots of time investment)	**Data requirements** (1 = standard inputs, 5 = specialized)	**Quality and availability of documentation** (1 = very accessible, 5 = technical language only)	**Website for further information**
Reserve selection	Marxan	Zonae Cogito		5	2	3	http://www.uq.edu.au/marxan/
	Marxan with zones	Zonae Cogito		5	3	3	http://www.uq.edu.au/marxan/
	Sites	ArcView		5			http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html
	Zonation	Stand alone	Compiled	5			http://www.helsinki.fi/bioscience/consplan/software/Zonation/index.html
Habitat connectivity	Corridor Designer	ArcGIS 10	Python	4	2	2	http://corridordesign.org/
	Circuitscape	ArcGIS	Python	5	2	4	http://www.circuitscape.org/Circuitscape/Welcome.html
	Linkage mapper	ArcGIS	Python	5		5	http://code.google.com/p/linkage-mapper/
	Unicor	ArcGIS	Python	5		5	None found
	FunConn	ArcGIS 9.1	Python	4	2	5	http://www.nrel.colostate.edu/projects/starmap/funconn_index.htm
	Wild Lifelines	ArcGIS 10		3	1	3	http://www.twp.org/what-we-do/scientific-approach/wild-lifelines
Species Distribution Modeling and	Expert Opinion	ArcGIS 10	N/A	5	1	1	

Viability							
	Maxent		JAVA	3	3	4	http://www.cs.princeton.edu/~schapire/maxent/
	Presence			5	3	4	http://www.mbr-pwrc.usgs.gov/software/presence.html
	RAMAS GIS	Stand alone	Compiled	5	5	3	http://www.ramas.com/index.php?option=com_k2&view=itemlist&layout=category&task=category&id=41&Itemid=80&lang=en#gis
Planning process integration	Natureserve Vista	ArcGIS 10	Python	2	2	2	http://www.natureserve.org/prodServices/vista/overview.jsp
	Miradi	Stand alone	Compiled	2			https://miradi.org/
Threats	Community Viz (Local Buildout)	ArcGIS 10		3		2	http://placeways.com/communityviz/
	Global Human Footprint	Raster dataset for ArcGIS, web interface	NA	3	1	3	http://sedac.ciesin.columbia.edu/wildareas/
	Future Human Footprint scenarios	Raster dataset for ArcGIS, web interface	NA	3	1	3	http://www.2c1forest.org/
	Future housing and impervious surface scenarios	Raster dataset for ArcGIS	NA	5	1	5	http://www.pnas.org/content/107/49/20887.full
Climate	Climate forecasts, historical data	Raster datasets, web interface	NA	3	1	3	http://www.climatewizard.org/

Reserve selection

One might well ask, are new reserves being established today? The answer would be most definitely yes; the World Database on Protected Areas shows a century of exponential growth in numbers of new protected areas globally (Figure 1) and the National Conservation Easement Database recently completed for the United States maps 80,756 easements (nearly 18 million acres) most established in the recent two decades (http://www.conservationeasement.us/).

Figure 1. Growth in number of internationally and nationally designated protected areas 1911-2011. Source: World Database on Protected Areas.



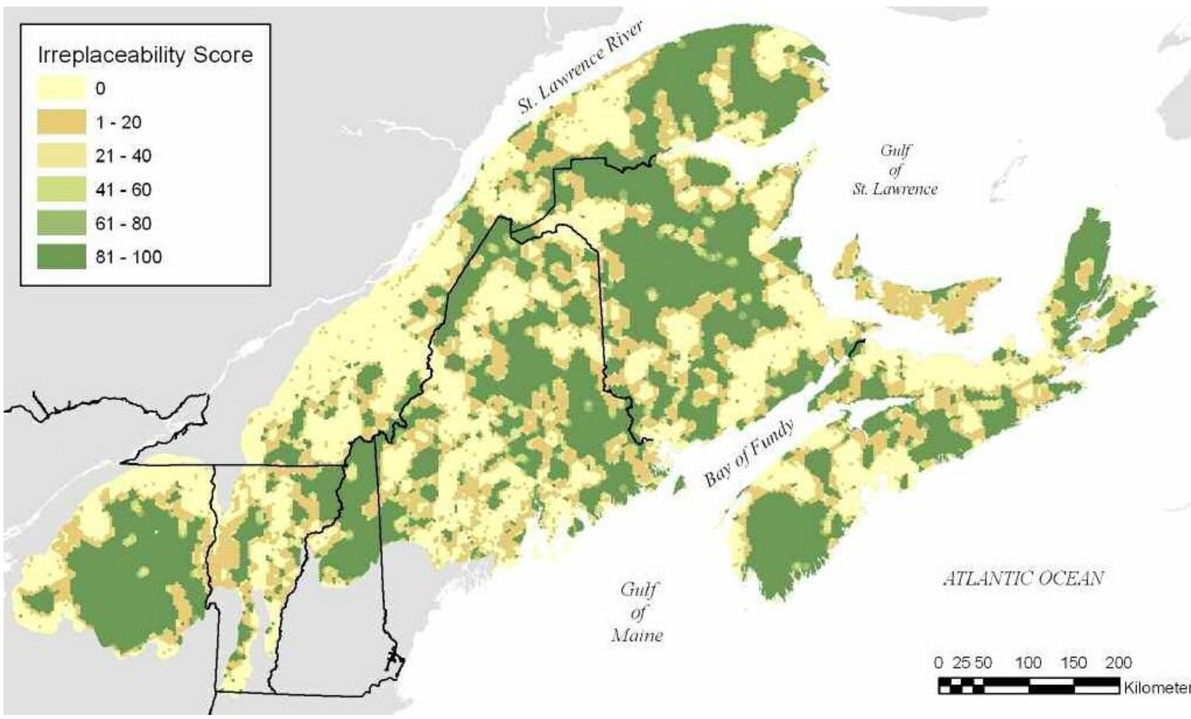
Source: IUCN and UNEP-WCMC (2012) The World Database on Protected Areas (WDPA): February 2012. Cambridge, UK: UNEP-WCMC.

The selection of new reserves or areas to expand existing reserves relates to the concept of “habitat cores”. Habitat cores may be described those areas of land and water extensive enough and containing enough habitat of specific types that viable populations may be maintained. This means that natural patterns of disturbance may act to maintain diversity. Also that the area is large enough to allow range shifts of species due to changes in ambient conditions and that the area is free of interference from roads and other human infrastructure (i.e. protected). An ideal system of reserves is thought to represent the regional pool of species and ecosystems, such that reserves are “irreplaceable” areas for maintenance of biodiversity (Noss et al. 2002, Trombulak 2010).

