Project Title: The Alaska Gap Analysis Program: modeling the distribution of vertebrate species using an inductive and deductive approach

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Synopsis of project: Throughout nearly all of the United States, the Gap Analysis Program (GAP) has been a critical development for biodiversity conservation: it enhances the development of statewide geospatial and biogeographical information, forges relationships and multi-disciplinary teamwork that leads to cooperative conservation planning, and provides an objective basis for a habitat-based, spatially explicit approach to biodiversity conservation planning across large regions (Scott et al 1993). Yet, a vast "gap" currently exists in the GAP Analysis Program, the state of Alaska. We propose to fill this need by laying the critical groundwork for the Alaska Gap Analysis Project: we propose a 3-year study to derive distribution baselines for Alaska biota as well as continue to develop an important institutional network of scientists, planners, and stakeholders who will cohesively guide future biodiversity-conservation efforts.

Alaska, however, faces many unique challenges in regards to conservation planning and mapping at the statewide scale. The Alaska Gap Analysis Project (AK GAP) will be the largest state-based Gap Analysis Project implemented to date by the U.S. Geological Survey (USGS). Until recently, Alaska was not included in any in any GAP mapping efforts, largely due to the sheer size and scale of the state for which such an analysis was thought to be cost prohibitive. In particular, the cost estimate for developing a statewide landcover map exceeded 2 million dollars. Fortuitously, the LANDFIRE Program of the U.S. Forest Service (FS) and the U.S. Geological Survey (USGS) began developing a landcover map for Alaska in 2006. This statewide map will be at the scale adequate for Gap Analysis (1:100,000), thereby eliminating such a significant cost from a gap analysis budget, and is anticipated to be completed by October 2009.

In 2006, the Alaska Natural Heritage Program (AKNHP) at the University of Alaska Anchorage (UAA) received a preliminary year of funding from the USGS National Gap Analysis Program to explore the potential for implementing species distribution modeling efforts in Alaska. The preliminary year of funding and planning allowed us to establish a core team of modelers and advisors with the collective expertise and infrastructure to undertake the challenges of species modeling in a state with over 6,600 miles of coastline and an area largely 1/5th the size of the entire lower 48 states. We were able to garner support from a strong group of stakeholders from the university system, private industry, non-profit and tribal organizations, and state and federal agencies who are eager to participate in partnerships, the review process, and/or data sharing of the Alaska Gap Analysis Project. We were also able to take preparatory steps to acquire state-wide ancillary datasets that will be used for species distribution modeling, build a preliminary structure for the species habitat associations database, and develop internet services for information exchange and data transfer by creating a project web-site, ftp-site and list-serve.

The objective of this project is to produce spatially explicit models that predict the range and distribution of terrestrial vertebrate species in Alaska to support analysis of conservation status. Traditional GAP modeling techniques that crosswalk species habitat associations to landcover classes may not be adequate to predict the distribution of species across such a vast landscape that encompasses myriad environmental gradients. To overcome the challenges associated with size and scale, we propose using a combination of deductive modeling (the standard for state based GAP projects) and inductive modeling techniques (statistical models of climatic and physical limits), similar to methods being explored by the Northwest Regional Gap Program

(Beauvais and Master 2005), to predict the distribution of terrestrial vertebrate species across their range in Alaska.

To predict the range and distribution of vertebrate species in Alaska, we will utilize an iterative, 16-step process over the duration of 3-yrs (FY2009 – 2011). During the first year, we will focus on several preparatory aspects of distribution modeling, including the selection of target species, formation of species-expert and review teams, establishing a data-gathering framework, collating occurrence data, and producing preliminary range maps. During this time we will also develop a web-accessible geodatabase to provide a platform for documentation, storage, and distribution of all datasets obtained, refined, and utilized during this project. In the second year, we will transition to the modeling process by focusing on refinement of analytical methods, including development of preliminary inductive and deductive models, populate the habitat-associations database, produce final range maps, and conduct a pilot project to test the effectiveness of modeling methods and the quality of the review process. During the final year of the project, we will focus on production and dissemination by combining inductive and deductive models to produce draft final distribution models for those species with sufficient data, validate models, facilitate a comprehensive expert review process, and incorporate expert comments to produce final distribution maps. This project will yield a number of products, including project reports, species-occurrence database, distribution atlas, and geospatial modeling products; all of which will be disseminated via a number of web-accessible digital outlets and incorporated into higher-educational curricula throughout the state.

Objectives: The objective of this project is to produce spatially explicit models that predict the range and distribution of terrestrial vertebrate species in Alaska to support analysis of conservation status. To achieve this objective, we will create a comprehensive species list of vertebrate species to be modeled, develop a database of occurrence records, geographic range, wildlife habitat associations, and then predict the distribution of each species using a combination of inductive and deductive modeling techniques to produce final maps for use in gap analysis. Our goal in combining the strength of these two modeling techniques is to improve the quality, precision, and application of the species distribution maps for use by land managers and as a valuable tool for conservation decision making at statewide, regional and local scales.

This proposal directly addresses one of the five major objectives of GAP: to map predicted distributions of vertebrate species for the U.S. (USGS Gap Analysis Handbook). As each of the objectives of GAP build upon one another, the result of the activities proposed herein will provide the requisite data layers to document the representation of vertebrate species and land cover types in areas managed for long-term maintenance if biodiversity. This information will then be made publicly available for use in land use research, planning, policy and management. This proposal specifically addresses the geographic area specified in the project announcement Addendum I, Objective 2: Vertebrate species models are needed for Alaska.

Background and justification: To date, Alaska has not been included in GAP mapping efforts, largely due to the sheer size, scale, and remoteness of the state, the lack of a spatially adequate landcover data set, and a general limitation of species specific distribution data. Mounting a gap analysis for Alaska is akin to conducting a regional gap analysis without having the benefit of the preceding statewide efforts. Until now, overcoming these significant data hurdles to realize GAP in Alaska has been widely perceived as cost prohibitive: Previous estimates for developing an appropriate landcover map alone have exceeded two million dollars. The lack of a comprehensive land stewardship layer and a paucity of information on species' distributions only compounded the anticipated costs.

