TECHNICAL MANUAL 6

September 2006

Building Biological and Threats Landscapes from ecological first principles, a step-by-step approach

Planning for successful conservation projects

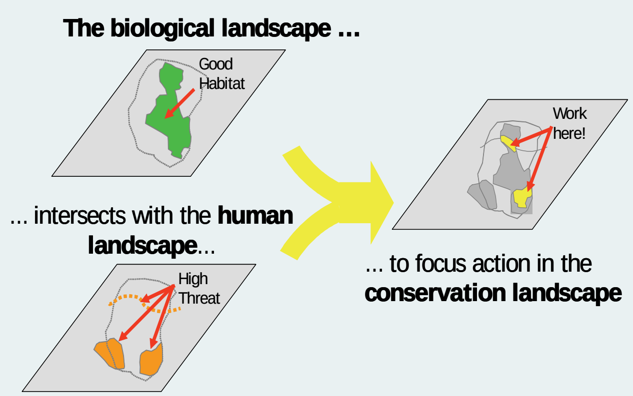
Effective wildlife conservation requires that we consider the complex mix of biological, social and economic factors that influence the ecological integrity of landscapes, and then focus our conservation efforts on activities that will have the most positive impact on wildlife populations and their habitat. This requires that we clearly understand the ecological needs of species and the human activities that impinge on them.

The Landscape Species Approach (LSA), developed by WCS' Living Landscapes Program, provides the coherent framework and practical tools needed to guide site-based conservation based on the needs of wildlife within large landscapes of human influence (Sanderson et al. 2002). This step-by-step process for planning and implementing conservation actions includes: (1) conceptual models for clearly defining a program's goals and objectives, (*see LLP Technical Manual 2*), (2) a participatory approach for prioritizing and mapping human activities that threaten landscapes and the wildlife within them (*see LLP Technical Manual 1*), (3) an objective and transparent process for selecting a complementary suite of target species that, if conserved, will help protect all biodiversity under their collective conservation canopy (i.e., Landscape Species; see Coppolillo et al. 2004 and *LLP Technical Manual 5*), (4) procedures for mapping habitat quality of Landscape Species and the impacts of human-caused threats on habitat, (5) guidelines for creating a "Conservation Landscape" to focus conservation activities in space, (6) a participatory process for prioritizing and strategically planning interventions, and (7) guidelines for developing effective monitoring frameworks (*see LLP Technical Manual 3*).

This manual is a guide for building Biological and Threat Landscapes (Step 4 above). Though the principles presented should interest all practitioners, their utility is greatly enhanced if you have: (1) read the descriptions of the LSA (available by email: conservationsupport@wcs.org) and (2) selected Landscape Species and identified the critical human activities threatening wildlife in your landscape (Steps 2 & 3 above).

Now you have the daunting task of creating Biological and Threat Landscapes, with three immediate objectives: (1) to show where the best habitat is for each Landscape Species; (2) to show where the important human-caused threats are occurring and how strongly they impact the species; and (3) to use the Biological and Threats Landscapes to create a Conservation Landscape—a spatially explicit map of your conservation priorities (*see Figure 1*). For now, we will focus on building the Biological and Threat Landscapes. The guidelines for creating Conservation Landscapes, setting population targets, and directing interventions will be detailed in our future technical manuals and bulletins.

Figure 1. The original conceptual overlay of the biological and human landscapes.

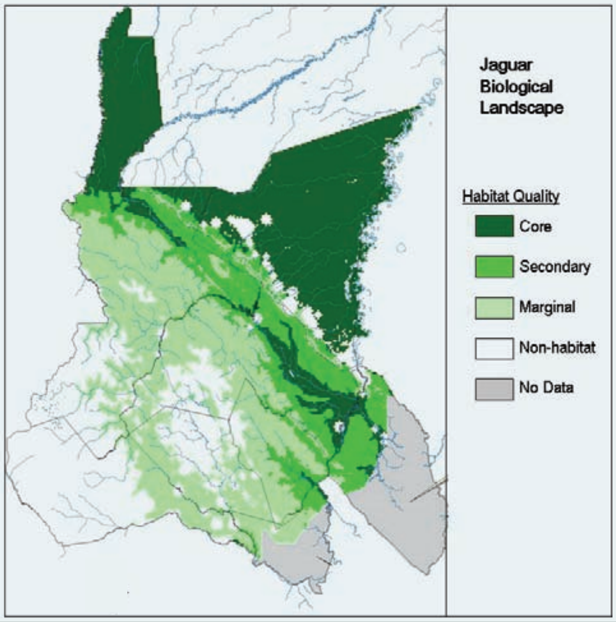


Part I. Overview

What are Biological Landscapes?

Biological Landscapes are maps of the distribution of Landscapes Species (conservation targets). They are typically maps of "habitat quality"[1] , indicating the capacity of areas to support a species throughout its life cycle.

Figure 2. A classic Biological Landscape, showing potential habitat quality for jaguars in the Madidi Landscape, Bolivia.



These maps of habitat quality are intended to reflect animal abundances on the ground—areas with high habitat quality will have high abundances, and areas with low quality will have low abundances. However, keep in mind that even an accurate map of "habitat quality" may not reflect actual animal abundances on the ground. For example, high quality habitat that theoretically can support lots of animals may in reality have very few animals. Two very common reasons for this are "source-sink dynamics" and "time lags" (***see Lessons Learned 1***).

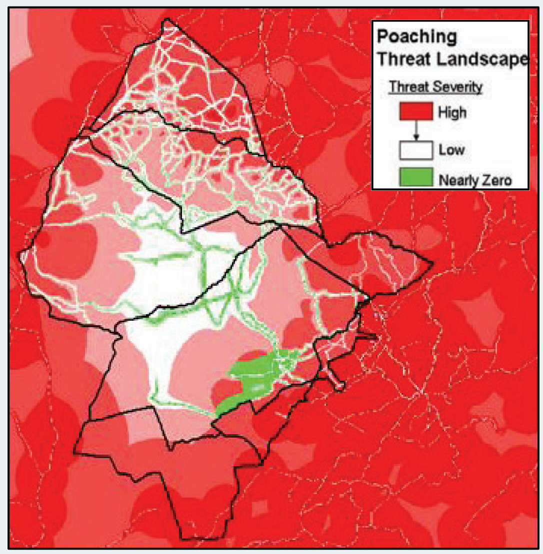
Although the typical version of the Biological Landscapes is a map of the "potential" distribution of the species in the absence of human-caused threats (***see Figure 2***), many sites have found it useful to make several versions of these distribution maps, including "current" and "future" species distribution (***see Lessons Learned 3***).

[1] Note, some people prefer other similar terms and concepts, including "habitat effectiveness", "habitat suitability", "habitat capacity", etc. We recommend not getting to hung up on terminology.

What are Threat Landscapes ?

Threat Landscapes are maps of the distribution of human activities that affect Landscape Species. Typically, we first make maps of threats independently of how they impact any particular species—representing the relative "severity" of the threat from place to place. Later, we translate these general "severity" maps into maps for particular species, making maps of relative "impact" (e.g., poaching has a big impact on elephants, but not on songbirds). In most cases, the spatial pattern of a threats' impact is pretty much the same for all species (e.g., the "bad" and "good" areas are the same for all species). For some threats, however, it is necessary to make a completely different maps for each species (e.g., for elephants, hunting pressure may be bad in one place, while for all other species, it's bad somewhere else).

Figure 3. A classic Threat Landscape, showing poaching patterns in the Rungwa-Ruaha Landscape, Tanzania.

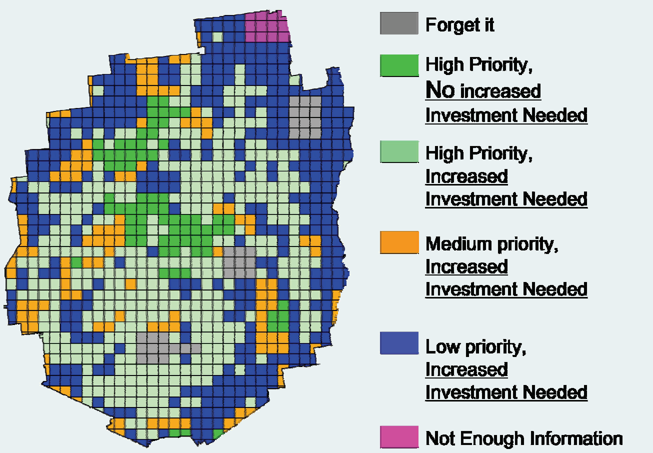


As Biological Landscapes reflect patterns in animal abundance, Threat Landscapes hopefully reflect patterns in how threats *reduce* animal abundances. In other words, areas with high threat have had or will have relatively large decreases in abundance, and areas with low threat have had or will have small decreases. However, again remember that threat severity on the map may not reflect actual decreases in abundances on the ground. For example, places that have low threat may see large decreases in abundance because of a threat occurring in another place. The same problems with "source-sink dynamics" and "time lags" occur when building Threat Landscapes (***see Lessons Learned 1***). Some sites have distinguished "Past" and "Future" forms of threats (***see Lessons Learned 3***).

What are Conservation Landscapes?

Although we won't discuss in detail how to make Conservation Landscapes, it's a good idea to know what they might look like and how Biological and Threat Landscapes will play a role in constructing them. Conservation Landscapes are, to put it simply, annotated maps of conservation priorities. They show those places that are a high priority for you to invest time and money, places that are low priority, places that are "already conserved", and "out of the question" places (like cities) that have little conservation value (***see Figure 4***). They can also be annotated to characterize the conservation actions, if any, you'll take in particular places.

Figure 4. Hypothetical example of a Conservation Landscape for the Adirondacks (not the actual map).