In practice, most existing reserves were put into place in something other than a systematic biological selection process (Margules and Pressey 2000). The emerging field of systematic conservation planning seeks to identify areas that are irreplaceable, categorize them as to levels of threat and vulnerability, and thus prioritize conservation action. Reserve selection is almost inseparable from other conservation planning activities including habitat connectivity (linking cores), and climate resilience. Several major pieces of conservation planning software, however, treat these as separate processes having the same end goal of a resilient, representative, interconnected network to protect biodiversity.

Reserve selection algorithms frequently employ the concept of optimality, which means that the goal is to identify the most valuable areas for conservation using the least amount of area (least cost). The software involves setting numerous assumptions, usually arrived at through consultation with regional experts and other stakeholders. For example, conservation goals (how much?) are frequently set through an iterative process for conservation targets (what?). Reserve selection then implies that the goals and targets have already been decided. The following is an example of output from the program MARXAN (Trombulak et al. 2008):

Figure 2. One scenario for reserve selection in the Northern Appalachian ecoregion of the United States and Canada. Irreplaceability scores come from the reserve selection software MARXAN, and represent the number of solutions in which a particular area was selected by the software given input parameters (Trombulak et al. 2008).



<u>Key Resources for Understanding Reserve Selection:</u>

Books:

Moilanen, A., K. A. Wilson, and H. P. Possingham, editors. 2009. Spatial Conservation Prioritization: Quantitative Methods and Computational Tools. Oxford University Press.

Trombulak, S. C. and R. F. Baldwin, editors. 2010. Landscape-scale Conservation Planning. Springer-Verlag, New York.

Online:

MARXAN website http://www.uq.edu.au/marxan/

Selected Articles:

Margules, C. R. and R. L. Pressey. 2000. Systematic conservation planning. Nature **405**:243-253.

Noss, R., C. Carroll, K. Vance-Borland, and G. Wuerthner. 2002. A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem. Conservation Biology **16**:895-908.

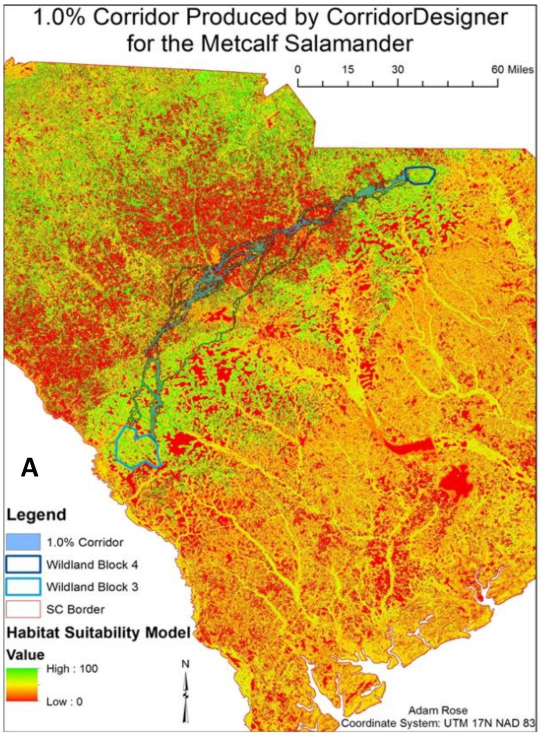
Pressey, R. L., H. P. Possingham, and C. R. Margules. 1996. Optimality in reserve selection algorithms:when does it matter and how much? Biological Conservation **76**:259-267.

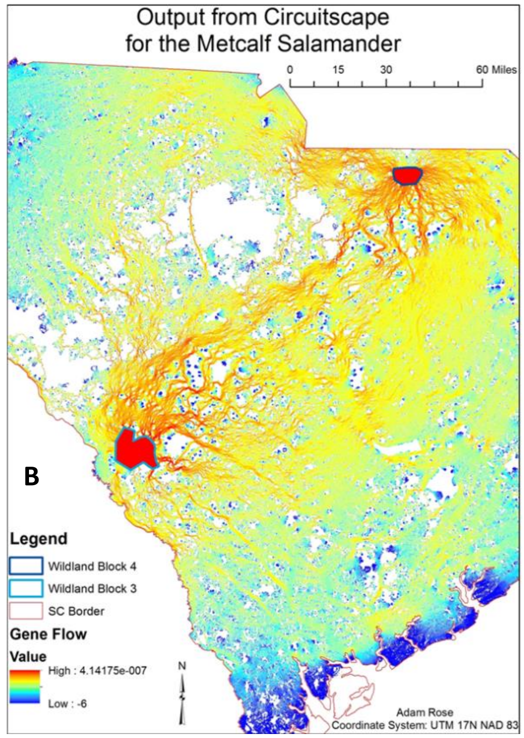
Habitat connectivity

Reserves that are not connected with natural land cover to other reserves become ecologically isolated and lose the diversity they were established to maintain (MacArthur and Wilson 1967, Newmark 1987). Island biogeographic processes act on “islands” on land as well as on sea, yet on land the processes of extinction, colonization, establishment, and adaptive radiation are influenced greatly by the variable quality of the surrounding “matrix” of land and water in which the reserve sits. Essentially, the more connected a reserve to others, the larger it acts and the more diversity it can support. Short of very large protected areas, protected areas connected through strategically located “corridors” or “linkages” will function better to protect biodiversity than those that are not(Noss 1983, Dobson et al. 1999).

In recent decades mapping corridors has become a sophisticated modeling process, with alternative choices of location. First, the basic concept of a discrete area called a “corridor” needs to be critically examined, and we need to ask whether it is biologically realistic to implement discrete polygons that are “highways” for focal organisms (Beier and Noss 1998, McRae et al. 2008, Beier et al. 2011). In some cases discrete corridors or connective areas may be desired. For example, if administrators of two reserves want to map passages for wildlife to move between their areas by creating road overpasses or underpasses, or removing other barriers. Then it would become desirable to identify and map discrete habitat areas or specific pinch points where passage is allowed (Figure 3a). Models can help identify important areas for connectivity, and where flow and resistance accumulate creating “pinch points” that, if removed might “unblock” movement (Figure 3b).

Figure 3. Output of two different modeling approaches for the same organism and landscape showing discrete corridors on the left, and a more diffuse flow of propagules with darker "pinch points" on the right. Also note the different pathways implied in each model even though the species, and input data are identical (A. Rose, P. Leonard, R. Baldwin unpublished data).