Fortuitously, a number of recent developments have brought Gap Analysis within reach for Alaska. In 2006, the LANDFIRE Program of the U.S. Forest Service (USFS) and the U.S. Geological Survey (USGS) began developing a landcover map at a scale adequate for Gap Analysis (1:100,000). Development of the LANDFIRE map (slated for completion October 2009) will eliminate the single greatest expense for conducting a gap analysis in Alaska. Additionally, the Nature Conservancy of Alaska completed their land stewardship analyses for Alaska in 2006 using protocols set forth by the National Gap Program (Smith et al. 2006). Finally, the Alaska Natural Heritage Program (AKNHP) has been working under contract to the Alaska Department of Fish and Game (ADF&G) since 2004 to draw together all available distribution, abundance, and status information for 400 vertebrate species in the development of the Alaska Comprehensive Wildlife Conservation Strategy and the Alaska Species Conservation Prioritization Project.

In 2006/07, the AKNHP at the University of Alaska Anchorage (UAA) received a preliminary year of funding from the USGS National Gap Analysis Program to explore the potential for implementing species distribution modeling efforts in Alaska. The initial year of funding and planning allowed AKNHP to establish a core team of modelers and advisors with the collective expertise and infrastructure to undertake the challenges of species modeling at the statewide scale. We were able to garner support from a strong group of stakeholders from private industry, state and federal agencies, non-profits, and tribal organizations who are eager to participate in an Alaska Gap Analysis Project, either through partnerships, expert participation in the map review process, or data sharing. Stakeholders helped identify numerous needs and uses for GAP data in the state and made recommendations on data products and data delivery systems that would be most useful to themselves and their institutions for conservation planning at local, regional and statewide scales. Alaska is now poised to begin vertebrate distribution modeling efforts essential to conducting a statewide Gap Analysis. Other states now take for granted the availability of a state-wide GAP map, predictive species models, and species richness layers to improve in their decision making processes. It is time for Alaska to have this same capability and the need is great. Alaska faces significant and immediate challenges with respect to land and resource development decisions in areas with varying state and federal protections.

Unlike most states, the overwhelming majority of the landbase in Alaska remains undeveloped, providing the rare opportunity for true proactive conservation. Alaska is a patchwork of federal, state, and local jurisdictions, each with its own mandate and responsibilities. Gap Analysis will provide the fundamental framework for these disparate management authorities to conserve species, habitats, and ecosystem functionality before major disruptions occur. GAP will enable land managers, policy makers, and stakeholders in Alaska to plan future development in a sustainable, responsible manner. At present, the major ecosystems in Alaska are relatively intact, and GAP will provide decision makers a tool to proactively assess the cumulative, long term consequences of various development strategies on habitats, habitat connectivity, and ecosystem function.

GAP will contribute immeasurably to landscape planning and conservation biology in Alaska by providing quality, peer-reviewed data products that lend a landscape level perspective, yet will still be useful for informed decision making at local and regional scales. A biodiversity database that extends beyond agency/political boundaries will provide a means for agencies to interact with each other to plan future projects or build upon existing ones. This centralized repository and distribution center for species occurrence data, predicted distribution maps, and metadata will allow researchers and land managers to identify gaps in existing knowledge and coordinate survey efforts to target particular species or particular habitats.

Species predictive distribution models will help guide inventory, monitoring, and research efforts, and will allow for more efficient use of field time and funds for state and federal wildlife management agencies alike. Because Alaska is so vast, rugged, and undeveloped, field inventories are unusually expensive due to the logistics associated with accessibility. Species distribution models will help determine where to target field inventories and investigations instead of selecting survey areas randomly or with little guidance. Other specific uses for GAP products already identified by stakeholders include: identification of focus areas that support the persistence of key species on Department of Defense (DOD) and state lands; directing waterfowl and shorebird surveys to detect potential pathways for the introduction of avian influenza (H5N1); and providing guidance for the Bureau of Land Management (BLM) Sensitive Species list and the U.S. Forest Service's (USFS) Species of Management Concern list.

GAP species predictive models will be used by federal and state resource managers (e.g., ADF&G, USFS, BLM) to identify priority areas for conservation. Efforts are already being planned by the USFWS and USGS in Alaska to use GAP data products to assess potential corridors/areas of connectivity between managed lands – an issue of utmost importance in a changing and developing landscape, particularly in the context of climate change. GAP data will be useful to land use planners to help determine area designations based on species richness or identify areas that could benefit an individual species. BLM would use results of the species richness analysis to identify areas in need of protection in their Resource Management Planning (RMP) process. The State of Alaska indicated they would use species richness data to help with proposals for refuge designations (such as Pebble Mine and Tangle Lakes).

Wildlife and biodiversity preservation are important on many levels in Alaska. They are important in terms of the function of ecosystems, but they are also vitally important in the function of economies. Subsistence use of wildlife occurs at a greater scale in Alaska than in any other state. Predictive species models will be an invaluable tool for ADF&G and the USFWS in managing important subsistence resources and the habitats that support them. Successful management of subsistence resources has major implications for wildlife populations, native cultures, local economies, and state fiscal resources.

From the subsistence economies of native communities, to the tourism driven economies of the cruise ship towns and towns along the road system, wildlife equals dollars. People visit Alaska not only for the vistas, but for the opportunity to view wildlife. Although subsistence and wildlife watching are the most frequently cited examples of wildlife's economic impact in Alaska, the most important impacts are frequently overlooked. Wildlife endangerment poses a serious threat to the other major economic engines of the state: land and resource development. Every federal listing of a species represents a loss of state sovereignty in terms of decision making and flexibility in natural resource development, which may represent an actual financial cost to the residents of the state. GAP will provide a starting point for land managers and policy makers to proceed wisely in development decisions that impact wildlife, and to insure the state retains control in determining which developments are in the state's best economic interest.