Biological and Threat landscapes can be combined to tell us where our actions may have the biggest impact. For example, places that have a high "Potential Habitat Quality" and high "Threats" are places where we could potentially conserve a lot of animals, by increasing their populations or by preventing future losses.

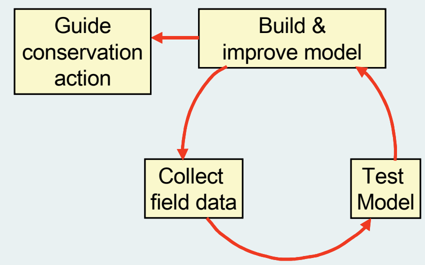
Of course, places where you *could* have big impacts aren't necessarily the places you'd want to conserve. What if the threat occurring in a place was really hard to eliminate or reverse (e.g., conversion of lands to agriculture), even though it was causing huge reductions in animal populations? What if local people were adamantly opposed to conservation? When making decisions about conservation priorities, the potential *cost* of action is just as important as its potential impact.

Look out for the Technical Manual on building Conservation Landscapes, for a more detailed discussion of how you can use Biological and Threats Landscapes, together with other relevant information, to help decide where you want to work.

Part II. Some context on models

Biological and Threat Landscapes are spatial models—models representing the spatial distribution (location and amount) of something. This manual is designed primarily for someone who is new to spatial modeling, and tries to guide you through the process of building Landscapes in a logical way. While we'll try to make the process as logical as possible, you should not expect it to be easy, quick, or ever *really* finished. Try to view the modeling process as equivalent to an adaptive management framework, where models represent your current understanding (a hypothesis), that is continuously tested and updated with new information. Although models are *always* simplifications and *always* imperfect, they are useful nonetheless because they can help guide conservation action based on the best-available, albeit incomplete, knowledge.

Figure 5. Modeling in the adaptive management framework.



For our purposes, there are two basic kinds of spatial models. **Empirically-based models** (also known as statistical models) are created using field-based observations, preferably collected in a statistically rigorous fashion. These data may come from (1) surveys for estimating actual abundance (counting animals, counting fishers) or indices of abundance (e.g., dung counts, opinion surveys), (2) studies tracking individual animals (e.g., telemetry), or (3) demographic or behavioral studies, etc. The association between these data and explanatory variables (e.g., vegetation type, rainfall) are examined, typically using a statistical technique such as linear regression, to produce a model for predicting the spatial distribution of the feature of interest.

Models based on first-principles (also known as expert opinion models) are not created directly from statistically sampled observations, but from more general information such as: (1) literature resources (often literature about other places); (2) qualitative descriptions of habitat use or severity of threats; (3) the general experience and opinion of researchers or, in their simplest form; and (4) from long-standing ecological principles and knowledge (e.g., larger body sizes are associated with larger home ranges). We typically build these types of models when we don't have good, direct observational data for application with rigorous statistical tools, as is often the case for wildlife and their threats. These models are best seen as hypotheses, that you will test in the future with more field data and experience.

It's worth noting that the distinction between empirical and first-principle models is somewhat artificial. Most models mix expert-experience (e.g., selecting probable predictor variables) and field data. It's likely that you will combine the approaches.

Lessons Learned 1
Why you wish you studied bacteria and plants

Years of studying different critters has taught ecologists that it's much harder to understand and predict the population dynamics of big, long-lived species, such as elephants and bears, than short-lived creatures like bacteria. Long-lives and big bodies translate into "time-lags", when causes and their effects are out of sync. For example, for many big creatures, like elephants, periods of low food production don't translate into high mortality rates, but reduced reproduction and delayed sexual maturation. Impacts of reduced habitat quality on abundances may not be detectable for decades, until lots of old elephants start to die, and there aren't enough young ones to replace them. The global population of humans is experiencing this exact effect now - our birth rates are falling, but our total population is still growing!

Another problem with big critters, as opposed to plants, is that they move, and consequently cause and effect can happen in different places. This results in annoying complexities (for the spatial modeler at least) such as source-sink dynamics. Consider the case of bears in the Lake Tahoe region of Nevada and Utah, USA (Beckmann and Berger 2003). People leaving their trashcans open in town cause bears from the wild forest to leave their top-notch habitat (the source) and head for a night out in the big city (the sink), where they get themselves shot or hit by cars.

Now these situations— when the threat occurs in one place or time, but the impact on populations occur in another— are enough to give spatial modelers the frights. We're just learning to incorporate such complexities, but we've got a long way to go. For the moment, we recommend that you keep it simple — assume that habitat quality (and human-caused changes to it) will be closely correlated with animal numbers (and changes to them) on your maps. Recognize, however, that habitat quality and abundance (and threats and population changes) are not always well correlated, at least in the immediate time and place. Also keep in mind that if you focus on improving habitat quality or preventing its further decline, animal population will follow eventually!

For more , see Van Horne (1983) and Pulliam (1988).

When comparing these two kinds of models, the literature suggests that empirical models are usually more accurate for spatial predictions (Pearce et al. 2001). If you have a large enough sample and appropriate explanatory variables, you can generally do a good job predicting how many animals will be in a particular location. However, there are two big drawbacks to building empirical models. First, you need lots of data, preferably collected in a statistically rigorous and unbiased fashion, with enough data to both build the model and test it. Such data require substantial investments of money and time, things we're often lacking.

Less obviously, but potentially more important, is that when working with direct observations of animals, it is difficult or impossible to separate out the effects of natural variables (e.g., topography, rainfall) from human-caused variables. For instance, if there are no gorillas in a particular place, is it because humans have killed them all, because the habitat is bad, or some mixture of both? Controlled experiments are often necessary to clearly separate the effects of natural from human variables. Unfortunately, with large landscapes, rare animals, and short time scales of conservation action, controlled experiments are rarely possible (Ferraro and Pattanayak 2006).

Decisions about whether to invest the resources to build an empirical model can be challenging, and should be based on your goals, data quality (e.g., sample size, bias, appropriate scale), and time and money constraints. In many if not most cases, field data will be too scarce, and a model based on first principles will help you better separate the influence of the human from the natural. Keep in mind that for conservation to move forward, decisions need to be made. Feel free to contact LLP for advice (see the contact information at the end of this manual). If you think you have enough data to build an empirical model, we recommend reviewing Manly et al. (2002) and Scott et al. (2002). With that said, this technical manual is primarily about building models from first principles. Even if you choose not to build an empirical model, ***don't throw out your field observations*** of animals or human activities! When building models based on first principles, field data can help provide clues to what habitat is important, help us ponder how animals are making choices, and clarify how humans are affecting animals. Most importantly, field observation can help validate our models, if not statistically, at least informally.

Part III: Important questions to consider before you begin making your models

Before you open your GIS software, it's a good idea to answer some basic and practical questions, the answers to which will have important implications when you actually begin making models. Start the modeling process by answering the following six questions:

<u>Question 1</u>: What is the focal area over which we will build Biological and Threat Landscapes?

In the lingo of landscape ecologists, your focal area is called your *spatial extent*, or the area over which you will produce your models. We recommend that before beginning, you clearly state what your initial focal area will be. It's likely that after going through the process of building landscapes, you will decide that your initial focal area was too small or too big, and that you will need to change it. But at least for a first run-through, be very clear about your focal area, and stick to it.

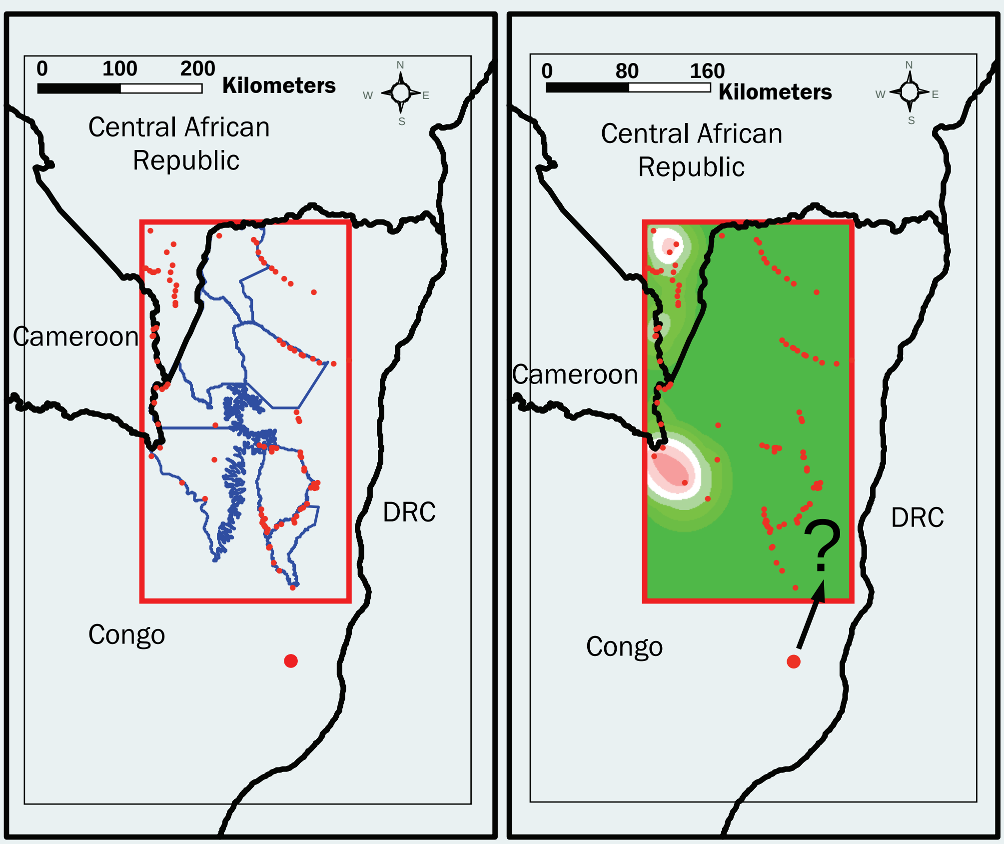
When choosing your focal area consider these points:

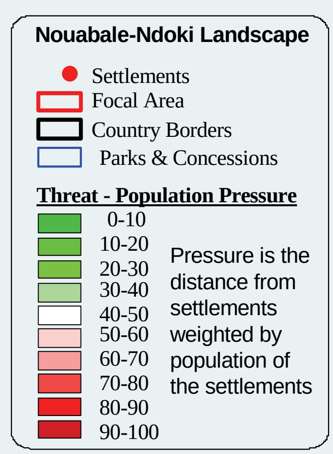
- Has your work historically focused within a park or a distinct political unit? Do you need to work beyond this boundary to successfully conserve your Landscape Species? If you have an inkling that any of your species needs habitat beyond the boundary, you need to consider how far beyond you will go (***see Lessons Learned 2***). If, however, you *strongly* believe that the area in which you've worked does or could easily support functional populations of your Landscape Species (maybe with a little

Lessons Learned 2

Choosing your focal area

In the Nouabalé-Ndoki Landscape in the northeastern portion of the Republic of Congo, conservation activities have historically focused on the national park and adjacent forestry concessions (left map). When planning biological and human landscapes, we decided to include an area beyond these boundaries because we thought this habitat might be important for animal populations within the national park. We located the boundary of our focal area for the models based on where we thought elephants (the widest ranging species) within the park within the park might travel (including habitat in 2 other countries). We then collected GIS data for this region. In retrospect, we made two small mistakes. First, the influence of human populations beyond the boundary of the focal area is important. Hunters from a large village to the south of the focal area travel a long distance to hunt animals within the focal area. Unfortunately, we didn't collect GIS data outside of the focal area, and therefore our Threats Landscapes don't reflect this influence (right map). A second mistake we made was that our focal area may have been too small, as elephants in the national park may require an even larger area than we originally thought.

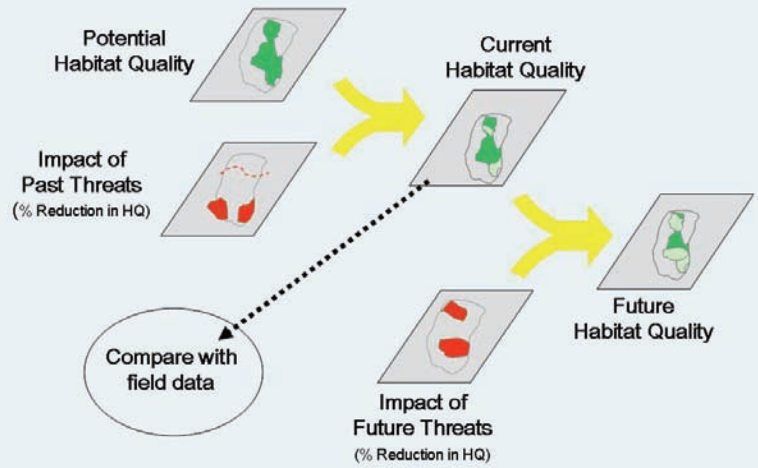


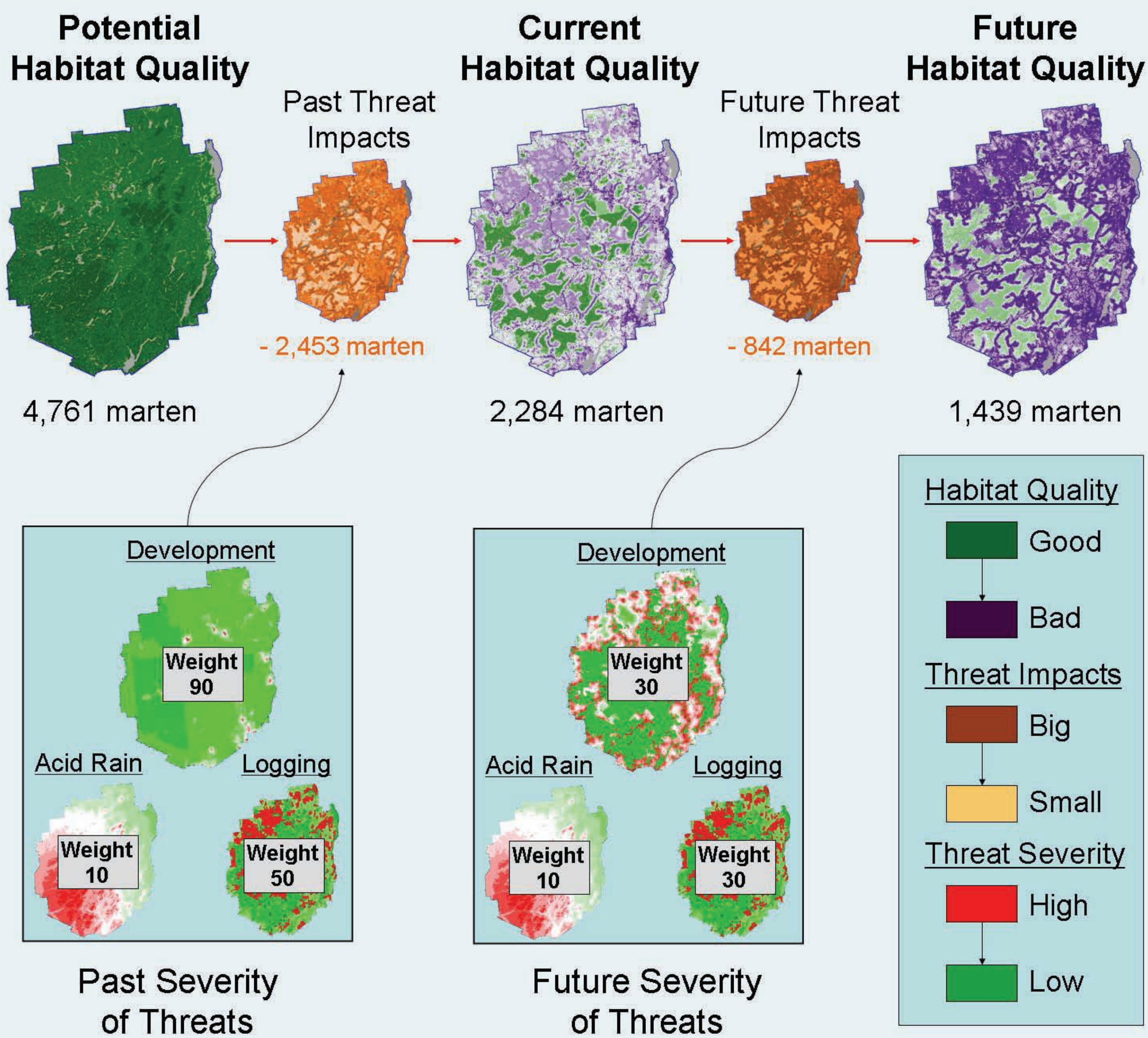


Lessons Learned 3

Separating the impacts of current and future threats

In the Adirondacks (below) and the Maya Biosphere Reserve, we decided to separate current and future threats. The spatial distribution of some threats were clearly different in the future as compared to the past (e.g., development in the Adirondacks). Contrary to our initial belief, separating past from future threats required very little additional work. By separating threats, we were able overlay our Potential Biological Landscape with the Past Threat Landscape to make a Current Biological Landscape, estimate the current abundance, and compare our modeled estimates of the distribution and abundance with field data. In some cases, it was clear that conservation actions aimed at recovering populations of landscape species would occur in very different locations than actions aimed at preventing future reductions.





conservation help), there's no need to model beyond your current boundaries. Remember that modeling over too big of an area is better than too small.
- Try to avoid letting human boundaries determine your focal area. Although political boundaries or data limitations (e.g., the edges of satellite scenes) often unavoidably determine what we model, remember that wildlife typically do not respect human-created boundaries. Consider using ecological criteria (e.g., watershed boundaries, specie range limits, bathymetric ranges, etc.). Another idea is to use the spatial needs of your Landscapes Species to determine the size of your focal area—you could model within political or park boundaries, but also include a buffer zone around these areas. The buffer width could be equal to the diameter of the largest home range for your Landscape Species.

Once you have settled on your focal area, create a polygon GIS file showing only this boundary.

Question 2: Do some impacts of humans belong in the Potential Biological Landscape?

Potential Biological Landscapes (as opposed to the Current or Future forms) represent what your landscape would look like if you mitigated threats. Unfortunately, in many cases, for all practical purposes your conservation project may not be able to do anything to mitigate some threats. These include threats that have already impacted wildlife (e.g., habitat destroyed by the construction of cities) and ones that will continue to impact wildlife far into the future (e.g., global warming). While many of us dream of one day having landscapes that are completely "natural", we suggest that in most cases, it's not a practical goal for conservation nor a good way to approach building Landscapes. If a particular threat is really outside of your sphere of influence, or you do not plan to address it within the time-frame of your project, you should include its impacts within your Potential Biological Landscape.

Some human impacts that might remain as part of you Potential Biological Landscape include:

- habitat destroyed by existing cities and towns
- habitat that has been converted to agriculture
- impacts of global warming or other broad-scale threats outside of your sphere of influence
- certain "unalterable" impacts of roads that have already been built, such as the vegetation removal or habitat fragmentation caused by a major highway. However, many "indirect" impacts of roads may be within your sphere of influence, such as access provided to hunters or future agricultural clearance along roads.