Land use planners would probably prefer to have more discrete polygon maps (Figure 3a) from which to make decisions, than a more diffuse output (Figure 3b) that could be more open to interpretation. Nonetheless, nature is highly variable and the more generalized approach (Figure 3b) may more accurately portray the many potential pathways. Therefore, land use planners should be open to both approaches and the potential for not just one, but multiple potential habitat corridors, for their landscape plans.

The growth in approaches to mapping habitat connectivity and pieces of software to do so matches the complexity of the problem. The website "Corridor Design" not only offers its own software (CorridorDesigner), but provides background on habitat connectivity as well as links to numerous other sources of information and software (http://www.corridordesign.org/). Likewise there are numerous scientific publications e.g., (Urban and Keitt 2001, Carroll 2006, Compton et al. 2007, Beier et al. 2008, Beier et al. 2011) and several recent books (Crooks and Sanjayan 2006, Hilty et al. 2006).

All pieces of connectivity software use an input layer that represents landscape resistance. Resistance is the degree that any kind of land cover presents resistance to movement by organisms. Resistance is sometimes scaled to individual species or taxa based on known habitat requirements; this more often is the approach in very localized habitat connectivity mapping projects (e.g., the example above for corridors between two known patches), but sometimes is employed regionally for species with well-known movement parameters. More often however there is the attempt to create generalized resistance surfaces that might work for groups of organisms; such resistance layers are often derived from mapped indexes of land cover transformation by humans, and naturalness (see below).

Changing climate has spurred on research on how to connect natural areas for predicted range shifts. Given the difficulty in predicting current species distributions, that is compounded when trying to predict future species distributions by the coarse grain size and relatively great uncertainty of future climate models, habitat connectivity models that incorporate climate change have utilized a coarse filter approach (see below). In such approaches identifying linkages/corridors incorporating similar land forms (i.e., "land facets") selected from the underlying heterogeneity of landscapes is assumed to provide for smooth range shifts by species adapted for those conditions (Beier and Brost 2010, Nuñez 2011).

Key Resources for Understanding Habitat Connectivity:

Books:

Crooks, K. R. and M. Sanjayan, editors. 2006. Connectivity Conservation. Cambridge University Press, Cambridge, U.K.

Hilty, J. A., B. Z. Lidicker, and A. M. Merenlender, editors. 2006. Corridor Ecology: the Science and Practice of Linking Landscapes for Biodiversity Conservation. Island Press, Washington D.C.

Online:

Corridor Design http://www.corridordesign.org/

Circuitscape http://www.circuitscape.org/Circuitscape/Welcome.html

Selected Articles:

Beier, P., W. D. Spencer, R. F. Baldwin, and B. H. McRae. 2011. Toward best practices for developing regional connectivity maps. Conservation Biology **25**:879-892.

Carroll, C., B. H. McRae, and A. Brookes. 2011. Use of linkage mapping and centrality analysis across habitat gradients to conserve connectivity of gray wolf populations in Western North America. Conservation Biology **26**:78-87.

Theobald, D. M., S. E. Reed, K. Fields, and M. E. Soule. 2012. Connecting natural landscapes using a landscape permeability model to prioritize conservation activities in the United States. Conservation Letters **2012**:1-11.

Species Distributions and Viability

Accurate species distributions are one of the most fundamental and difficult to obtain sources of information, for conservation planning. Yet, if they exist, reliable species distribution models (SDMs) can form the basis of irreplaceability analyses that are integral to the selection of resilient systems of reserves (Trombulak 2010). Difficulties in producing accurate SDMs include sparse point locations for known locations, coarse environmental data, lack of information on confirmed absences, land use changes, and climate (Scott 2002, Mackenzie et al. 2006, Franklin 2009). Conservation planning has attempted to circumvent some of these problems by using "coarse-filter" approaches that assume relationships between underlying environmental variability and species diversity (Hunter 1991, Anderson and Ferree 2010).

Historically, SDMS were species range maps produced by experts examining field collections and conditions in which specimens were collected (e.g., habitat, elevation), and drawing potential range boundaries based on an extrapolation of those conditions (e.g., maps found in field guides). The current way of doing this is not very different, yet involves a number of approaches using mapping software. Maps of species distributions are products of a modeling process in which known locations are used to develop predictive models based on mapped environmental variables. The goal is to predict where species might occur, based on known conditions at known locations where they do occur. Approaches vary as to the degree of expert opinion involved, number and distribution of known species locations, information on absences, and use of environmental data (Franklin 2009). All SDMs are recognized as incomplete as they will likely change not only as environments change, but as more data are available to parameterize the models.

Accurate maps of species distributions can be integral to conservation planning. For instance one goal of reserve selection is to represent regional species diversity in a set of reserves. Software like Marxan can use mapped species distributions as targets in the conservation scenarios. Endangered Species conservation is a particularly compelling case for accurate mapped species distributions.

Recently in conservation planning there has emerged the idea that the underlying diversity of land forms, elevation, and soils may be used as a surrogate for species distributions. Such "coarse filter" approaches may be particularly useful in two situations 1) at very large spatial extents, and 2) in times of rapid environmental change. Bioclimatic envelope modeling for species distributions helps to understand how change may influence specific biotic communities, and can be included in conservation plans, yetis subject to a great deal of uncertainty(Lawler et al. 2009, Seo et al. 2009). Coarse filter approaches recognize uncertainty and make as a goal overall conservation of diversity without as much regard to species or current assemblages.

For single species management (e.g., under the Endangered Species Act) the gold standard of prediction is accurate population viability models. Such models rely upon demographic data that is difficult, time consuming, and expensive to obtain. Nonetheless if demographic data can be obtained for habitat areas, maps can be produced for predicted population viability under alternative management/conservation scenarios(Akcakaya et al. 2004). For conservation planning it can be particularly powerful to understand the influence of habitat connectivity, reserve size and shape, and various management scenarios on long-term viability of populations. For example, the restoration of populations of large carnivores, which has umbrella effects for other species, is a case where population viability modeling has helped to identify areas important for connectivity and core habitat (Carroll et al. 2003, Carroll 2006, 2007, Carroll et al. 2011). The Joint Venture partnerships utilize population-habitat-area relationships in their conservation plans (e.g., http://www.chjv.org/).

Key Resources for Understanding Species Distributions and Viability:

Books:

Akcakaya, H. R., M. Burgman, O. Kindvall, C. Wood, P. Sjogren-Gulve, J. S. Hatfield, and M. A. McCarthy, editors. 2004. Species Conservation and Management: Case Studies for RAMAS GIS. Oxford University Press, Oxford, U.K.