Alaska is rich in natural resources of many kinds, but especially those finite resources vital to energy and metal production. Current issues that will affect the disposition and conservation status of vast areas of Alaskan land include: the proposed development of an overland natural gas pipeline; new petroleum leasing in areas of the National Petroleum Reserve Alaska and the nearshore regions of Bristol Bay; recent recommendations from the Bureau of Land Management (BLM) to open 159 million acres of land (currently under a D1 withdraw designation) to exploration for mineral mining or oil and gas drilling; and the proposed Pebble Mine – the largest North American open-pit gold mine, located at the headwaters of two of the most productive salmon spawning rivers in Alaska. Although Alaska's habitats are relatively intact, wholesale development of these resources without effective planning can lead to negative impacts on biodiversity and habitat connectivity, on the subsistence lifestyle of native communities, on Alaskan quality of life, and on local economies dependant on commercial fishing, tourism, sport fishing, and recreational hunting. GAP will provide policy makers, land managers, and entrepreneurs a means of proactively evaluating the potential impacts of various resource development projects across the landscapes and jurisdictions where the impacts will be experienced most acutely, and will provide state policy makers a tool for viewing the cumulative impacts of multiple projects and for assessing the various competing costs of development projects.

Climate change is one of the single greatest challenges ever faced in land use management. The impacts of these changes, not only on wildlife, habitats, and ecosystems, but on infrastructure, culture, and local economies are myriad, interconnected, and exceedingly difficult to predict accurately. Alaska is already experiencing dramatic climatic impacts: permafrost loss is draining wetlands vital to the world's waterfowl and water birds; loss of sea ice threatens the function of arctic marine ecosystems, the survival of marine mammals, and the native communities that depend upon them for subsistence. Changes in vegetation brought about by this unidirectional climatic variation will have profound impacts on the wildlife of the region, and those individuals and economic entities that depend upon them. Completing a gap analysis for Alaska will provide a real starting point to anticipate how climate change might manifest itself in Alaska's ecosystems and economies, and will provide the basis for informed planning to meet these changes, mitigate problems, and perhaps even capitalize on opportunities.

<u>Work Plan/Approach/methods:</u>

Approach

Tracey Gotthardt, AKNHP Program Zoologist, will coordinate the vertebrate distribution modeling efforts for Alaska. Modeling effort will be divided among three regional modeling teams located at the three major campuses within the University of Alaska system: University of Alaska Anchorage (UAA), University of Alaska Southeast (UAS) and University of Alaska Fairbanks (UAF). AKNHP (at UAA) will be responsible for modeling species that occur predominantly in southcentral and southcoastal Alaska and the Aleutian Islands, Dr. Sanjay Pyare, UAS, will oversee modeling efforts in Southeast Alaska and Dr. Falk Huettmann, UAF, will supervise modeling efforts for northern and western Alaska. In an effort to reduce travel time and costs, we are adopting this regional modeling approach to take advantage of expert contacts and sources of data that may be locally/regionally available.

Proposed procedures for modeling the distribution of vertebrate species in Alaska

Traditional GAP deductive modeling techniques that crosswalk species habitat associations to landcover classes, and rely heavily on expert opinion, may not be adequate to predict the distribution of terrestrial species in Alaska. In a landscape as vast as Alaska, it is likely that expert opinion will be significantly lacking for most habitat types. To improve upon traditional GAP modeling techniques, and to enhance the quality and usefulness of the species distribution maps overall, we propose to map the distribution of terrestrial vertebrate species in Alaska using a combination of deductive and inductive modeling techniques, following methods developed for the Northwest Re-Gap Project (Beauvais and Master 2005).

Predictive spatial modeling has been used increasingly over the past 20 years to relate sparse biological or survey data to remotely mapped environmental attributes, thereby allowing distributions of biological entities to be extrapolated across an entire region of interest (Guisan and Zimmerman 2000, Scott et al. 2002, Guisan and Thuiller 2005, Ferrier and Guisan 2006). Inductive (predictive spatial) models are empirical models that relate field observations to environmental predictor variables, based on statistically or theoretically derived response surfaces (Guisan and Zimmerman 2000). Inductive modeling of georeferenced species' occurrences is a powerful way to identify suitable environments on continuous and ordinal variables, such as elevation and climatic gradients, while deductive modeling works best with categorical variables such as landcover and soil type.

The most common strategy for estimating the actual or potential geographic distribution of a species is to characterize the environmental conditions that are suitable for the species, and to then identify where suitable environments are distributed in space (Pearson 2007). Distribution maps are, in effect, a spatial subset of range, with much interdigitation of suitable and unsuitable environments (Beauvais and Master 2005). Because deductive model development will require use of the completed LANDFIRE map (anticipated October 2009), we will begin the distribution modeling process by first creating inductive models for select target species (those species with sufficient and representative occurrence data for this type of modeling). Once the completed LANDFIRE map becomes available, we will then model species distribution using deductive techniques. We will combine the results of the two independently derived models to develop a final species predicted distribution map based on appropriate habitat and environmental variable associations, and delimited by range limits of the target species.

We propose to map the range and distribution of select vertebrate species in Alaska using an iterative, 16-step approach. We anticipate it will take three years (FY2009 – FY2011) to complete this effort. Here, we present our proposed work plan in chronological order. Each "step" is followed by detailed methods that describe how that action will be achieved.
We plan to complete steps 1-3 during the first 12 months of the project (this funding request); steps 4-10 during months 13-24, and step 11-16 during months 25-36.

Step 1: Finalize a comprehensive list of target species to model and identify members of the species team. Develop a geodatabase for storing and organizing all data associated with species modeling.

<u>*Target species selection*</u>

About 600 species or subspecies of vertebrate animals regularly occupy Alaska's terrestrial habitats (Alaska Natural Heritage Program 2007). AKNHP will develop a list of terrestrial birds, mammals, and amphibians for inclusion in distribution modeling efforts using the *Checklist of Alaska Birds* (Gibson 2008), the *Checklist of Recent Alaska Mammals* (MacDonald and Cook 2007), and *The Amphibians and reptiles in Alaska, the Yukon, and Northwest Territories* (Hodge 1976) and compare the results with the Heritage Program's state species list. Working together, the modeling team and species team (described below), will develop criteria for inclusion of target species to be modeled and AKNHP staff will revise the list using the agreed upon criteria.

