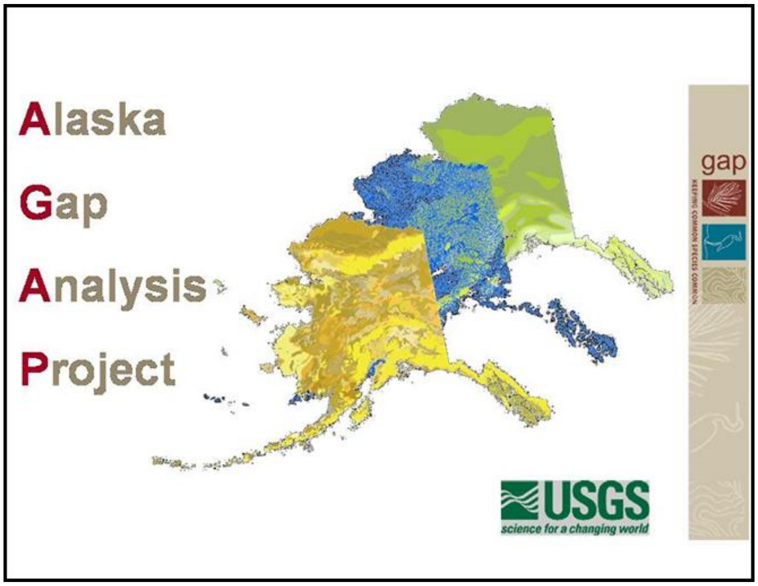
PREDICTING THE RANGE AND DISTRIBUTION OF TERRESTRIAL VERTEBRATE SPECIES IN ALASKA

DRAFT REPORT



Tracey Gotthardt, Sanjay Pyare, Falk Huettmann, Kelly Walton, Miles Spathelf, Kelly Nesvacil, Andy Baltensperger, Grant Humphries, and Tamara Fields

Alaska Natural Heritage Program
University of Alaska Anchorage
Anchorage, AK

Environmental Science & Geography Programs
& Spatial Ecosystem Analysis Lab (SEALAB)
University of Alaska Southeast
Juneau, AK

EWHALE lab-Biology and Wildlife Department
Institute of Arctic Biology
University of Alaska Fairbanks
Fairbanks, AK

Photo credit: Bill Thompson

Recommended Citation:

Gotthardt, T., S. Pyare, F. Huettmann, K. Walton, M. Spathelf, K. Nesvacil, A. Baltensperger, G. Humphries, and T.L. Fields. 2014. Predicting the Range and Distribution of Terrestrial Vertebrate Species in Alaska Draft Report. The Alaska Gap Analysis Project. University of Alaska.

Table of Contents

List of Tables

List of Figures

The Gap Analysis Concept

The Gap Analysis Program (GAP) is a nation-wide program administered by the U.S. Geological Survey (USGS). The overall goal of GAP is to assess the extent to which species and vegetative communities are represented within the protected areas network (Scott et al. 1993). Gap analysis has been used to assess conservation status and the need for protection in light of landscape changes, habitat loss, and climate change (Mackey et al. 1988, Fairbanks and Benn 2000, Rodriguez et al. 2007), as well as informing decisions about land management priorities (Scott et al. 1993, Maxted and Dulloo 2008). It has also been used to evaluate the distribution of reserves in a landscape by identifying areas that are potentially rich in biodiversity, but are not well protected (Scott et al. 1993, Margules and Pressey 2000).

Introduction

Species distribution models are predictions about the occurrence of species within a particular area (Csuti 1994). Traditionally, the predicted occurrences of most species begin with samples from collections made at individual point locations. Most species distributions are small-scale (e.g., >1:10,000,000) and derived primarily from point data for field guides. The purpose of the GAP vertebrate species distribution maps is to provide more precise information about the current distribution of individual native species within their general ranges. With this information, better estimates can be made about the amount of habitat available for individual species and the configuration of the habitat.

Gap analysis uses predicted distributions of native vertebrate species to evaluate their conservation status relative to existing land management (Scott et al. 1993). Maps of vertebrate species distributions created by GAP may be used to answer a wide variety of management, planning, and research questions related to individual species or groups of species. In addition to the maps, great utility may be found in the collection of occurrence records and summaries from the literature that are assembled into databases used to produce the maps.

Spatial models are an important tool for understanding wildlife-habitat relationships and for guiding natural resource management decisions (Pearce and Ferrier 2000, Penhollow and Stauffer 2000, Brugnach et al. 2003). For predictive models to be useful tools in the decision making process they must be accurate, general, and easy to apply (Van Horne and Weins 1991). Techniques employed to model the predicted distribution of species have made substantial advances since the implementation of the first state-based GAP projects in the early 1990s. While the basic concepts remain the same, the techniques and the utility of the output have also improved, providing resource managers and planners finer scale estimates of probability of presence across large land areas (Beauvais et al. 2013).