Franklin, J. 2009. Mapping Species Distributions: Spatial Inference and Prediction.Cambridge University Press, Cambridge, UK.

Online:

Maxent software for species habitat modeling http://www.cs.princeton.edu/~schapire/maxent/

AMNH Species distribution modeling courses and background information

http://biodiversityinformatics.amnh.org/index.php?section_id=82&content_id=140

Selected Articles:

Carroll, C., R. F. Noss, P. C. Paquet, and N. H. Schumaker. 2003. Use of population viability analysis and reserve selection algorithms in regional conservation plans. Ecological Applications **13**:1771-1789.

Elith, J., S. J. Phillips, T. Hastie, M. Dudik, Y. E. Chee, and C. J. Yates. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions:43-57.

Threats (Buildouts and Naturalness)

Conservation planning anticipates threats to biodiversity and to prioritize conservation actions based on how vulnerable sites are to threats (Abbitt et al. 2000, Lawler et al. 2003, Theobald 2003). Generally speaking, threats are human activities that have a negative impact on conservation goals. Not all threats to biodiversity are anthropogenic, and not all anthropogenic activities are threats (some things people do enhance diversity)(Baldwin 2010). Conservation planning seeks to identify, understand, and map the distribution of activities that are known to threaten diversity and function of ecosystems. Such threats include: human population density, housing density, roads, road traffic, gas and oil development, some forestry and agricultural methods. Fire suppression, flood control, and other activities to control ecological process have also been considered threats (van Lear and Waldrop 1989, Rood et al. 2005, Noss et al. 2006).

Modeling land use change has been a productive area of conservation planning research. There is a large amount of evidence that of all the influences on biodiversity, land use change is the most proximate and severe threat, resulting in habitat degradation, loss, and fragmentation (Tilman et al. 1994, Vitousek et al. 1997, Harding et al. 1998). The ability to develop predictive maps of land use change and loss of naturalness in the landscape has increased rapidly over the past decade, and they have been used prioritize landscapes for conservation action (Trombulak et al. 2008).

Key Resources for Understanding Mapping of Threats:

Books:

Turner, M. G., R. H. Gardner, and R. V. O'Neill. 2001. Landscape Ecology in Theory and Practice. Springer-Verlag, New York.

Online:

Stein, S. M., R. E. McRoberts, R. J. Alig, M. D. Nelson, D. M. Theobald, M. Eley, M. Dechter, and M. Carr. 2005. Forests on the edge: housing development on America's private forests. Gen. Tech. Rep. PNW-GTR-636, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.http://www.fs.fed.us/openspace/fote/

Landscape Change Program, USFS North Central Research Station http://ncrs.fs.fed.us/4153/deltaIMS/

Selected Articles:

Baldwin, R. F. and P. G. deMaynadier. 2009. Assessing threats to pool-breeding amphibian habitat in an urbanizing landscape. Biological Conservation **142**:1628-1638.

Sanderson, E. W., M. Jaiteh, M. A. Levy, K. H. Redford, A. V. Wannebo, and G. Woolmer. 2002. The human footprint and the last of the wild. Bioscience **52**:891-904.

Theobald, D. M. 2003. Targeting conservation action through assessment of protection and exurban threats. Conservation Biology **17**:1624-1637.

Climate

The scientific community has strongly communicated the need to understand human actions in the context of rapid, current and future climate change (Dale 1997, Walther et al. 2002, Thomas et al. 2004). Conservation planning seeks to integrate climate change, and as such is considered a “climate adaptation” strategy (Girvetz et al. 2009, Nuñez 2011). Large, interconnected areas of high naturalness are more likely to provide climate corridors to accommodate range shifts, than many, smaller, fragmented areas, and will likely also sequester carbon, mitigate effects of drought, flood, and storm events (Dale 1997, Vorosmarty et al. 2000, Hilty et al. 2012). While a great deal of uncertainty exists as to how many areas and ecosystems will be influenced by climate, climate change has changed the context of conservation planning.

Conservation planning that integrates climate change addresses the problem of interacting stressors and how they are likely to influence the resilience of systems, including the ability of species to shift their ranges given land use change and habitat fragmentation. During past climate change events species’ ranges shifted; that is the history of the Earth (Davis et al. 1980). Under the situation we currently face, habitat fragmentation due to roads, agriculture, and other land uses threatens the ability of species to shift their ranges (Heller and Zavaleta 2009). In response conservation planners have developed various approaches to develop “climate corridors” (Beier and Brost 2010, Nuñez 2011). Climate corridors attempt to “string together” landscape elements that will provide a smooth transition for populations that are migrating over time, in response to climate.

As mentioned earlier under “Species Distributions and Viability”, a “coarse-filter” approach to conservation planning seeks to conserve enough area with enough underlying diversity of land forms, soils, and topographic features that would become the “arena” for future evolution. New communities will assemble over time as ambient conditions change. Modeling approaches represent the diversity of Ecological Land Units (ELUs), in addition to or instead of species ranges in conservation plans (Anderson et al. 2006, Anderson and Ferree 2010).

Key Resources for Climate and Conservation Planning:

Books:

Hilty, J. A., C. C. Chester, and M. S. Cross, editors. 2012. Climate and Conservation: Landscape and Seascape Science, Planning, and Action. Island Press, Washington D.C.

Online:

Climate Wizard http://www.climatewizard.org/

Climate and conservation http://www.conservation.org/learn/climate/Pages/climate_overview.aspx

Climate change and landscapes http://www.wcs.org/conservation-challenges/climate-change.aspx

Selected Articles:

Bierwagen, B. G., D. M. Theobald, C. R. Pyke, A. Choate, P. Groth, J. V. Thomas, and P. Morefield. 2010. National housing and impervious surface scenarios for integrated climate impact assessments. PNAS **107**:20887-20892.

Girvetz, E. H., C. Zganjar, G. T. Raber, E. P. Maurer, P. Kareiva, and J. J. Lawler. 2009. Applied climate-change analysis: The Climate Wizard Tool. PloS ONE **4**:e8320. doi:8310.1371/journal.pone.0008320.