Having stressed a practical perspective, however, it is important that you ***do not simply focus on what is easy, nor underestimate what you can do as a conservation project.*** Do not let practicality stop you from setting the bar high.

Question 3: Should we divide Threat Landscapes into "Past" & "Future" forms? Do we need a "Current" version of the Biological Landscape?

As we've applied the Landscape Species Approach in more and more places with more species, we've recognized that the classic version of our approach, with one Biological Landscape per species and one Threat Landscape per threat, is sometimes insufficient.

In most applications of the LSA, we have not specified whether a particular threat occurred in the past, is currently occurring, or has not yet occurred but is a "looming" possibility. However, in some applications of the approach, we have found it useful to make "Past" and "Future" representations of Threat Landscapes (***see Lessons Learned 3***). By Past Threat Landscapes, we're referring to the impacts and spatial pattern of a threat *up until the current moment in time*. By Future Threat Landscapes, we're referring the threat *from this moment to some time in the future* (usually 5-10 years). The best dividing line between the past and future representations of the same threat is whether reductions in the population have already occurred. The Past Threat Landscape should represent reductions that have already occurred, while the Future Threat Landscape should attempt to represent changes that will occur soon or may occur in the future.

You may find that you do not need to distinguish between Past and Future forms of a threat—its sufficient to have a map of the threat and unimportant to distinguish whether the threat has already reduced or will reduce populations. Often this will be the case for threats that act directly on populations (e.g., hunting or poaching) rather those that change habitat structure (e.g., logging or agricultural conversion). For threats like poaching, mitigation simply involves stopping an ongoing activity and allowing populations to recover on their own, without any additional work to assist or speed recovery. For threats like logging, activities you need to perform to recover from past impacts (e.g., reforestation) are different than those you need to do to prevent the threat from occurring in the future.

We recommend that you discuss for each threat whether it's useful to distinguish its past and future forms. The following three questions may help:

1. Do we need or want to make a map of the Current distribution of the Landscape Species (Current Biological Landscape)? To make one, you will need to overlay the "Potential" Biological Landscape with Past versions of the Threat Landscapes (i.e., how the threats have reduced populations up until this point in time).
2. Is the spatial pattern of the threat changing, such that its past pattern is very different than its current or likely future pattern?
3. Are the actions we'd take to *recover* from past impacts of the threat very different than actions we'd take to *prevent* further impacts in the future?

Whatever you decide, we recommend that you be clear about what your Threats Landscapes represent. Are they a representation of the past, future, or current distribution of the threat or some combination thereof?

<u>Question 4</u>: What GIS data, at minimum, do we need to begin modeling?

As you get into modeling, you will find you always need more GIS data. However, we can guarantee that you will need some basic data to start and recommend you compile it before you start modeling, including a habitat map of some sort (land-use/land-cover, vegetation, reef structure, bathymetry, etc.), jurisdictional boundaries, roads, and water resources. Keep in mind that some important habitat features may be too small to detect within your base habitat map (e.g., salt licks, mall streams, or vernal pools may be too small to be detected by satellite imagery). Some data may be important on a species-by-species basis. We recommend that you make a list of the baseline GIS data sets that you have, those you need but which don't exist, and how the datasets you do have should be improved. ***See Lessons Learned 4*** for sources of some basic GIS data layers. LLP also

Lessons Learned 4
Free Basic GIS layers and sources

If detailed data sets are not locally available, these global data are available for free. These data are often not detailed enough or are inaccurate at local scales, but are a good starting point. (LLP staff also have compiled a much larger database of global GIS data sets and sources of Remote Sensing data. Feel free to ask LLP staff or staff in the regional hubs if you'd like the database).

Layer	Data Name	Provider	Source
General Administrative and Infrastructure(e.g., political boundaries, rivers, roads, etc.)	VMAP ESRI World Basemap Data	NIMA ESRI	http://www.mapability.com/ http://www.esri.com/data/download/index.html
Human Population	Gridded Population of the World (GPW) v. 2 LandScan	CIESIN Oak Ridge National Lab	http://sedac.ciesin.columbia.edu/gpw/ http://www.ornl.gov/sci/landscan/
Land Cover	Global Land Cover Characteristics (GLC)	USGS, Univ. of Nebraska, European Commission Joint Research Centre	http://edcdaac.usgs.gov/glcc/glcc.asp
Protected Areas	World Database on Protected Areas (WDPA)	UNEP-WCMC, IUCN WCPA, International NGOs	http://geodata.grid.unep.ch/
Topography & Elevation	Shuttle Radar Topography Mission (SRTM)	NAAS, USGS	http://glcf.umiacs.umd.edu/data/srtm/
Ocean Bathymetry	ETOPO5	National Geophysical Data Center (NGDC)/NOAA	http://www.ngdc.noaa.gov/mgg/global/global.html

has a comprehensive database of global data resources (to obtain, see the contact information at the end of this bulletin).

HINT: You may need GIS data beyond the area you choose to model because habitat quality and severity of threats may be affected by factors outside of your focal area (*see **Lessons Learned 2***). Consider the geographic source of threats (e.g., where do hunters come from? where does pollution come from?) and whether this information is needed.

<u>Question 5</u>: Should we model in a raster (grids) or vector (polygons, lines, points) environment?

You need to have ArcInfo or the spatial analyst extension (for ArcView or ArcGIS) to model in raster, and generally some specialized GIS training. Raster modeling in general will be more convenient, more powerful, faster for the computer, and require less file space than trying to build Biological and Threat Landscapes with vector layers. However, if you don't have the software (ArcInfo or Spatial Analyst), or feel that you need to model using a base polygon layer (e.g., vegetation communities or patches, jurisdictions), vector modeling is possible. Most likely, your data will come in both raster and vector formats, but whenever possible you should convert your vector data sets into rasters when modeling (e.g., distance to shores, density of roads).

<u>Question 6</u>: What spatial resolution should we use?

Spatial resolution or grain size is the minimum area for which you would like habitat quality or threats values to be displayed. In most cases, this will be a grid or pixel size (e.g., 10m or 1km on a side), but if you choose to model using polygons, its likely to be based on jurisdictions (e.g., parks, town boundaries), ecosystem boundaries, vegetation types, or a combination of these. If you choose polygons, we recommend creating a base polygon file that shows a unique polygon for each area within which you would like to calculate unique habitat or threat values. In the case of polygons or grids, consider that the resolution of existing data (e.g., satellite-derived land-cover) will limit the grain size (usually to 30-100m). For ease of calculation, it's often best to choose a multiple of 10 (100m, 1 km). In general, the grain size for model building should not be coarser than the spatial scale at which you will likely implement interventions and management. Though very high resolution (i.e., small grain size) provides enormous detail it can make files too big to process easily. On the other hand, by choosing to use low resolution (i.e., large grain size) information, you risk masking the variability in habitats that is important for wildlife species. For most purposes, and given the resolution of readily available base data layers, a grain size of 100m to 1km on a side will be appropriate for the vast majority of sites and species.

Part IV. Building Landscapes step by step

In this section we provide step-by-step guidance to help inexperienced modelers build Biological Landscapes and Threat Landscapes. Although the processes are similar for building Biological and Threats Landscapes, for clarity we provide separate guidelines.

Potential Biological Landscapes: habitat quality in the absence of threats

Step 1: Enter the modeling mindset. Here are some hints about the philosophy of habitat modeling:

- **Do not start with the data, start with the biology.** Many times people think like this "Well, we have a land-cover map, rivers data, roads data, and elevation data. How do we put these 4 things together to make a model of jaguar habitat quality?". We recommend, however, that you try to think *first* of the variables that are truly important for your species, *then* figure out how your data can help you map those variables—"Jaguars need a prey base, need water, need to be able to move, and feel safest in forests. Now, how can we use the GIS data to represent these variables?" (*see **Lessons Learned 5 and 7***).

- **Think "long-term" and "big-scale".** Try not to get wrapped up too much in how animals select habitat within a particular season, or how individuals make small-scale choices between "patch A" vs. "patch B". Try to think like this: "O.K., I'm an elephant moving into this landscape. Where is the best place for me to put down my permanent home? Where can I meet all my lifetime needs, like having water and food throughout the year, having a place to reproduce and raise my kids, having a secure place away from predators…"

- **Think abundance, not presence/absence.** When building landscapes, strive to go beyond maps of where you think the species might be present or absent, to maps of where you think there could be more or less animals.

- **Approach your landscapes as "hypotheses."** Don't get bogged down by the fact that you may not have a lot of field data to support your model assumptions. Landscapes should be your best guesses, based on the available information, about how your species and their habitat may be distributed across the focal area. Part of your research and monitoring objectives will be to gather additional information, to test these hypotheses, and refine your Landscapes.

- **Imagine the species reaching "equilibrium" with its environment.** We expect that our Landscapes will take on a bit of a hypothetical quality, in that they represent what populations would be if they reached "equilibrium" with the environment (i.e., carrying capacity). Although, as biologists, we all recognize that "equilibria" are very rare in real ecological systems, the concept does allow us to build models useful for discussing conservation priorities.

- **Calculate habitat quality for one grid cell at a time, but don't forget about the spatial context.** Although the resolution (grain size) of your models may be a grid cell, most of the animals don't limit their assessment of habitat quality to a grid cell ("Is this 30 m cell good habitat?"). They assess habitat quality in the context of their ability to move within an area typically much larger than a grid cell (their home range, for instance). Therefore, while habitat quality for a particular grid cell may be partly influenced by what is actually happening in that cell (e.g., agriculture), it's probably more dependent on what's around that cell (forest is all around and a stream is 100 m away). ArcView has several ways to help you evaluate spatial context, including distance functions and focal windows (***see Figure 6***).