<u>*Identify species team members*</u>

One of the first steps in the modeling process will be to select the members of the "Species team". This team will be a core group of three to five individuals who will conduct the initial review of range and distribution maps and models, the habitat associations database, and other preliminary products and who will also help identify needed outside experts for review of draft maps and models. During 2006/07, AKNHP established contact with potential team members and expert reviewers (refer to Gotthardt and Fields 2008, Appendix II for full list). Team members will be selected based on geography, taxonomic expertise and ability to commit to the project for its full duration.

<u>*Develop geodatabase to support AK GAP*</u>

To provide a platform for documentation, storage, organization and distribution of all datasets associated with species modeling, we propose to develop a web-accessible geodatabase to support AK GAP. The geodatabase will store and display all preliminary maps and other datasets to be reviewed by experts and will provide a web-accessible portal for expert review. This will substantially reduce the amount of travel time necessary for review of draft maps and models, and other associated documentation. The geo-database will provide a single location to share datasets among project cooperators as well as provide a single location to back up the data. The geodatabase will be housed at the Arctic Region Supercomputing Center at the University of Alaska Fairbanks.

We will pattern the structure of the geodatabase from the web-accessible geodatabase currently being designed for the Northwest Re-Gap Project (see Beauvais 2005). We anticipate that revisions will be necessary to retrofit the Northwest geodatabase so that field names, etc… are applicable to Alaska; however, the basic structure and function of the Northwest Re-Gap database has been researched and product-tested and will likely require minimal modification for use in AK GAP.

Step 2: Produce preliminary range maps based on data from NatureServe and overlay with 8-digit HUCs. Decide upon data fields needed for occurrence database.

Delineating species ranges

Distributional limits are a necessary ingredient of the vertebrate modeling process, because they allow us to place bounds on where a species is predicted to occur. We define range, here, as the total areal extent occupied by a given taxon. Range maps are usually characterized by large all-encompassing polygons with very little interdigitation of occupied and unoccupied space (Beauvais and Master 2005, Beauvais 2006). Specific techniques and procedures for range mapping are presented in more detail below, and closely follow methods developed by Beauvais and Master (2005) for the Northwest Re-Gap Project.

The initial overlay of published maps has already been performed by NatureServe (Arlington, Virginia) for mammals, birds, and amphibians. These maps are publicly available (http://www.natureserve.org/getData/animalData.jsp) and are regularly reviewed and updated by Heritage Program biologists. During 2006/07, in preparation for GAP modeling activities, AKNHP staff downloaded NatureServe range maps for most terrestrial vertebrate species in Alaska, clipped them to the Alaska coastline and georeferenced them in a common projection (AK Albers). Once the target species list is finalized, we will identify the species for which range maps are missing (e.g., many of the subspecies) and produce range maps based on literature descriptions or other available data sources.

For each target species, we will delineate range extent using the best available information. Individual species range maps will be tessellated with 8-digit HUCs, which will act as the standard analysis unit (thereby replacing EPA's EMAP hexagons - the standard unit for most state-based GAP projects).

Select data fields for occurrence data

Acquisition, synthesis and organization of georeferenced species occurrence data is essential to accurately model and map species' range and distribution. A first step will be to establish standardized protocols and data fields to be used in databasing of species occurrence records. Standard Heritage data fields that will be suggested for inclusion are: Unique record ID, primary data source, secondary data source, species Latin name, species common name, infra-species designation, date of most recent observation, other observation dates, life history stage (when available), latitude and longitude coordinates of the geographic location of the observation (including projection, datum, accuracy and precision), observer name and affiliation, reliability of taxon identification, data sensitivity, and observation (point) type.

Step 3: Gather species occurrence data for select target species and conduct preliminary review of range maps by species team.

Occurrence Data Collection

AKNHP maintains an extensive database of documented and georeferenced species locations for vertebrate species within the state. We will use AKNHP's Biotics database as a starting point for existing occurrence data and capitalize on the expertise and infrastructure of AKNHP to act as a central clearinghouse for additional occurrence data gathered through this effort. A benefit to housing occurrence data at AKNHP is that it will remain dynamic, as it is periodically maintained and updated. Storing GAP data at AKNHP will insure the continued upkeep of species occurrence data and will also provide a portal for data distribution long after the AK GAP project is completed.

The occurrence data housed within the AKNHP Biotics database is mostly related to rare or threatened species, and even for the rare species (Heritage ranks G1-G3, S1-S3), some current documentation is lacking. For the more commonly occurring species, and for rare species with poor documentation, it will require substantial additional effort to compile, synthesize and georeference occurrence information gleaned from published and unpublished literature, museum specimen data, other existing wildlife databases, and unpublished data and field notes obtained directly from researchers.

Species occurrence databasing for Alaska will be guided by the AK GAP vertebrate species list, described in Step 1. Occurrence data acquisition, synthesis and organization above and beyond existing Heritage data will be assigned to one of the three regional modeling teams. Each team will be responsible for compiling and georeferencing individual species location information from published and unpublished sources, filtering the observation data for duplicate records, erroneous or suspect location information, and reconciling the numerous coordinate systems used to record locations from diverse data sets. Each team will provide a statewide dataset of documented occurrences to AKNHP, as comprehensive as possible, for each target species on the list for their region within 18 months.

Preliminary review of range maps
At this time, the species team will review and comment upon the preliminary range map for each assigned species. Recommendations for modifications will be in the form of adding or removing 8-digit HUCs to better define the target species range.

Step 4: Filter occurrence data for duplication and historical records and incorporate comments from species team on range maps to produce draft range maps. Attribute range maps with occurrence data.

Once the occurrence database is complete, occurrence data will be filtered to remove duplicate records. Occurrence data will also be filtered for historical records. The modeling team will determine the designation for "historical" based on the quality and quantity of available data.