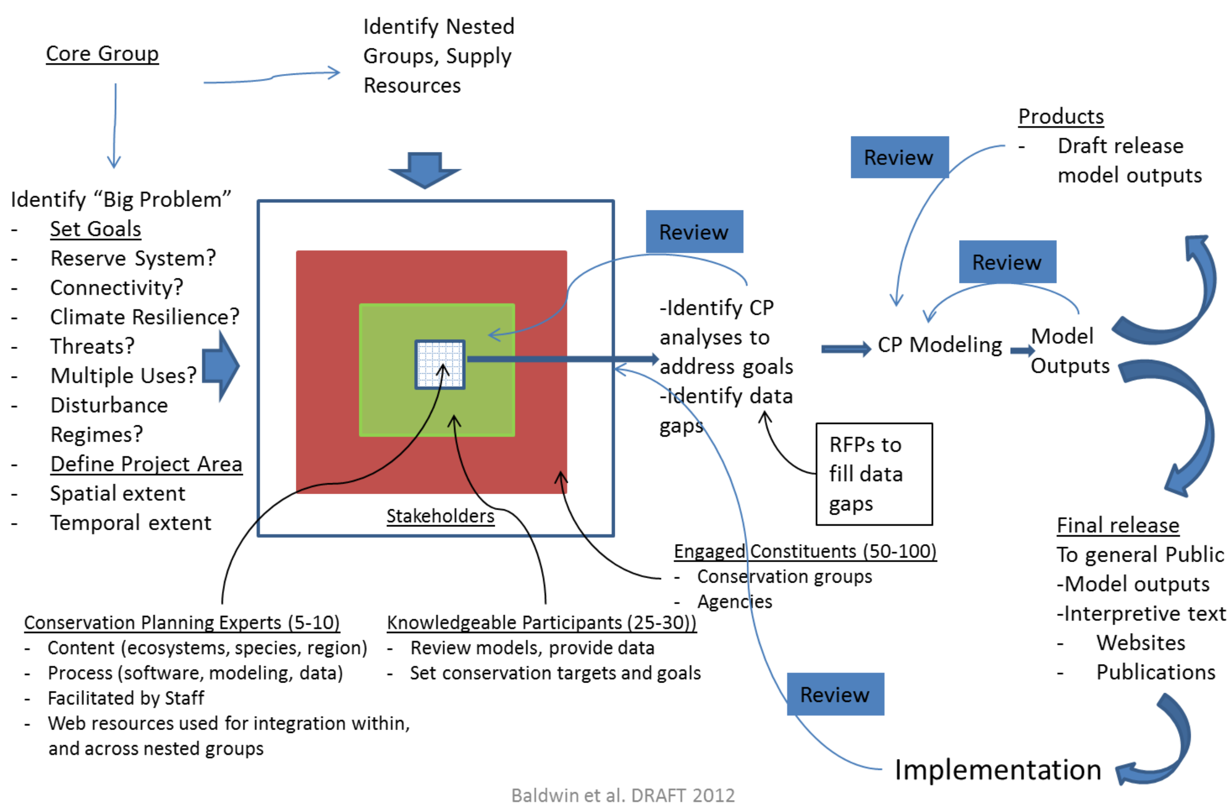
Hannah, L., G. F. Midgley, T. Lovejoy, W. J. Bond, M. Bush, J. C. Lovett, D. Scott, and F. I. Woodward. 2002. Conservation of biodiversity in a changing climate. Conservation Biology **16**:264-268.

Integrative Planning

Conservation planning cannot succeed as an academic project alone; doing research and publishing papers is the basis for systematic conservation planning but most of the people involved with making plans work will not read those papers, and are more concerned with social context(Jacobson and Duff 1998). If those “stakeholders” are engaged in the conservation planning process from the beginning, they will be more likely to understand and implement plans. For conservation planning, integration of people throughout the scientific planning process and including feedback loops from stakeholders after implementation is what distinguishes the field as something that is not a purely academic exercise.

The process of conservation planning explicitly integrates people throughout. Ideally this occurs in nested groups with those with more engagement and expertise closer to the modeling effort, and those more interested in application/implementation further removed yet fully informed (Beier et al. 2011). A core group of conservation planning experts conducts modeling exercises informed by larger groups. Feedback loops at every stage of the project are essential for insuring that the planning products make sense to stakeholders. Following implementation, monitoring for success and more review occurs (Figure 4).

Figure 4. Flow of steps and feedback loops involving nested groups of participants in a conservation planning process.



Expert input and review is often part of conservation planning processes (Noss et al. 2002, Trombulak et al. 2008, Beier et al. 2011). In the past expert review was kept more or less as a black box. There is evidence that "unpacking" the box of expert review and treating that input as qualitative data improves the conservation planning process by making decisions about modeling more transparent and thus more amenable to wider groups of stakeholders and implementation (Beazley et al. 2010).

Adaptive Approach to Conservation Planning

Conservation planning can be considered in an adaptive management context. Maps and models are subject to repeated review by nested groups of stakeholders. Feedback from monitoring and new data become integrated into new rounds of modeling; such an iterative process is thought to engage stakeholders and lead to longer term success (Margoluis and Salafsky 1998, Knight et al. 2009).

Because conservation planning involves multiple scales and thus levels of governance, attempts to model complex biological systems and often predict the future, relies upon experts for model input and review, it rapidly becomes a complex social process. The decisions may be science-driven, but the process of making decisions based on maps and models and other research implies an organizational structure that is managed. Specific measures of success are identified (e.g., population targets, areas conserved), and monitoring assesses to what degree goals are met.

Evaluation of Conservation Planning Software for use by the Appalachian LCC

Conservation software provides tools for support of specific situations (see table one.). Many of these programs are written to assist with problems commonly encountered in planning conservation strategies and activities for an area. Some deal with specific facets of conservation issues, like habitat analysis, population assessment, or land use planning. These were written to deal with specific elements or targets in conservation planning and are considered to be modeling tools. Most are based on land cover and land use datasets with some attributes added to give more detail that might allow translating into habitat or ecosystem niches. The land class or interpreted data is often imported to the modeling software and then new attribute values (like weights) are added or calculated to make the program work. For example land cover is easily assigned habitat value (for any target species) if one knows its size and position both in the terrain and relative to other features on the surface of the earth. Most conservation software programs cannot be used in all situations to solve all conservation issues in a project area. Often a project will require using several programs as tools working independently, but used in combination. However, there are a few that are written or, have been adapted, to manage the whole conservation planning process while allowing incorporation of some of the others as tools.

This gives rise to the idea that these tools might need to be used in some particular order to plan regional or sub-regional conservation. For example reserve selection software cannot be used until the conservation goals and targets have been decided and connectivity requires that the larger reserves have been designated. Also, habitat interpretations only occur after target species have been decided. So, the first software to be considered for any area is the one that helps frame and give direction to the use of the others. In table 1 these programs are listed under "planning process integration" and for purposes of our discussion will include Miradi, NatureServe Vista, and CommunityViz. All three of these have been used separately to structure large conservation planning projects.