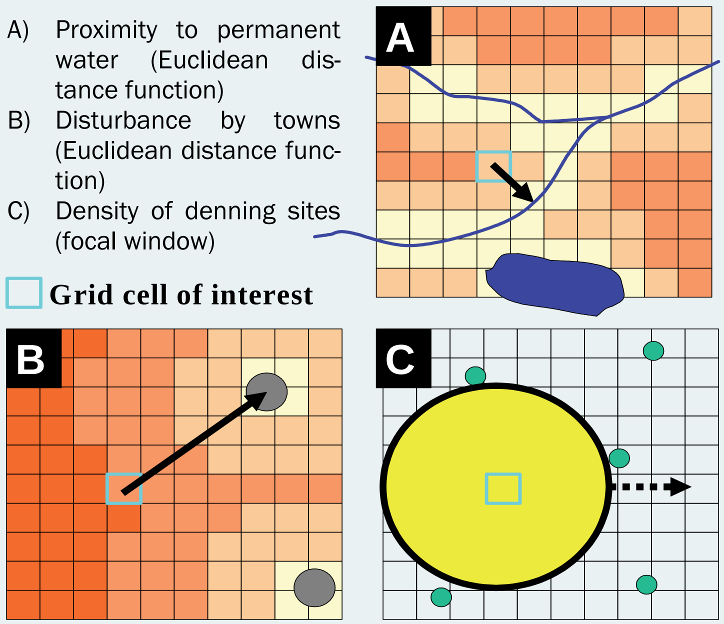
Step 2: Gather relevant information on the biology of each species and solicit the help of species experts. We suggest surveying the scientific literature available for each of your Landscape Species. Take note of variables that are potentially important for species-habitat relationships (habitat quality), relevant home range sizes, and pay particular attention to different spatio-temporal scales that are reported (e.g., annual home range size, seasonal range sizes, etc.). Also, collect all relevant field observations (of the species, of threats) that you can, especially if they can easily be incorporated into your GIS, as these data are always helpful for directing the modeling process and providing informal validation of the models. If you have completed a Landscape Species Selection process using the LLP software, much of this information will have already been compiled.

We also recommend that you solicit the help of at least one acknowledged expert for each species. The best possible situation is for the person building the biological models to be familiar with the literature and for the species expert to be present during the construction of the model. As the best models develop over a series of iterations, having a species expert comment on progressive drafts is critical to building useful models.

Step 3: Outline the model structure. Although your first instinct may be to open ArcView and start manipulating the data, the modeling process is usually more efficient, clear, and, accurate if you spend a little time outlining how each Biological Landscape will be constructed. We suggest that you first write out habitat relationships in sentences, then convert sentences into graphs. It's amazing how clear modeling becomes when you have to write your logic out in words! An outline will not only be valuable for organizing your ideas, but will be invaluable a few months later when you want to revise the model, but can't remember exactly what you did. It can also serve as a valuable place to store file names and descriptions. Spend the minutes now to make a process outline and keep it up to date. It will save you hours later! (***See Lessons Learned 5*** on the next page for some guidelines and examples for outlining your biological model.)

Step 4: Open ArcView and make your model! Now that you've planned your model, making it is relatively easy. Here are some simple hints to keep in mind as you go along. Also ***see Lessons Learned 7*** for some handy ways to make calculations in ArcView.

Figure 6. Modeling using the spatial context.



Note: Grid colors in A and B show the Euclidean distance from the closest feature of interest (streams in A, towns in B). Lighter colors are shorter distances.

- If in doubt, save any intermediate grids and shapefiles ("Convert to Grid" or "Convert to Shapefile") along the way rather than deleting them. You will return to many and use them for different species. When you've finished the models, spend some time cleaning up intermediate steps that you don't need.

- Keep a running record in Notepad or Word of all steps (whether you save the results or not) and how each was created (the inputs, the outputs, the calculation method, etc.) It is generally easy to copy formulas from ArcView's "Map Calculator" into Notepad.

- Put all steps, variables, and results on a scale of **0-100**, not 0-1, 0-10, or some other scale. This will help you make easy "back of the envelope" calculations, keep sufficient precision along the way, and avoid rounding errors. We recommend that your final biological layer represent "potential relative habitat quality", on a scale of 0-100, where the best place on the landscape has a value of 100, and a value of 0 means that the species is completely absent. ***See Lessons Learned 5.***

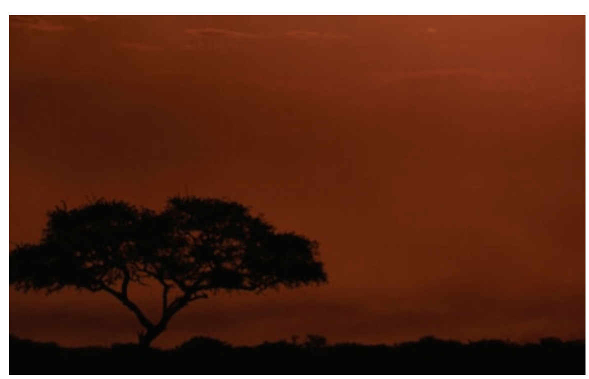
- Whenever a decimal place appears in a grid, remove it by converting the grid from "floating point" to an "integer grid". For reasons specific to how ArcView saves grids, grids that have a decimal point (floating point) often take up a lot of space on your hard drive and take much more time to process in later calculations. "Integer grids" are much more efficient (this is part of the reason we suggest you stay away from using a 0-1 scale).

Threat Landscapes: Impact of threats on potential habitat quality

Step 1: Enter the modeling mindset

- **Think like an animal *and* a human.** Threat Landscapes require you to think, on a cell-by-cell basis, about how humans distribute themselves across the landscape and how they affect your species. Think about how many humans may use a particular grid cell and what kind of impact they will have on habitat quality. As with the Biological Landscapes, habitat quality may be impacted by what's occurring on a particular grid cell of interest, but may also depend on the context around that cell (***see Figure 6***).

- **Roads are the great "facilitator."** Many sites are tempted to model roads as a direct threat, and therefore as a separate threat in the model. However, the major impact of roads (and rivers, and trails, etc.) is typically to increase the impact of other threats - allowing access to hunters, facilitating forest clearance, etc. If you build an individual model for "threats from roads", it will be difficult to remove the impact of roads from other threat models. Consider building a base "cost-access" model as a basis for several threats, which incorporates roads, sources of human population, and travel costs (**see Lessons Learned 9**). More direct impacts of roads may be modeled as distinctly independent threats. Direct impacts of roads, while usually less severe, include things like the removal of forest to build the road, disturbance associated with traffic, and barriers to movement/dispersal.



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Lessons Learned 5

Outlining your model for the Potential Biological Landscape

We recommend sketching out your model in sentence form before you proceed. Writing the model in sentence form will help you clarify the analysis and clearly separate explanatory variables. Try the following:

a **List the variables that impact the distribution of the species in your landscape.** Include both the biological variables and those human activities that you've decided are part of the Potential Biological Landscape. For now, don't worry too much about whether you actually have the GIS data necessary to model these variables. Think about variables that determine the boundaries of the species local range (presence/absence within the landscape) and those that have an important impact the number of animals within the local range.

b **Indicate whether each variable limits the presence of the species in parts of the landscape, affects the abundance of animals but does not limit presence, or variables that do both**:

- **Variables that limit presence, and affect abundance.** Many variables can limit whether a species is present in particular parts of the landscape—they are either *absolutely* required or will *absolutely* exclude the species. For example, a salt lick within 10 km is required for elephants to be present in a part of the landscape. Usually, these variables also have an impact on how many animals live in an area, and so modify habitat quality. For example, the number of salt licks impacts how many elephants occupy a particular part of the landscape. These types of variables typically include water, food, or nutrient sources (e.g. permanent water, a particular plant or prey species, salt), nesting, spawning, or denning sites, certain types of thermal or security cover, the presence of certain competitors, environmental variables (e.g., temperature, salinity) and minimum patch size.

- **Variables that affect abundance, but do not limit presence.** Some variables can affect how many animals are in a particular location, but may not necessarily cause the species to be completely absent. These include things like food abundance or quality characteristics (e.g., plant productivity, forest age, prey/predator type or density), depth, slope, precipitation, current speed and direction, etc.

- **Variables that only limit presence.** In some rare cases, a variable may limit whether a species is present in particular parts of the landscape, but not have any quantifiable impact on abundance. Often this is because our understanding of the relationship between the variable and the species' abundance isn't very good, and we can only state the relationship in black-and-white terms (e.g., we know that elephants need salt licks, but have no idea how the number of salt licks is related to elephant abundance).

c **Identify a GIS layer or layers that you need for relating each variable to habitat quality or presence/absence.** If you don't have an existing layer for a variable, think about proxies or "approximate" substitutes (e.g., I don't have a map of prey abundance, but instead a map of sea surface temperature that is a good proxy for prey abundance).

d **Make each variable explicit in terms of what you are measuring and its biologically meaningful spatial-temporal scales.** Make explicit what you will measure about each variable, both in terms of units and scale. Are you measuring density, simple presence/absence, taking a mean, etc.? Also, it will be necessary to assess many variables at spatial scales larger than the individual grid cell (your grain size). This is primarily because your species can move to meet their needs (e.g., to get water, to find food), and the resources in any one location are complemented by neighboring areas (within the movement limitations of your species). Answer the question "At what spatial scale will I assess this variable?" We suggest a default scale of the annual home range, but for some species and variables, other scales may be more relevant (seasonal home range, life-time home range, daily home range).

e **Using sentences, make explicit the relationship between each variable and habitat quality or presence/absence.** Consider the effect of each variable ***independently*** of other variables—assuming that the habitat is otherwise perfect for the species (e.g., "Assuming that everything else is perfect, what is the relationship between the density of nesting sites and habitat quality?").

f **Convert your sentences to graphs or tables relating each variable to potential habitat quality and presence/absence.**

g **Make a flow-chart which specifies the steps in your model** - including the GIS layers involved, the GIS techniques you will use to manipulate the layers, and equations you will use for calculating potential habitat quality. Spend some time thinking hard about how you will combine different layers in your model (e.g., should I add them, multiply them, take an average, normalize them?). We suggest that you score all model variables on a scale of 0-100. **See Lessons Learned 6 and 7** for some additional help.