The modeling team will review, assess, and if necessary, modify the preliminary range map for each assigned species to produce a draft range map (version two). The now completed occurrence data will be overlain with the draft range maps for individual species. Additional HUCs will be added to species maps for occurrence points that fall outside of the documented range. All HUCs in the range map will be attributed by the most recent date of documented observation of the target taxon. Due to the immensity and ruggedness of the Alaska landscape, and issues associated with accessibility that this engenders, it is likely that not all HUCS will be attributed with a date corresponding to occurrence data. However, at this stage, if a HUC is included in a species range, it is still suspected to be occupied, even if occurrence data are lacking. The result will be a third version draft range map attributed by most recent date of observation.

Step 5: Decide upon species that will only be modeled at the range level, assign select target species to modeling teams, and conduct expert review of draft range maps.

Once the species list is complete, we will attribute individual species by habitat specialization. This attribution will help guide decisions in relation to the intensity and type(s) of distribution modeling that will be required and, thus, the quality of occurrence data that will be necessary. For some of the extremely widespread and abundant vertebrates (e.g., *Ursus americanus*, *Turdus migratorius*), it is anticipated that we will produce only a range map. For some of the other rather cosmopolitan vertebrates (e.g. *Ovis dalii*), we may map their distribution through rather simple modifications to their range maps, such as deductive selection of particular land cover types. All remaining species will require more intensive modeling and mapping of distribution. This step will identify species in each category, and thereby assist in allocation of subsequent efforts by the modeling and species team.

Target species will be assigned to regional modeling teams based on a general inspection of range maps, i.e. species centered in a particular region (southcentral/central, southeast, or north/northwest) will be assigned to that regions team. Using the third version range maps attributed with occurrence data (Step 4) and the habitat specialization attributes described above, the species team will now decide on species that will only be modeled at the range level.

At this stage, it will be necessary to coordinate expert review of draft range maps. Reviewers will be asked to identify commission or omission errors for HUCs that define a species range.

Step 6: Identify species that can be modeled inductively and assemble needed environmental data layers for inductive modeling based on analysis of variation in environmental data.

The species team will review the occurrence data for each target species to determine which species have sufficient and representative data for inductive modeling.

Environmental data layers

During 2006/07, AKNHP acquired and processed numerous existing environmental datasets for use in future vertebrate distribution modeling exercises. The majority of the datasets were statewide in scale, although several regional datasets were also obtained. For species whose geographic range is restricted to Southeast Alaska, we will have access to all ancillary data housed within the UAS, Southeast Alaska GIS library (http://gina.uas.alaska.edu/joomla). A detailed list of existing ancillary data layers is provided in Gotthardt and Fields (2008; Appendix III). All data layers were georeferenced into a common projection (Alaska Albers) and datum.

Identify axes of variation in environmental data and select variable menu

Following methods developed by the Northwest ReGAP Project (Beauvais and Master 2005), we will perform statistical analyses to identify major axes of environmental variation in state-wide environmental datasets. We will use Principal Components Analysis (PCA) to explore continuous environmental gradients, and ordination techniques such as RandomForest and TreeNet for categorical variables such as landcover. Our goal with this analysis is to identify those variables that explain most of the environmental variation in the region and that are also relatively independent of one another.

The results of this analysis will be used to establish a menu of statewide- mappable variables for use in modeling the distribution of all taxa. We will also create a list of optional statewide -

mappable variables to be used in distribution modeling at the discretion of the species team as well as a list of regional variables (e.g. Southeast Alaska) for species that require more fine scale analyses (e.g., many insular endemic species). Mapping variable menus will be provided to the species team and expert reviewers to help guide variable selection for both inductive and deductive model development.

Step 7: Incorporate expert comments to produce final range maps, produce inductive models and have species team review preliminary output.
At this time, the modeling team will explore techniques being utilized by other state-based and regional GAP programs to incorporate contradictory comments from reviewers (e.g. Bayesian Belief Networks). Once a method has been decided on, we will use it to incorporate expert comments on draft range maps to produce a final range map for each target species.

Produce inductive models
The first step in this process will require filtering occurrence data, using estimates of home range size and other life history information, to reduce spatial autocorrelation. From the filtered occurrence data, we will select modeling and independent validation data sets (25% of occurrence points will be held back for model validation). For each target species, we will perform exploratory analyses of filtered occurrence data and all associated continuous and ordinal variables (from the variable menu produced in Step 6) to identify and prioritize those variables that best predict distribution. Another component of this analysis will be to determine if the target species is selecting for different ecoregions within its range. If ecoregion is selected as a high priority variable, the modeling team will need to more closely evaluate the need for separate distribution models in separate ecoregions (see Beauvais and Master 2005).

We intend to follow progressive and powerful inductive modeling methods such as outlined in Elith et al. (2005), which encompass Maximum Entropy (Maxent), TreeNet, RandomForest (boosting and bagging) and other advanced predictive methods (i.e. Mahanobilis Distance, Vector Machines, Ensemble Models). Inductive models will be developed for each target species identified in Step 6 using the filtered occurrence data, all continuous and ordinal variables identified through analyses, and a pseudo-absence dataset. The resulting map will be a biophysical “envelope” within which the target species is predicted to occur. Preliminary output from inductive models, including variable selection and modeling algorithms used, will be reviewed by the species team.

Step 8: Incorporate comments from review of preliminary output of inductive model and build upon existing habitat associations database for all species being modeled in Alaska.
Comments from the species team relating to the preliminary review of the inductive models will be incorporated by the modeling team to develop a second draft inductive model.

