Conceptual Approaches to Climate Change Assessments

(One or more of these approaches would be useful while conducting a vulnerability assessment, a scenarios analysis or to develop on adaptation plan)

Climate envelope models

Link species occurrence (landcover, biome) to climate data empirically in order to forecast to future conditions. Climate envelope models are species distribution models that only use climate layers as environmental predictors. The Center for Biodiversity and Conservation has published a online resource for developing a species distribution model that includes reviews on data sources, modeling algorithms and performance assessment (http://biodiversityinformatics.amnh.org/index.php?section=sdm_guide

- **Examples of Tools:**
  - Open Modeller – a free software (http://openmodeller.sourceforge.net/index.php?option=com_frontpage&Itemid=1) that provides a flexible environment for building species distribution models. Open modeler provides access to multiple algorithms including Random Forests, artificial neural networks (ANN) and ecological niche factor analysis (ENFA).
  - MaxEnt – maximum entropy modeling of species distributions. Maxent is a free software (http://www.cs.princeton.edu/~schapire/maxent/) that produces models of species geographic distributions based on presence-only data. It was designed specifically for modeling distributions when users have access to historical and/or current species localities, but do not have data on sites where the species is known to be absent. Latitude/longitude information on where species have been found and environmental data potentially correlating with species' distributions are the required input. When climate-related factors are believed to drive the current distribution of a species, these variables can be used to generate a model of the current climate envelope, and then the software can project that preference onto models of future climates. Such projections may provide information on future range shifts the species will experience. Habitat suitability is indicated on the output map layers by various colors that indicate how suitable the habitat will be for certain a certain species, given the climate scenario entered into the model. Data needs: data for environmental variables (incl. precip, elevation, etc.) and species occurrence data.
  - SDM Package in Program R. Program R is an open source programming environment for statistics and graphics (http://www.r-project.org/). Program R users can use the Species Distribution Modelling Tools package to process and visualize species distribution models (http://www.rforge.net/SDMTools/index.html) .
  - GIS - A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. Most commonly used program is ESRI's ArcGIS.
- **Online data sources:**
  - Natureserve – http://www.natureserve.org/getData/USecologyData.jsp (contains Natureserve's Gap Analysis Program (GAP) and Landfire Program, as well as terrestrial ecological data for systems of the U.S.)
  - SNAP - http://www.snap.uaf.edu/ (The Scenarios Network for Alaska and Arctic Planning (SNAP) website contains data related to plausible scenarios of future conditions based on a changing climate, in order to allow for better planning in the uncertain future of Alaska and the Arctic)

Threshold approaches

For some species, climate thresholds have been described that limit life history. For example, salmon species have distinct temperature thresholds above which survivorship and spawning are compromised. When linked to climate data (SNAP), these thresholds can be forecast and mapped. Some ecological systems also have thresh

- **Examples of Tools:** Basic math, Raster calculator in ArcMAP
- **Online Resources:**
  - The Resilience Alliance maintains an online database of ecological thresholds (http://www.resalliance.org/index.php/database)

No regrets approaches

Some conservation approaches are robust and worthwhile regardless of changing future conditions. For example, increasing landscape connectivity or conservation reserve size is a no regrets approaches.

- Examples of Tools:
  - MARXAN – Marxan is freely available conservation planning software (http://www.uq.edu.au/marxan/). It provides decision support to a range of conservation planning problems, including: the design of new reserve systems, reporting on the performance of existing reserve systems, developing multiple-use zoning plans for natural resource management. Marxan can be applied to a wide range of natural resource management issues in terrestrial, freshwater, and marine systems. The program is efficient and useful in collaborative conservation planning and design, providing many potential solutions to complex problems. Marxan produces spatially explicit maps that depict cells which are the most desirable for conservation, given a set of weighted attributes. Data needs: attributes for areas that you would like to consider in the planning model (depends on what you are using it for, but vegetative map, species occurrences, riparian attributes, soil attributes, elevation, climate data, etc.).
  - Corridor Designer – An add-on to ArcGIS that allows development of a linkage design that best supports movement for multiple focal species. Corridor Designer allows for the development of corridors that provide continuity within areas with recurring units of relatively uniform topography and soils, which is intended to provide a linkage that will provide connectivity for wildlife given potential changes as a result of climate change.
  - Linkage Mapper - a GIS tool designed to support regional wildlife habitat connectivity analyses. Linkage Mapper 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.
  - Circuitscape - a free, open-source program which borrows algorithms from electronic circuit theory to predict patterns of movement, gene flow, and genetic differentiation among plant and animal populations in heterogeneous landscapes. Circuit theory complements least-cost path approaches because it considers effects of all possible pathways across a landscape simultaneously. Linkage Mapper (see above) is now integrated with Circuitscape.