Examples:

(a)
- *nesting beaches*
- *permanent water/ coastline*
- *Elevation/depth*
- *disturbance from towns*
- *patch size*
- *competition from species X*
- *land-cover type*

(b, limit presence and affect abundance)
- *permanent water* is required for presence and affects abundance
- *land-cover* affects abundance and determines presence/absence
- Area covered in coral affects habitat quality and limits presence/absence

(b, affect abundance but do not limit presence)
- *Disturbance from towns* impacts habitat quality but does not limit presence
- Availability of *nesting beaches* impact abundance but do not limit presence

(b, only limit presence)
- *depth* only limits presence/absence
- *Patch size only* limits presence/absence
- *competition for species X* excludes the species

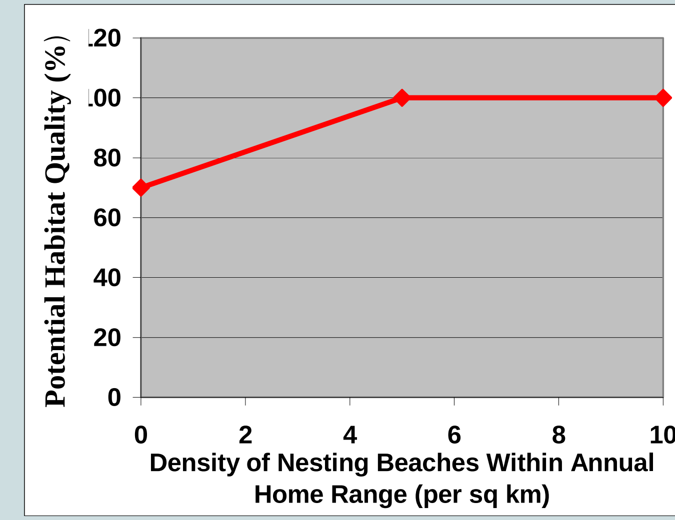
(c)
- See Lessons Learned 7

(d)
- *density of nesting beaches* within the home-range
- *presence of permanent water* within the dry season home range
- the mean *land-cover quality* within the annual home range
- *density of nesting trees* affects within the annual home-range
- Area covered in coral within the spawning range

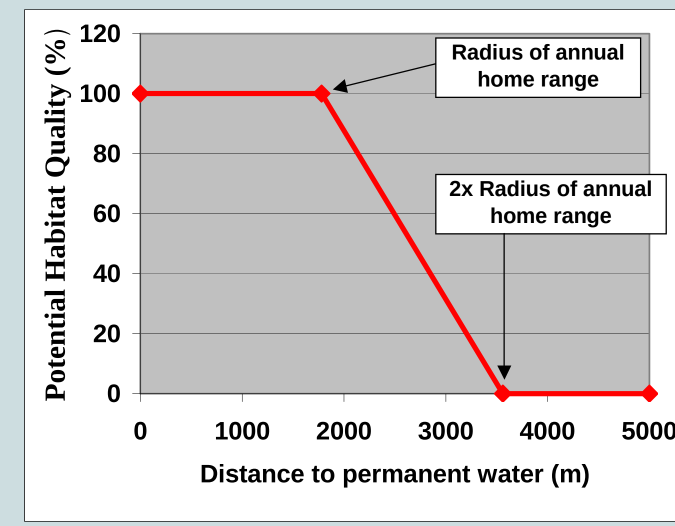
(e)
- If the *density of nesting beaches* is $\geq 5/km^2$, and all other variables are perfect, then habitat quality is 100 (100%). If density of nesting beaches is $<1/km^2$, and all other variables are perfect, then habitat quality is 60.

(g)
- See Lessons Learned 6 & 7

(f)
- Density of nesting beaches within the annual home range impacts habitat quality but does not limit presence.



- Distance to permanent water impacts habitat quality and limits presence.



- Land-cover types within the annual home range affect habitat quality and can limit presence.

Land Cover Class	Potential Habitat quality (% of highest habitat quality)
Evergreen Forest	20
Deciduous Forest	100
Mixed Forest	60
Open Wetland	0
Forested Wetland	80
Urban	5
Natural Grassland	20
Agriculture	5

Living Landscapes Program—Building Biological and Threats Landscapes

Lessons Learned 6
Combining model variables

There are many ways to combine different variables in models. It's important to be aware of how different mathematical combinations (e.g., adding, multiplying, averaging) can affect the importance of each variable in the final score.

Typically, if you have constructed the main variables in your model to be truly independent (e.g., they independently limit habitat quality and do not compensate for other variables), then they can be multiplied together to calculate habitat quality. However, earlier steps may involve other calculations.

Use the following guidelines, but also test the model as you go along to make sure results make intuitive sense:

Multiplicative relationships: Use when each variable in the relationship independently "limits" the result, for instance, when each variable potentially limits habitat quality. In such a relationship, every variable in the equation has the capacity to "zero" the total. Taking the "minimum" of several variables is similar, but in this case, the result will be dependent on only 1 variable, rather than a combination of all.

Additive relationships and (arithmetic) means: Use when one variable can "compensate" for the lack of another. For example, the "availability of prey" may be the sum or average of the density of 2 different prey species.

Normalizing and standardizing: Normalizing values by constants (e.g., dividing by the highest number to put all values on a 0-1 scale) or standardizing variables (when they are on different scales) during different steps of the model can have unexpected impacts on the final results. Be careful and think about what it means.

Again, we suggest that you generally think on a scale of 0-100, where 0 means "as bad as it can be" (for additive relationships) or "no animals will be here" (for multiplicative relationships), and 100 means "as good as it gets" or "highest habitat quality."

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Lessons Learned 7
Making the calculations within ArcView

Once you've outlined your plan for making a Biological or Threat Landscape, its time to use ArcView (or whatever GIS package you use) to make calculations for you. To the right is an example of the steps involved in making the Biological Landscape for jaguars in the Maya Landscape, Guatemala.

Below are some hints on how to use ArcView to make some useful calculations. The spatial analyst extension is needed for any calculations using grids.

Focal Windows for Grids (spatial averages, sums, etc.): Under the Analysis menu, choose "Neighborhood Statistics"

Applying equations to Grids: Under the Analysis menu, choose map calculator.

Converting between Integer Grids and Decimal Point (Floating Point) Grids: Under the Analysis menu, choose map calculator. Select the grid you want to change, change the pull down menu from "Logarithms" to "Arithmetic", then click the "Float" button (to change to decimal points) or the "Int" button (to change to integer values).

Finding the Minimum or Maximum Values of a list of grids: Under the analysis window, select map calculator. Then enter the following, filling in the red parts with your input grids or commands:

InGridA.LocalStats(#GRID_STATYPE_MIN, {InGridA, InGridB, InGridC, ...})

InGridA.LocalStats(#GRID_STATYPE_MAX, {InGridA, InGridB, InGridC, ...})

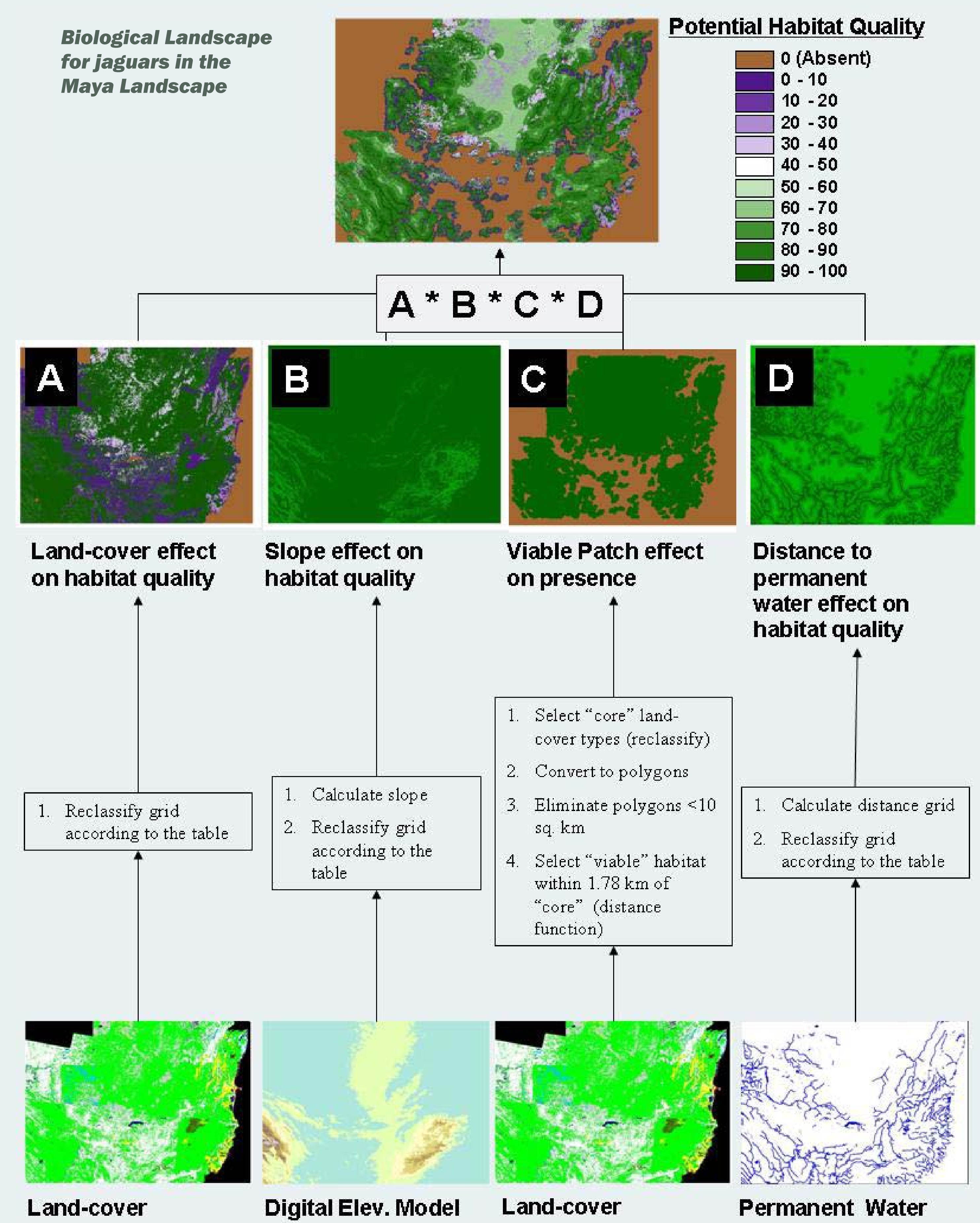
Applying a conditional statement to a grid: Statements like "If the value is X, then do this, otherwise do that" can be handled by ArcView. Under the analysis window, select map calculator. Then enter the following, filling in the red parts with your information:

(InGrid Condition).con((Then, Else)

Example: (InGrid <3000).con((Ingrid*30.AsGrid + 100.AsGrid, 100.AsGrid)

Recalculating Areas and Perimeters of Polygons: the X-tools extension has a nifty option for recalculating these attributes after you've changed (clipped, unioned, etc.) a shapefile.

Reducing the resolution of a grid by aggregating cells: If you want to reduce the resolution of a grid, and you want the resulting grid to be some function of the original cells (like a mean or a sum) get the Grid Analyst extension, which has an "Aggregate function".



- **Do I need separate threats model for each Landscape Species?** You will probably have around 5 different threats and 5 Landscape Species. Do you need 25 separate threats models (one for each threat-species combination) or are 5 "general" threats models sufficient? Does the spatial distribution of a threat differ substantially for any of your species, and therefore require a separate species-specific model? For instance, the relative spatial distribution of hunting is often the same for many species— the risk of being hunted is always highest in a particular place, independent of whether the hunting is directed at elephants or bongo. In these cases, it is sufficient to build one threat model for the species, and just multiply the entire threat by a different constant that represents the severity of the threat for each species. However, for some species, humans will act quite differently (e.g., fishing vs. hunting; subsistence hunting vs. safari hunting), and a different spatial model may be necessary.

HINT: Consider modeling "past" threats separately from future threats (*see Lessons Learned 3*).

Step 2. Gather data on threats. For Threat Landscapes, much of your data will come from maps and information collected during the Human Activities Assessment (*see Technical Manual 1*), the landscape species selection material (especially the vulnerability scores), the species experts, and other experts working in the area (e.g., park guards). We recommend that you incorporate information and maps from the Human Activities Assessment into your threats models in much the same way as you might incorporate field data into your biological models: use it to guide and validate your model building, but don't rely on it completely. When interpreting information from Threats Assessments, keep a few things in mind.

First, in terms of making Threat Landscapes, we typically produce final landscapes for direct threats (those that have direct impact on animals and their populations) rather than indirect threats (those variables, such as access or lack of management) that modify the severity or spatial distribution of direct threats. However, we certainly use indirect threats to help us model the spatial distribution of direct threats.

Second, while most of threats that are important for the entire landscape will have been listed in the workshop, some threats that are important for particular species may have been missed. You should think about what activities are important for each Landscape Species, and add these to the threats that impact the entire landscape.

Finally, maps from the workshops are fantastic information but imperfect for model building because they: (1) often do not have good spatial resolution, (2) are generalized for the entire system or groups of species, (3) are likely to reflect people's biases toward places they know, but lack accurate information for where people don't spend much time, and (4) may only reflect the presence/absence of a threat, but not the relative severity of threats from one place to another. Your goal will be to convert the information from the workshop maps so that it most accurately reflects the distribution of threats in your landscape.

Step 3. Outline the model structure for each threat. As with the Biological Landscapes, we suggest making an outline, this time concentrating on variables that affect the spatial distribution and severity of threats. We suggest first making an outline for each threat, without making the threat specific to each species. Then, in steps 4-8, you can make the threat specific to particular species. ***See Lessons Learned 8*** for an example outline.

HINT: If the spatial pattern of a threat is very different for a particular species, then you may want to make a separate outline for each species.

Step 4: Open ArcView and make your threats models! See the same hints for building Biological Landscapes.

Step 5: Make your general threats models species-specific, in terms of reduction in habitat quality. If your Threat Landscapes are general and not species -specific, make them species-specific (***See Figure 7)***. This will involve relating threat severity to reductions in habitat quality for each species. One simple way to do this is to multiply the entire landscape by a constant that represents how severely the particular threat impacts the species in question. For instance, at its most severe location on the landscape, hunting may reduce elephant habitat quality by 90%. For bongo, however, hunting will only reduce habitat quality by 50% at that same location. The multiplier for elephant would then be 0.9 for elephant, and 0.1 for bongo.

Step 6: Create a Combined Threat Landscape. For each Landscape Species, create a combined Threat Landscape representing the total reduction in habitat quality by all threats (***See example***

Lessons Learned 8

Outlining your threat models

As with the Biological Landscape, we recommend explaining your model in sentence form before proceeding. It's best to do this for each threat individually first, then to relate threat severity to reductions in habitat quality for each species (See Step 5 in the text for building Threats Landscapes).

Example: the Threat from Subsistence Hunting

a **List the important variables that impact the distribution of each threat in your landscape.**

- *Human population*
- *Distance to a market (for chicken and beef)*
- *Travel cost though habitat types*

b **For each variable, identify a GIS layer that you need for relating that variable to the severity of the threat.**

- *Human population* — census blocks
- *Distance to village* — villages
- *Travel cost though habitat types*—land-use/land-cover, roads, rivers

c **Make each variable explicit in terms of what you are measuring and biologically meaningful spatial scales.** As with the Biological Landscapes, make explicit what you will measure about each variable. Are you measuring density, simple presence/absence, taking a mean, etc? Also, if necessary, make each variable explicit in terms of a biologically meaningful spatial scale. Again, whether or not a threat is occurring on a particular grid cell may not be the only thing to consider. The movements of your species at a broader spatial scale that bring it into contact with the threat may be important (e.g., annual or seasonal home range).

- *Human population* within 10 km — number of people (simple example)

OR

- *Cost-distance* (travel time from villages weighted by village population—see Lessons Learned 9)

d **Using sentences, explain the relationship between each variable and threat severity.**

e **Convert your sentences to graphs or tables that relate each variable to threat severity.**

- See simple examples below

OR

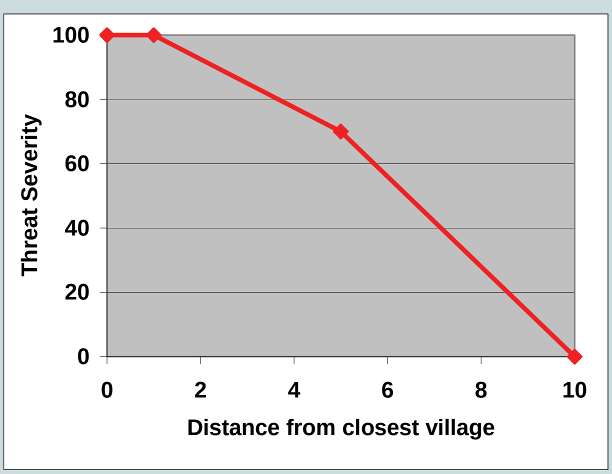
- Use relationships defined by cost-access modeling ArcInfo (see Lessons Learned 9)

f **Make a flow-chart which specifies the steps in your model** - including the GIS layers involved, the GIS techniques you will use to manipulate the layers, and equations you will use for calculating threat severity.

- See Lessons Learned 7 & 9

g **Repeat for each threat.**

- Threat Severity is highest (100) from 0-1 km, decreases linearly to 70 between 1 and 5 km, and then decreases to 0 by 10 km.



- Threat severity increases as human population within 10 km increases.

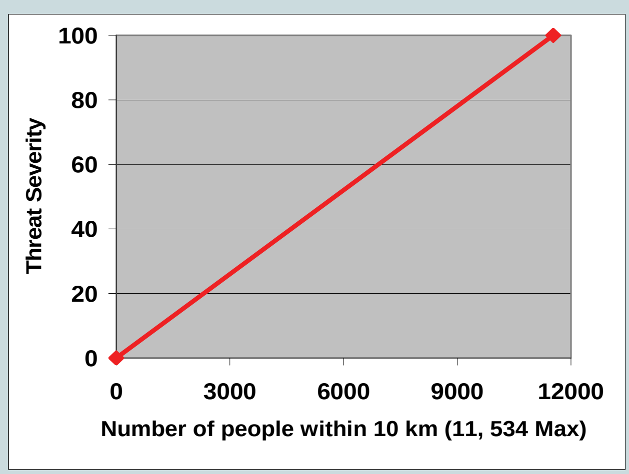


Figure 7. Relating threat severity to reduction in habitat quality for individual Landscape Species. Converting general Threat Landscapes to species-specific Landscapes can be as easy as multiplying the general Landscape (showing threat on a relative scale of 0-100) by a constant. For instance, at its most severe place on the landscape, subsistence hunting reduces habitat quality for Bongo by 50%.

in Lessons Learned 3). Calculation of the combined Threat Landscape will differ from case to case, but in general it should be some weighted average of the threats, where the weights are equal to the average impact of the threat on the Landscape Species (possibly the average vulnerability score from Landscape Species Selection). If you built your threats models such that they represent % reduction in habitat quality, the equation might look like this:

$$100 - \left\{ \frac{(100 - \text{Threat}_1) * (100 - \text{Threat}_2) * (100 - \text{Threat}_3)}{100^{\,i-1}} \right\}$$

% total reduction in habitat quality (0 to 100 scale) = Where i is the number of threats.