At the same time, AKNHP will continue to populate the habitat associations database in preparation for deductive modeling processes. The goal of the habitat association’s database is to identify, through documented sources, those physiographic characteristics with which a species is associated, that are mapped or can be derived from existing maps (Csuti and Crist 2000). Literature review, record location, and consultation with experts will be used to develop target species habitat associations. During 2006/07, AKNHP developed a preliminary structure for a habitat association's database to document and categorize wildlife-habitat relationships for use in deductive models. The database, constructed in Microsoft Access, contains fields for descriptions of habitats with which each species is associated, related references, elevational limits, habitat use dispersal distances for feeding, breeding, etc.., and fields to include modeling assumptions and caveats. We will improve upon the existing database structure by adding a matrix containing the ecological systems derived from the LANDFIRE map legend (available Sept. 2008, Boggs pers. comm.). The species team may also recommend additional fields (i.e. hydrographic features, soil texture characteristics, and landforms) to further aid with deductive model development.

During 2006/07, AKNHP acquired wildlife habitat relationship databases from WA-, OR- and MT-GAP, and vertebrate characterization abstracts from adjacent Canadian Heritage Program's (e.g., British Columbia). We populated the Alaska database for 37 pilot species using pertinent literature and what we were able to extract from the other wildlife habitat relationship databases.

AKNHP staff will conduct a literature review and continue to populate the habitat descriptions for the species on the AK GAP vertebrate species list not already included during the pilot. The descriptive habitat associations from the literature will then be cross-walked to ecological systems and other associated variables. This process will be overseen by the species team in association with AKNHP ecology staff and other invited experts. Once reviewed internally, a draft habitat associations database will be sent to experts for review.

Step 9: Build deductive models for those species for which there is sufficient habitat associations data.

We will build deductive models for each species for which there are sufficient habitat associations data. Deductive models will be developed following methods described by Csuti and Crist (2000) in the Gap Analysis Handbook. Deductive models will be derived using a combination of occurrence data, the ecological systems described for an individual species in the habitat associations database, and any additional categorical variables (e.g. landform, soil type) selected by the species team for a particular species. Additional life history variables (identified in Step 8) may also be incorporated into the model (i.e. distance to water, elevational limits).

In summary, we will extract associations for each species and determine if they are inclusive (e.g. include all landcover class z) or exclusive (e.g. distance to water buffer). The model will be written in the form of a query that selects and excludes categorical variables according to associations and ecoregions. The resulting map will be a draft deductive model.

Step 10: Conduct pilot project on combining inductive and deductive modeling techniques on the Kodiak Archipelago.

We will conduct a pilot project to test the proposed modeling methodologies. We have selected the Kodiak Archipelago for the pilot testing area: the archipelago is a microcosm of southern Alaska; it contains a range of landforms (islands, coast, interior, mountains, lakes, rivers), vegetation structural types (monotypic evergreen forest, deciduous forest/woodland, heathlands) and it supports land uses (urban, suburban, silvicultural, non-developed) characteristic of southcentral and southwestern Alaska. The Kodiak Archipelago was included in the first stage rollout of the LANDFIRE map, thus, ecological systems and the completed landcover map are currently available for pilot testing.

Nine mammals and 100 breeding birds are known to occur on the Kodiak Archipelago. Based on the quality of available occurrence data, habitat associations data, and environmental data, the modeling team will select a subset of these species to test a variety of inductive modeling algorithms and standard Gap-based deductive methods to model the distribution of target species. We will assess the accuracy of the draft maps and will also evaluate the efficiency of the review process by conducting a full expert review.

For this effort, we have garnered the support of wildlife staff from the Kodiak National Wildlife Refuge (which encompasses 1.9 million acres and approximately 2/3rds of the Kodiak Archipelago). Refuge staff will support the pilot by providing access to species and other refuge datasets, assisting with data interpretation and coordination of expert review, and providing in-kind logistical support.

Step 11: Using the results and lessons learned form the pilot project, combine inductive modeling and deductive modeling results to create preliminary distribution maps.

We will use the results of the pilot study to ascertain whether or not we need to modify our proposed methodologies, accuracy assessment techniques, or improve upon the review process. We will make all necessary changes to any of the preceding steps and rerun any prior analyses, if necessary, before proceeding with future modeling procedures.

Once we have incorporated any and all changes as a result of the pilot project, we will integrate the results of the draft inductive model (biophysical envelope) with the draft deductive model for each target species. The envelope will be clipped to only those portions that fall within the types designated as suitable on all categorical variables within the deductive model. We will then integrate (clip) species range limits into the combined draft distribution map. The goal here, in addition to the stand alone inductive and deductive models, is to achieve a predicted distribution map based on appropriate habitat and environmental variable associations, as limited (but not truncated) by range limits. The product of this map intersection will be a preliminary distribution map for each target species.

Step 12: Conduct an accuracy assessment of preliminary distribution maps and have maps reviewed by species team.

Similar to methods being employed by Northwest Re-Gap (Beauvais and Master 2005), and for consistency, we will assess the accuracy of each species model using a validation dataset (25% of occurrence points held back). Quantitative measures of accuracy will be calculated using area-under-curve (AUC) measures from receiver-operating-characteristic (ROC) plots, Boyce Indices (for presence-only approaches), r2 and similar metrics. Percentage of error associated with commission and omission and will be presented in a Confusion Matrix. In addition to these traditional metrics, we will consider the new development of error matrices that are robust to prevalence, as well as others that take autocorrelation and spatial distribution into account.

Similar to steps 3 and 7, at this point it will be necessary to have the species team review results of the preliminary distribution map, underlying raw data and validation statistics.

Step 13: Incorporate comments from species team to produce draft distribution maps.
Based on the results of the accuracy assessment, the species team may provide recommendations on how to increase the accuracy of specific species models. Draft distribution maps for target species will be produced by incorporating species team comments and repeating steps 11and 12, if required.

Step 14: Conduct expert review of draft distribution maps.
Finally, the species team will coordinate expert review of draft distribution maps, underlying raw data and validation statistics. Experts will provide input on model quality and make recommendations for adjustments to model variables similar to how species teams provided their initial input. Essentially, steps 7 to 13 will be repeated by expert reviewers, rather than the species team, and they will review and modify the most updated map products.