Miradi

<u>Description of the program</u>: Miradi is based on the 'Open Standards for the Practice of Conservation' published in 2007 (Version 2; there is now a version 3, published in 2013). Miradi is one of the few holistic approaches to conservation planning that is generic enough to help organize and manage entire projects. CAP's Open Standards are a project management framework specifically tailored to be applied to a broad range of conservation projects. Because it is independent of sites and frames a process that is not tied to any one project, it can be used in any conservation planning project. Miradi programs this framework to standardize the management of any conservation project.

Miradi uses the following, loosely paraphrased (by me), steps found in the "Open Standards" framework:

1. Identify the conservation elements or targets that are important (**Identify elements**).
2. Assess the targets for location, quantity, quality, and threats (**Assess targets**).
3. Evaluate them against the project plan and objectives to set goals (**Identify Conflicts**).
4. Develop conservation strategies to best resolve conflicts and meet goals (**Set goals**).
5. Develop a plan of action to accomplish the conservation goals (**Plan actions**).

6. Provide some way to evaluate the success of the plan of action (**Monitor & Evaluate**).

7. Be prepared to repeat the process frequently to accommodate new changes or adjust for failures resulting from the original plan (**Adjust actions**).

Miradi's graphic user interface (GUI) looks like a cross between "TurboTax" and a graphic modeling tool and is fairly user friendly. It does not use GIS layer information directly, work in a GIS environment, or link to a GIS program. Because it implements the Open Standards framework, Miradi gives support to holistic planning, management, and monitoring of conservation projects, leaving the resolution of specific issues with specific elements to expert and stake holder opinion. It does not use other modeling tools directly, but allows them to be used as independent support of planning steps. Therefore like the Open Standards framework, Miradi is not a site specific program, however, the projects it is used to plan and manage are all site specific and all its steps require that the project area be decided before planning begins. Then each step can be decide by the stakeholder group with or without the support of other modeling software, however conservation planning models are specifically designed to support decision making actions like these.

Relevance to AppLCC: Miradi has built in helps (from the open conservation framework) that could be used to give structure to and support conservation planning at the overall Appalachian LCC level. It might also provide structure to planning projects for sub regions of the Appalachian LCC area. While direct inputs are all interactive with the program, land cover, terrain, and environmental can be used independently and in combination with other tools to support decision making in answering the direct inputs required by this program. These data layers are in our collection of datasets for the Appalachian LCC area.

VISTA

Description of the program: VISTA started as a support tool for land use planning, that would give due consideration to conservation elements of interest and help reconcile their needs with other land uses by identifying conflicts and offering alternatives. It is supported by NatureServe and its later versions are envisioned as a toolkit framework that can incorporate the other conservation planning programs as part of an adaptive management process. However, the toolkit envisioned is more like a confederation than a unified box of tools that support an entire conservation planning process in a single working environment. Even though some other conservation programs do not run in the same GIS environment, they are viewed as support tools with results that can feed VISTA's decision support process. For example, VISTA can create output to be used in MARXAN and can also import results from MARXAN to support suggested solution alternatives. Other conservation programs are incorporated into VISTA's adaptive management process as "Development Planning" tools, "Planning Process" tools, "Data and Modeling" tools, and "Conservation and Mitigation" tools. FromTable 1, VISTA would include 'Community VIZ' and 'Urban Sim' in the development planning category. 'Miradi' is listed as planning process; "Marxan", "Marxan with Zones, and "Zonation" are in the conservation and mitigation category and most other programs are in the data and modeling category. So after the conservation elements of importance have been decided, and after they have been assigned their levels of importance, prioritized and evaluated with the support of the appropriate tools, VISTA can help you identify conflicts in the landscape and by "out-sourcing" to optimization software (like MARXAN) help formulate policy to reconcile those conflicts with project goals. Monitoring and adjusting plans are added to make the adaptive process complete.

So, it's possible to envision VISTA as a toolkit to support MIRADI's open framework process, or to see MIRADI as a "Planning Process" tool to support VISTA's adaptive process. In either program the Appalachian LCC stakeholders with support from experts would have to decide targets, weights of targets, and cost among other values to input. NatureServe provides direct support for the VISTA program.

Relevance to AppLCC: Land cover is the main input dataset for VISTA. Land cover with interpretative factors of the different focal species and estimates of change in the land cover or land use. Other data is required, most as spatial data layers about the elements of interest chosen to represent the project area. These may include species distribution, required habitat, and other biological and ecological system layers. In addition to the conservation databases including element goals, you will need a vector or raster GIS layer of the project area that indicates different land uses as separate features which are identified in an associated database (or separate layers for each land use). These additional layer are not in our dataset collection, but can be derived from them using some of the other conservation planning programs.

CommunityViz

Description of the program: CommunityViz planning software is an extension for ArcGIS Desktop. As a GIS-based decision-support tool, it demonstrates the implications of different plans and choices. It supports scenario planning, sketch planning, 3-D visualization, suitability analysis, impact assessment, growth modeling and other techniques. While CommunityViz may be most suitable to localized planning, it has been used for state wide resource analysis and to get a vision of the future for a region under a "business as usual" assumption that gives planners an opportunity to target where change might do the most good.

Because it runs in a GIS environment, CommunityViz, unlike the other project programs, can incorporate numerous data layers that might include the entire infrastructure of a region. Also it has a number of built in tools to assist with viewing alternative scenarios. The alternatives can be based on the built in tools or on user built tools and equations. This makes it a powerful tool for getting a vision of impacts caused by planned changes or that result from natural changes, like climate change. In addition CommunityViz has the visualization tools to communicate the need for change or additional funding.

Relevance to AppLCC: The input datasets for CommunityViz include all of the datasets in our collection plus more with data about infrastructure like roads, transmission right of ways and anything else that occupies a significant area of the surface of the earth in the project area and might influence the focal species. This program might also use some of the data layers interpreted or developed by other conservation planning programs. In addition it requires inputs about planned changes, like development areas or energy farms that might impact the future of the project area.

The Appalachian LCC could use CommunityViz as a data repository for conservation resources and planning throughout the region. By doing this they would eventually build a complete set of infrastructure layers that could be used to both evaluate alternative scenarios in their region and provide data for other conservation software programs. While CommunityViz does not have the conservation planning structure of the other two programs discussed, it supports decision making within such planning environments.