- Connectivity Analysis Toolkit (CAT) – free software that combines several connectivity analysis and linkage mapping methods in a user-friendly interface. The software facilitates calculation of centrality metrics, which evaluate paths between all possible combinations of sites within a given landscape to rank the contribution of each site to facilitating ecological flows.

Including climate in population models

Stochastic effects, as shift in birth/death rates, can be used to assess whether climate change will increase likelihood of extinction.

- **Examples of Tools:**
  - RAMAS – Risk Assessment Management and Audit Systems (RAMAS) software has multiple applications for environmental analysis. RAMAS provides powerful software for ecological risk analysis and population viability analysis. This software incorporates GIS, dynamic patch structure, and forest dynamics and allows estimation of conservation values for multiple species across a landscape.

Forecasting Using Historical Empirical Trends

Some ecological trends have been documented from historical observation. For example, the rate of treeline rise has been documented from the 1950s-2000s for the Kenai Mountains. These rates can be applied to forecast future conditions. For example, we can predict alpine loss in the Kenai Mountains in the next 10 years assuming the rate remains stable.

Examples of Tools: Usually basic math

Applying Mechanistic Models Based on Current Conditions to Future Conditions

- **Examples of Tools:**
  - ALFRESCO (available through SNAP; http://www.snap.uaf.edu/modeling.php) – Software that simulates the response of vegetation to a changing climate and disturbance regime. ALFRESCO is a state-and-transition model of successional dynamics that explicitly represents the spatial processes of fire and vegetation recruitment across the landscape. The software does not model fire behavior, but rather models the empirical relationship between growing-season climate (e.g., average temperature and total precipitation) and total annual area burned (i.e., the footprint of fire on the landscape). ALFRESCO also models the changes in vegetation flammability that occurs during succession through a flammability coefficient that changes with vegetation type and stand age.
  - SLAMM – Sea Level Affecting Marshes Model. The software uses NOAA tidal data, USFWS NWI data, and USGS Digital Elevation Model data (can also use LIDAR elevation remote sensing data) to simulate the dominant processes (inundation, erosion, overwash, saturation, and accretion) in wetland conversions and shoreline modification that occur as a result of long-term sea level rise. SLAMM-View is a web browser-based application that provides tools for improved understanding of results from research projects that employ the Sea Level Affecting Marshes Model (SLAMM) (http://www.slammview.org/).

Ranking Species in Terms of Vulnerability to Climate Change

Used to systematically compare species vulnerability (exposure, sensitivity, adaptive capacity) to identify species with the highest conservation priority.

- **Examples of Tools:**
  - Natureserve Climate Vulnerability Index Tool– an excel-based spreadsheet (http://www.natureserve.org/prodServices/climatechange/ccvi.jsp) that walks the user through a standardized framework to assess species vulnerability with factors that relate to climate change exposure, sensitivity and adaptive capacity.
  - SAVS (System for Assessing Vulnerability of Species) - identifies the relative vulnerability or resilience of vertebrate species to climate change. Designed for managers, the SAVS is an easily applied tool that uses a questionnaire of 22 predictive criteria to create vulnerability scores. The user scores species' attributes relating to potential vulnerability or resilience associated with projections for their region. Six scores are produced: an overall score denoting level of vulnerability or resilience, four categorical scores (habitat, physiology, phenology, and biotic interactions) indicating source of vulnerability, and an uncertainty score, which reflects user confidence in the predicted response. http://www.fs.fed.us/ccrc/tools/savs.shtml

Identifying the Components of a Species Vulnerability

Some tools can be used to identify whether exposure or sensitivity is driving species vulnerability to identify the factors that may be managed.

- **Examples of Tools:**
  - Natureserve Climate Vulnerability Index Tool – see above for further explanation

Literature Review and Synthesis

There is a lot of existing literature and data relevant to climate change that can be easily incorporated into conservation projects and decision making processes, without having to do advanced modeling or extensive survey work. A review of existing literature and data is an essential step in all of the potential approaches mentioned, but can also be used on its own to support conservation assumptions, decisions and/or strategies. This is a relatively quick, easy, and scientifically credible way to incorporate climate change into conservation decisions.

- **Examples of tools:** Books, journal articles, websites, and databases that have information related to climate change and your area of interest or study.
- **Potential Applications:** Section 7 Consultations, Conservation Planning and Design, HCP's, Listing and Recovery, etc.