Step 15: Incorporate comments from outside experts and results of accuracy assessment to produce final distribution maps.
By summarizing all expert input and resolving conflicting expert inputs for each target species (described in Step 7), the modeling team will produce final distribution maps for each target species. Final distribution mapping and validation will occur by repeating the modeling process for any species distribution map in need of revision as recommended by experts.

Step 16: Send all final range and distribution maps and models, along with all associated data to the National Gap Analysis Program for quality assurance/quality check (QA/QC) review and write final project report.
We will send all final distribution maps, models and associated data and documentation to the National Gap Analysis Program for quality assurance/quality check (QA/QC). While the data undergo QA/QC, we will produce a final report that summarizes project methodologies, analyses and results. If required, we will make all necessary changes to final distribution maps as per the comments from the National Gap Analysis Program. Once the final distribution maps have been approved, we will collate them into a vertebrate species distribution atlas.

<u>**Preliminary Results and Prior Work (if applicable*):***</u> During 2006/07, AKNHP received preliminary funding to explore the potential for implementing species distribution modeling efforts in Alaska. During that year we were able to establish a core team of modelers and advisors; garner support from stakeholders from private industry, non-profit and tribal organizations, and state and federal agencies and universities; identify needs and uses for GAP data products; received recommendations on data products and data delivery systems that would be most useful for conservation planning; designed a preliminary structure for a habitat associations database and populated it for select species; assembled ancillary data sets for distribution modeling; identified and tested new distribution modeling approaches that utilize traditional GAP-based deductive models and new inductive techniques to generate more robust and accurate models; and developed a project web-site, ftp-site and listserve in preparation for information exchange. See Gotthardt and Fields (2007) for summary report.

<u>**Planned Products:**</u> The Alaska Gap analysis will produce a number of products. First, we will produce interim progress reports at the end of each funding cycle during the first 2 years. Second, at the end of the third year, we will summarize all project methodologies, analyses and

results in a final technical report. Third, we will collate the final species distribution maps to produce a comprehensive Alaska Species Distribution Atlas. Fourth, to conduct outreach about Alaska Gap project and Alaska biogeography among the public and non-technical groups, we will combine and modify the Alaska Species Distribution Atlas and our final report into a single condensed and simplified document. Fifth, raw species-occurrence data will be made available as a consolidated database in both tabular form and as georeferenced spatial data in geodatabase formats. These data will adhere to conventional statewide and national data standards (AGDC, etc.) and include comprehensive metadata with relevant links to additional information about data production, QA & QC, etc. Sixth, to support other analytical and/or educational efforts among agencies in the state of Alaska and the university system, we will provide environmental data sets and associated secondary products from base imagery (e.g. LANDFIRE products) as a consolidated database of digital raster coverages that have been standardized. These data will also adhere to conventional statewide and national data standards (AGDC, etc.) and include comprehensive metadata with relevant links to additional information about data production, QA & QC, etc. Seventh, modeled products such as target-species distribution will be made available to collaborators in digital raster format (and in other formats, on request) with associated documentation. Eighth, we anticipate producing at least 1 peer-reviewed publication focusing on relevant topics such as the conservation status of target species, case studies in biogeography, and/or research techniques in biogeographic modeling. And finally, ninth, F. Huettmann and S. Pyare will develop educational coursework and workshop curricula at the University of Alaska that highlight Alaska Gap case studies, data, techniques and other products as central themes.

Dissemination of Project Results: Relevant products (interim and final reports, the Alaska Species Distribution Atlas, and the public report) will be made available to the National Gap Analysis Program via the internet through the project website and ftp, as well as CD-ROM format with appropriate documentation. Project results will be disseminated to product end-users and the public in Alaska through a variety of media. Simpler data products, such as the species occurrence database, will be made available in tabular & geodatabase formats through regional and national data clearinghouses (e.g. the Southeast Alaska GIS Library, Nature Serve) as well as viewable in interactive formats through statewide and regional Internet Mapping Service (IMS) applications (e.g., Alaska Mapped, GINA - UAS). Larger data products (environmental datasets and modeling products) will be distributed on request via DVD-format and ftp. Principal investigators will present more technical results of the statewide analysis at local (Anchorage Audubon), statewide (Alaska Bird Conference, the Wildlife Society annual meeting) and national (GAP Analysis Conference) conferences and working group meetings. In addition, we intend to publish any applicable results of original or innovative methods in relevant peer-reviewed journals, such as the Journal of Biogeography, Diversity and Distributions. Finally, a critical form of dissemination will occur among Alaska's next generation of scientists, natural resource managers, policy makers, and school teachers through the enhancement of educational curricula at the University of Alaska. Several technical and non-technical undergraduate and graduate courses (including those attended by K-12 school teachers) in introductory environmental science and biology, landscape ecology, biogeography, introductory and advanced GIS, and remote sensing, will be modified to explicitly incorporate several facets of the Alaska Gap project, including case studies, species occurrence and environmental datasets.

References cited:

Alaska Natural Heritage Program. 2007. Database query for all terrestrial vertebrates known to occur in Alaska from the Heritage Program's Biotics database.

Beauvais, G.P., D.A. Keinath, P. Hernandez, L.Master and R. Thuston. 2006. Element distribution modeling: a primer. Wyoming National Diversity Database, Laramie, WY. 42pp.

Beauvais, G. and L. Master. 2005. Proposed procedure for modeling range, distribution, and habitat quality for vertebrates for Northwest Re-Gap.

Csuti, B. and P. Crist. 2000. Methods for developing terrestrial vertebrate distribution maps for Gap Analysis. Gap Analysis Handbook. Accessed online at: http://gapanalysis.nbii.gov.

Elith, J., C.H. Graham, R.Anderson, M.Dudik, S. Ferrier, A. Guisan, R.J. Hijmans, F. Huettmann, J.R. Leathwick, A. Lehmann, J. Li, G. Lohmann, B.A. Loiselle, G. Manion, C. Moritz, M. Nakamura, Y. Nakazawa, J.McC. Overton, A.T. Peterson, S.J. Phillips, K. Richardson, R. Scachetti-Pereira, R. E. Schapire, J. Soberon, S. Williams, M.S. Wisz and N.E. Zimmermann. . 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography 29:129-151.