Reserve Planning Software

Description of the program: Optimization programs, like MARXAN combined with a GIS environment (raster), or Zonation, with its prioritization of theme layers (large scale raster layers), attempt to minimize cost while maximizing biodiversity. Both of these programs were originally written using metallurgy equations to select the best blend of species diversity and cost. They have been expanded to handle multiple layers and zones to prioritize suggested solutions from best to worst (MARXAN with Zones; Zonation). They require expert input about species presence (based on sampling or best estimates) and reliable input data about cost. Cost in these models are not necessarily defined in terms of money, but may refer to tradeoffs in ecosystem services. They require that each of these data inputs and each land use be in separate raster layers for analysis. Zonation has been extended to allow input of point observation data and include analysis of connectivity and edge effects. Our list of optimization programs is not complete, it has only the most well known ones at this time. There is a fairly new program called 'InVest' that is designed to use GIS (raster layers) to investigate ecosystem benefit tradeoffs. This program is designed to give insight to what is lost or gained by changes to one ecosystem element in terms of the other benefits produced by that same ecosystem. With additional learning and data, this program can also offer decision support for proposed actions and help explore alternatives toward achieving project goals.

Relevance to AppLCC: While these programs may be used abstractly to support decisions about levels of protection, zoning regulations, minimizing economic losses to stake holders, they were designed to select areas for the protection of target species. They support the selection of areas large enough to perpetuate target species and maintain biodiversity while minimizing losses (coarse filter) can be done with existing data, but no fine filter approach can be undertaken until target species have been selected and existing protected areas have been evaluated. The Appalachian LCC might use one of these software programs at the LCC region level or to evaluate alternatives at some sub regional level for a specific project with already defined goals.

The grid layers for defining the input data to these programs are usually developed in ArcGIS as raster data and then exported as ASCII grid datasets. There have to be ASCII grid data layers for land cover, cost, and zones, because these are required inputs. There may also be layers for ground sample data. Output data are graphs that can be interpreted into ASCII grid layers and imported back into ArcGIS to aide in the visualization process. Usually repeated runs are necessary to evaluate alternative scenarios. Of the required direct input data, only land cover is currently in our data collection for the Appalachian LCC.

Connectivity Programs

Description of the program: Here, we present evaluations of three connectivity programs: circuitscape, corridor designer, and linkage-mapper. There are several others in our table (1) that appear to be out of date and several new programs and tool kits that focus on more then just connectivity alone and may add some functionality to these three (CAT, CONEFOR SENSINODE, CONNECT, AND UNICOR).

There are several different approaches to the application of connectivity software. The first assumes there are large patches of suitable protected habitat for a given focal species and that the objective is to connect them. The second is a more general approach to analyzing the landscape to develop a sustainable network of habitat corridors with the objective of maintaining a focal species with greatest biodiversity. Third a combination of these two can be used to develop and maintain a diversity of habitat to sustain multiple focal species in a larger region.

Circuitscape

Circuitscape is a stand-alone python program that models ecological connectivity across landscape networks. Circuitscape was developed to apply (electric) circuit theory to problems in landscape ecology. For a given species it is supposed to identify connectors between habitat patches and give a probability that animals (or other things) use that path or do not use it. It is also used to identify 'choke' points in the connecting network.

It uses maps of habitat in ASCII grid format that can be exported from raster maps used or created in ArcGIS. Maps that have been reclassified to reflect conductance or resistance based on the original habitat types. Also another map (optional) that defines regions or patches of very high quality habitat for grouping. The GUI prompts for additional information like whether or not the input grid contain resistance or conductance values.

In the Appalachian LCC area or a sub-area, once focal species and goals have been decided, Circuitscape might be useful as one of several tools to evaluate connectivity between protected areas. While Circuitscape identifies multiple pathways to connect larger patches, other software might be more useful in identifying robust networks and maintaining them.

<u>Relevance to AppLCC</u>: The input data sets for Circuitscape do not exists in their proper format for the Appalachian LCC area. They will have to be developed for each target species selected based on published information, expert opinion, and stakeholder input. This data usually comes from interpretation of the land cover data combined with surface location and other influences thought to be important. The land cover data and terrain data are in our datasets for the Appalachian LCC area.

Corridor designer

<u>Description of the program</u>: Corridor designer is a toolkit that works within the ArcGIS environment. Corridor designer classifies habitat suitability for a target species into population habitat, breeding habitat, or habitat patches. It then calculates best connecting routes, and identifies barriers and bottlenecks. It attempts to connect breeding habitat patches with each other, but can also connect habitat patches.

This program uses raster analysis and reclassification to identify suitable habitat for the target species. It then groups those areas into patches and evaluates their suitability for population, breeding, or just suitable habitat patches based on size and other parameters. It then attempts to classify links of usable habitat between the major habitat patches, giving first priority to linking breeding habitat patches. In calculating and evaluating possible linkages, bottlenecks and barriers might be identified.

<u>Relevance to AppLCC</u>: Initial inputs for Corridor designer are land cover, Dem, roads, and text files with reclassification information. Land cover and DEM datasets for the whole Appalachian LCC area are included in our collection of data. Road data changes frequently, and is not currently in our data collection. The reclassification tables are developed independently for each focal species/project area and do not exists at this time. Additional input data for Corridor Designer are developed by the program tool from these initial inputs.

Linkage-mapper

Description of the program: Linkage-mapper is a GIS tool designed to support regional wildlife habitat connectivity analyses. It consists of several Python scripts, packaged as an ArcGIS toolbox, that automate mapping of wildlife habitat corridors. It uses GIS maps of core habitat areas and resistances to identify and map linkages between core areas. Each cell in a resistance map is attributed with a value reflecting the energetic cost, difficulty, or mortality risk of moving across that cell. Resistance values are typically determined by cell characteristics, such as land cover or housing density, combined with species-specific landscape resistance models. As animals move away from specific core areas, cost-weighted distance analyses produce maps of total movement resistance accumulated.

Linkage-mapper tools can identify adjacent (neighboring) core areas and create maps of least-cost corridors between them. It then mosaics the individual corridors to create a single composite corridor map. The result shows the relative value of each grid cell in providing connectivity between core areas, allowing users to identify which routes encounter more or fewer features that facilitate or impede movement between core areas. Linkage Mapper also produces vector layers that can be queried for corridor statistics.