For instance if 3 threats independently reduced habitat quality by 90%, 50%, and 10% respectively (as in ***Lessons Learned 3***), then the total reduction in habitat quality would be:

$$100 - \left\{ \frac{(100 - 90) * (100 - 10) * (100 - 50)}{100^{2}} \right\} = 95.5\%$$

Step 7: Overlay your Biological and Combined Threat Landscapes. If you have separated current threats from future threats, you should be able to calculate a "current habitat quality" layer by multiplying your past Threat Landscape ("% total reduction in habitat quality" from above) and your Biological Landscape *(see **Lessons Learned 3**)*:

Current habitat quality = (Potential habitat quality) * (100 - % Total Reduction in habitat quality)

Step 8. Take a few well deserved days off.

Conclusions

Now what? Now that you have reasonable maps of species potential distribution and the impacts of threats, the next thing to start asking yourself is "how can we use this information to help us prioritize where we work in the landscape?" The models hopefully can help you decide what actions to take as well as help you design practical monitoring schemes. Collection of field data to test and refine your models and your conservation decisions is the heart of adaptive management.

To create Conservation Landscapes (i.e., a map showing your conservation priorities), you will certainly need your Biological and Threat Landscapes. You may also decide to include information on conservation costs and more "fuzzy" information on conservation opportunities, challenges, and the history of your landscape. The Living Landscapes Program is actively developing methods for mapping conservation priorities in space, including using specialized software such as Marxan (Ball and Possingham 2000) and C-Plan (New South Wales 2001) to facilitate complex decision-making. Keep and eye on the Living Landscapes website for a new Technical Bulletin on building Conservation Landscapes.

Further Reading

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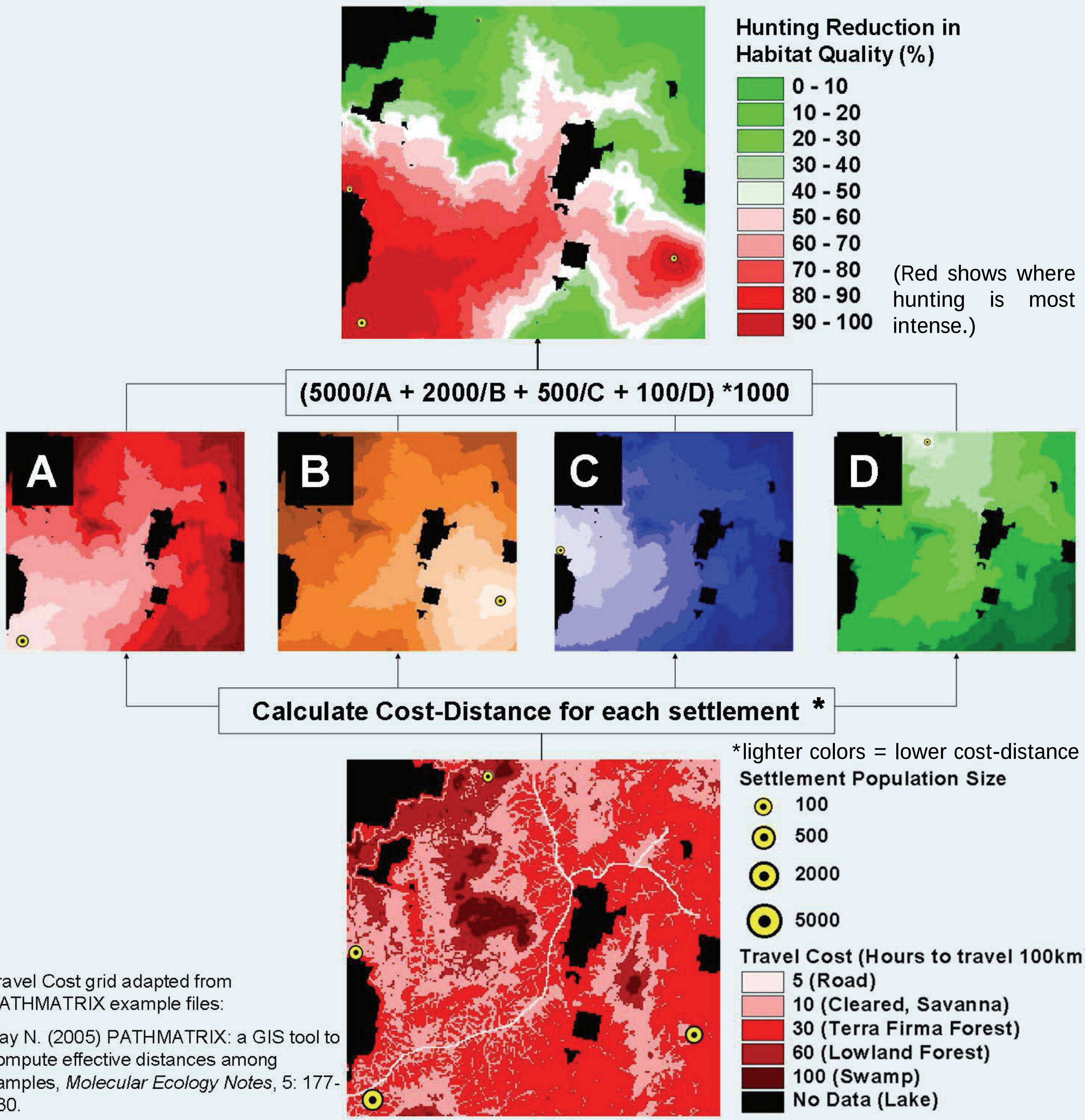
Lessons Learned 9

Using Cost-Distance and Path-Distance analyses to calculate human access

Many threats are based on how accessible locations on the landscape are to human beings. For instance, the risk of being killed by a hunter or poacher usually depends in part on how difficult it is to travel from human settlements to places on the landscape. Others threats include risk of land conversion, fire risk, and even disease. One simple way to calculate the “access cost” for a destination is to calculate the Euclidian (straight-line) distance between that destination and the source (e.g., a city), such that places further away from the destination have a higher travel cost (i.e., resulting in lower hunting pressure). A more realistic calculation of travel cost might also include the relative ease with which people can travel through certain types of land-cover. So, for instance, destinations within swamps are more difficult to access than destinations on roads. This type of analysis can be done in ArcView using the “Cost Distance” extension (available free from ESRI). Even more realistic models of access cost can be created using ArcInfo Grid (pathdistance command), which incorporates more factors that affect travel cost such as topography and flow direction (stream flow, wind, etc.). Below is an example of using a cost-distance model to represent the threat from hunting.



Travel Cost grid adapted from PATHMATRIX example files:

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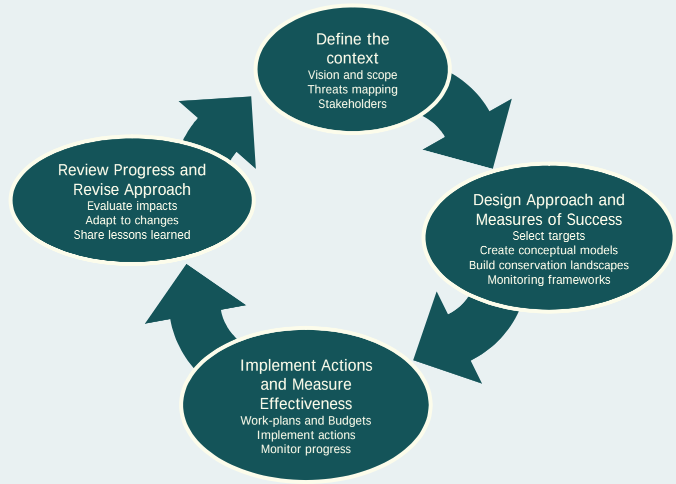
Living Landscapes Program Manuals

WCS's Global Conservation Programs work to save wildlife and wildlands by understanding and resolving critical problems that threaten key species and large, wild ecosystems around the world. Simply put, our field staff make decisions about what causes the needs of wildlife and of people to clash and take action with their partners to avoid or mitigate these conflicts that threaten wildlife and their habitat. Helping our field staff to make the best decisions is a core objective of the Living Landscapes Program.



We believe that if conservation projects are to be truly effective, we must: (1) be explicit about what we want to conserve, (2) identify the most important threats and where they occur within the landscape, (3) strategically plan our interventions such that we are confident that they will help abate the most critical threats, and (4) put in place a process for measuring the effectiveness of our conservation actions, and using this information to guide our decisions. The Living Landscapes Program is developing and testing, with our field programs, a set of decision support tools, designed to help field staff select targets, map key threats, prepare a conservation strategy, and develop a monitoring framework.

The application of these tools is described in a series of technical manuals which are available by email from conservationsupport@wcs.org. These how-to guides are designed to provide clear and practical instructions. If after using the manual to run a strategic planning exercise you have any suggestions as to how we might improve the instructions please let us know.

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