Ferrier, S. and A. Guisan. 2006. Spatial modeling of biodiversity at the community level. Journal of Applied Ecology 43: 393-404.

Gibson, D.D., S.C. Heinl and T.G. Tobish, Jr. 2008. Checklist of Alaska Birds. University of Alaska Museum, Fairbanks.

Gotthardt, T. and T. Fields. 2008. Alaska Gap Analysis Project: Phase I Final Report. Assembling ancillary data and convening cooperators and species teams for GAP vertebrate distribution modeling efforts in Alaska. Alaska Natural Heritage Program, University of Alaska Anchorage, 31 pp.

Guisan, A. and W. Thuiller. 2005. Predicting species distribution: offering more than simple habitat models? Ecology Letter 8:993-1009.

Guisan, A. and N.E. Zimmerman. 2000. Predictive habitat distribution models in ecology. Ecological Modeling, 135: 147-186.

Hodge, R.P. 1976. Amphibians & reptiles in Alaska, the Yukon, & Northwest Territories. Alaska Northwest Publishing Company, Anchorage, AK. 89 p.

MacDonald, S.O. and J.A. Cook. 2007. Checklist of recent Alaska mammals. University of Alaska Museum, Fairbanks.

Pearson, R.G. 2007. Species Distribution Modeling for Conservation Educators and Practitioners. Synthesis. American Museum of Natural History. Available at: http://ncep.amnh.org.

Scott, M.J., F. Davis, B. Cusuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D.Erchia, T.C. Edwards, J. Ulliman, and R.G. Wright. 1993. GAP Analysis: A Geographic Approach to Protection of Biological Diversity. Wildlife Monographs 123:1-41.

Scott, J.M., P.J. Heglund, J.B. Haufler, M. Morrison, M.G. Raphael, M.B. Wall and F. Samson. 2002. Predicting species occurrences: issues of accuracy and scale. Island Press, Covelo, CA.

Smith,C., S. Feirer, R. Hagenstein, A. Couvillion and S. Leonard. 2006. A conservation blueprint for Alaska: Assessing Protection of Alaska's Terrestrial Biodiversity. The nature Conservancy of Alaska, Anchorage. 16 pp.

Project Personnel:

Tracey Gotthardt, Program Zoologist, Alaska Natural Heritage Program

Tracey has been the Program Zoologist at the Alaska Natural Heritage Program (AKNHP) since 2000. She received her B.S. in Biology from Radford University and her M.S. in Ecology from the University of Alaska, where her thesis work involved modeling the interactions of harbor seals in relation to their prey in Prince William Sound, Alaska. She then worked for the USFWS Migratory Bird Management Program, where she studied seabird foraging interactions and developed models to predict the distribution of prey species. Since joining AKNHP as the staff zoologist, she has been responsible for program development, and planning, conducting, and directing conservation related research projects. These have included inventory and monitoring projects in both marine and terrestrial environments, coordinating with state, federal, and NGO organizations to identify conservation targets, and development of educational curricula and public outreach programs. A large component of her current work involves development and management of a GIS database for monitoring conservation status and mapping the occurrence of Alaska's species of concern. She is assisted by a staff zoologist, two research technician, and two data managers.

Dr. Falk Huettmann, University of Alaska Fairbanks, EWHALE lab

Falk is a 'digital naturalist' working for the global village. He studied Forestry at the Universities of Goettingen, Freiburg/ NISK-Norway and Munich. After working at a Whale Watching/Research Facility in Norway, he received a Robert-Schuman Scholarship from the European Parliament in Luxemburg on fisheries, and collaborated with a Conservation NGO in Brussels. Traveling and working in Africa, Russia and Europe on wildlife, conservation and biological computing and database topics, he did his PhD in Eastern Canada on GIS-Databases and Pelagic Seabird Distribution Modeling. He then started his Russian research in the Sea of Okhotsk on 'Australian shorebirds', and worked for two years as a Research Coordinator at Simon Fraser University, Vancouver, on Marbled Murrelet's and Old-Growth Forests. Falk became a Killam PostDoc-Fellow with the Geography Department, University of Calgary, developing Future Landscape Model Scenarios for Grizzly Bears in the Rocky Mountains using Remote Sensing and software. Falk teaches tropical and other field schools, and has extensive experience with Governmental Agencies as well as with Metadata/online biodiversity database sharing. Currently, Falk collects data in Papua New Guinea and Central America, and is involved with databases and predictive synthesis modeling in Polar regions. He works with the ArcOD project on Arctic Biodiversity, models Alaska's landscape corridors, and is an Assistant Professor in Wildlife Ecology with the University of Alaska, where his EWHALE lab does projects on digital Land- and Seascape Ecology world-wide.

Dr. Sanjay Pyare, University of Alaska Southeast

Sanjay has been a Professor of GIS and Landscape Ecology at the University of Alaska Southeast in Juneau, Alaska, since 2005. He has a Ph.D. in Conservation Biology from the University of Nevada Reno and a B.S. in Biology from Hartwick College. His research foci are the biogeography and landscape ecology of Alaska biota, as well as quantitative spatial analysis in natural resource management contexts. He coordinates the regional node of Geographic Information Network of Alaska (GINA), a spatial analysis and geospatial outreach center which also houses the Southeast Alaska GIS Library, a multi-agency project with the Nature Conservancy, U.S. Forest Service, U.S. Fish and Wildlife Service, and the Alaska Dept. of Fish and Game. His research includes an NSF-funded project to develop Biogeo-Informatix: a portal that integrates biological, geospatial, and local-knowledge databases in a GIS to model and monitor species distributions. He is also a project co-leader in the Landscape Genetics research group, an NSF-EPSCoR project that is conducting a cross-cutting research in historical, current, and future aspects of Alaska biogeography. He is currently also President of the Northwest Section of the Wildlife Society, and he is assisted by 1 post-doctoral researcher, 2 fulltime research associates, and 3 graduate students.