Relevance to AppLCC: The latest version of Linkage-mapper uses several other programs in its toolbox to make it more robust than the above programs. For example, it uses Circuitscape to help identify bottlenecks; Centrality Mapper to derive corridor centrality; Barrier Mapper to detect important barriers; and Climate Linkage Mapper to identify corridor shifts due to climate change. This program requires input data similar to the two previously discussed. As before, land cover and terrain data (DEM) are in our datasets, but roads are not and the reclass tables do not yet exists for the Appalachian LCC area.

The use of Linkage-mapper in the Appalachian LCC area will require a great deal of research and thought put into the interpretation and creation of data layers for the project area. However, this program expands the ability of the previously discussed connectivity programs when linkage is an apparent or pre-decided goal.

Overall comments connectivity analysis: For most connectivity programs described above, we have the basic layers (land cover, DEM for entire AppLCC), to undertake a structural (coarse filter approach). In our current dataset, we lack data on road network and permeability/traffic on these roads. Resistance maps will have to be developed for each species on a case by case basis, and this can be done when a suite of species have been selected. It is important to note that a number of new connectivity approaches are evolving now, including the resilient landscapes/resistant kernel approach being applied by The Nature Conservancy. Connectivity is an ever-moving target and an area of rich development at the moment. Resistant surfaces that were once static now have the option of being considered dynamic (see NALCC LCAD work).

Species Distribution Modeling

Species distribution models can help identify and prepare data layers for input to some of the above programs. They include programs to estimate the presence, absence, or distribution of a target species. They may also be used to evaluate the viability of a target species' population. Others may use existing data to build a history of a population's existence and distribution. And others may assist in translating land cover into habitat maps for target species. All of the programs have use during the process of building data layers of the input rasters for many of the reserve location and connectivity programs. They might also be of use in evaluating which species to target in conservation planning.

Maxent

Description of the program: Maxent uses environmental layers key to the existence of a specie along with known location of the species to predict where the target species might exists. This program breaks down the range of a focal species to identify where that species might exist based on the environmental characteristics (temperature, precipitation, aspect, and so on) where it is already known to exist. In other words, it attempts to identify its niches. The frequency and geographical distribution of these niches may also give some insight to its survivability under current conditions. This, in turn, could provide a starting point of evaluating the impact of any proposed changes in the quantity and/or quality of the target species' niches.

Relevance to AppLCC: This program could be used by the Appalachian LCC as a tool to evaluate the current state of a potential target species and do risk assessment to its niches and thus its future existence. It supports decision making in choosing target species and in evaluating activity impacts later on. Because of urban growth in such a large area this type of evaluation may need to be repeated frequently.

The inputs for these evaluations are the environmental datasets and terrain data. Temperature and precipitation are in our collection of datasets. Land cover is also in this collection, but slope location, aspect and other terrain data will have to be developed from the digital elevation model (DEM) that is in the data collection for the entire Appalachian LCC area.

RAMAS GIS

Description of the program: RAMAS GIS is a "stand alone" program with several tools to assist in building metapopulations of a species, building time change maps, assessing ecological risk and/or risk of extinction for the focal species. It runs independently, but the input data is ASCII grid layers like those used in other models. In addition, it is a user interactive program, requiring the user to have expert knowledge about the species of interest and its habitat requirements. RAMAS GIS, like maxent, can be useful in evaluating potential target species and identifying the locations of their habitat.

Relevance to AppLCC: The input datasets are specific for each focal species and project area combination. They do not exist for the Appalachian LCC area at this time. Some of these raster data can be developed in a GIS program and exported to the ASCII grid format required for input to this GIS program. RAMAS GIS contains tools to develop the other layers required. The same land cover, terrain, and environmental used above and in our data collection are the layers necessary to build these inputs.

Conclusions

The current state of programs (tools) for conservation planning is that there are numerous disjunctive programs that are designed to assist with different facets of conservation planning. The number of modeling tools is growing rapidly, but each new tool seems to operate in its own working environment and be aimed at an isolated problem identified by the authors. While a few claim to have evolved into programs to deal with the whole process, none really do that in a convenient manner in a single working environment. GIS appears to be the most used and convenient working environment for planning and resolving conservation issues. Since each of these tools requires massive amounts of work and comes from different parts of the world, the current approach is to try to patch the different programs together to support as much of the whole conservation planning process as possible. We have attempted to demonstrate that the whole process is not currently supported.

We have discussed and listed what conservation tools presently exist. We tried to give some insight as to how they work, what datasets might be needed and how each might be used to support the conservation planning process. We have attempted to point out where each tool might be used in conservation planning for the Appalachian LCC and that there are no tools to automate the entire process of conservation planning for the Appalachain LCC, nor for any other defined project area. Before any of these tools can help, there needs to be a vision of what needs to be accomplished including some idea of what need to be adjusted (fixed) and some goals to go with that vision. Then it is necessary to select some target species that are true indicators of those problems and can be used to measure the current state of affairs and the progress of planned activities; be it positive or negative.

In all cases, conservation planning is for a single defined project area on the surface of the earth and each project is site and resource specific. Also, each project is independent of others and has a different set of stake holders with different interest. It appears that what is needed is a set of tools to choose from that can deal with all these different situations and, at the same time, work together and trade data for more or less seamless analysis and planning.

Key Resources for Understanding Integrative Planning:

Books:

Margoluis, R. A. and N. N. Salafsky. 1998. Designing, Managing, and Monitoring Conservation and Development Projects. Island Press, Washington D.C.

Trombulak, S. C. and R. F. Baldwin, editors. 2010. Landscape-scale Conservation Planning. Springer-Verlag, New York.

Online:

Miradi software for conservation decision support https://miradi.org/

NatureServe Vista software for conservation decision support http://www.natureserve.org/prodServices/vista/overview.jsp

California Essential Habitat Connectivity Projecthttp://www.dfg.ca.gov/habcon/connectivity/

Selected Articles:

Knight, A. T., R. M. Cowling, H. P. Possingham, and K. A. Wilson. 2009. From theory to practice: designing and situating spatial prioritization approaches to better implement conservation action. Pages 249-259 *in* A. Moilanen, K. A. Wilson, and H. P. Possingham, editors. Spatial Conservation Prioritization: Quantitative Methods and Computational Tools. Oxford University Press, Oxford, UK.

Stem, C., R. A. Margoluis, N. N. Salafsky, and M. Brown. 2005. Monitoring and evaluation in conservation: a review of trends and approaches. Conservation Biology **19**:295-309.

Theobald, D. M., T. Spies, J. D. Kline, B. Maxwell, N. T. Hobbs, and V. H. Dale. 2005. Ecological support for rural land-use planning. Ecological Applications **15**:1906-1914.