The species distribution modeling component of the Alaska Gap Analysis Project (AKGAP) provides a statewide perspective on the distribution of vertebrate species in Alaska. Prior to this effort there were few maps available, digital or otherwise, showing the likely present-day distribution of species across their ranges in the state. Because of this, many species (i.e., those not threatened with extinction or not managed as game animals) are generally not given sufficient consideration in land-use decisions in the context of large geographic regions or in relation to their actual habitats. Creating a consistent spatial framework for storing, retrieving, manipulating, analyzing, and updating the totality of our knowledge about the status of each vertebrate species is one of the most necessary and basic elements for ensuring that rare species and the more common species are included in day-to-day management decisions.

Objectives

The objective of this project was to produce spatially explicit models, using consistent and repeatable methodologies, to predict the range and distribution of terrestrial vertebrate species in Alaska to support analysis of conservation status. Traditional GAP deductive modeling techniques that crosswalk species habitat associations to land cover classes, and rely heavily on expert opinion, may not be adequate to predict the distribution of all terrestrial species in Alaska. In a landscape as vast as Alaska, it is likely that expert opinion is significantly lacking for most habitat types. Therefore, to achieve our modeling objectives, we utilized information and techniques developed by earlier Gap Analysis Projects (Cassidy et al. 1997, Boykin et al. 2007), and also applied some of the newer machine-learning modeling techniques being used by the Northwest Gap Project (e.g., using the MAXENT modeling software package to produce models that are independent of land cover data; Aycrigg and Beauvais 2007, Beauvais et al. 2013), in an attempt to improve the quality, precision, and application of the species distribution maps.

Project Partners

Funding for this project was provided by the U.S. Geological Survey, National Gap Analysis Program. J. Aycrigg served as the vertebrate species modeling coordinator, while K. Gergely and A. McKerrow served as project managers.

AKGAP project staff represented a broad range of expertise drawn from the three University of Alaska (UA) campuses: Anchorage (UAA), Southeast (UAS), and Fairbanks (UAF). The workload for the project was divided among the three university campuses, with UAA serving in a coordination role. This core group of staff is referred to as the “species modeling team” throughout this document. The species modeling team helped design the modeling approach, gathered occurrence data and literature sources, and coordinated the review of each iteration of the models

Additionally, staff at UAA was responsible for synthesis of occurrence data and data management, synthesis, review and cross-walk of habitat relationships information, range map development, model development, expert review coordination, and final project synthesis. UAA staff included T. Gotthardt, M. Spathelf, K. Walton, K. Nesvacil, and T. Fields.

Staff at UAS was responsible for creating all ancillary data layers used in the modeling process. They were also instrumental in creating and maintaining the web-based expert review portal. UAS staff included S. Pyare, M. Callahan, J. Nielson, K. Holman, and M. Plivelich.

UAF staff assisted with range map and metadata development, developed the code to automate inductive modeling, and scripted and conducted the model assessment. UAF personnel included F. Huettmann, A. Baltensperger, G. Humphries, and M. Lindgren.

Methods

Species List Development

The focus of this project was terrestrial vertebrate taxa, including birds, mammals and amphibians. To develop our list of species for modeling we consulted the *Checklist of Alaska Birds* (Gibson et al. 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), the Species of Greatest Conservation Need (SGCN) in the State of Alaska's Wildlife Action Plan (ADF&G 2006, Appendix 7), and compared these to Alaska's Heritage Program's state species list. This initial species list was as broad as possible and included numerous infra-taxa. We then sequentially excluded taxa that did not meet the selection criteria described below. Taxonomy and scientific and common names were updated throughout the course of the project and standardized following the Integrated Taxonomic Information System (ITIS, http://www.itis.usda.gov). The ITIS code was preserved through all subsequent processing of the species list, and used throughout the project as the unique taxon identifier.

<u>Seasonal attribution for migratory taxa:</u> We recognized that seasonality of migratory taxa was an important consideration when producing our range and distribution maps, especially for avian taxa that only spend time breeding and rearing young in Alaska, yet winter outside the state. Because we were most interested in modeling the distribution of taxa that were either resident or known breeders in the state, we assigned a seasonal attribute to the original list of taxa that was either: "breeding", "non-breeding" (wintering), or "both" (year-round resident, non-migratory).

For each target taxon, we produced a range map that addressed occurrence in all seasons. However, due to time and resource constraints, as well as limited data availability during winter months, we only produced distribution models for taxa known to breed in the state. Furthermore, we did not model the distribution of any taxa during migration.

Scant information is available about the migratory movements of bats in Alaska (Parker et al. 1997), therefore all bats were considered "year-round" residents and modeled accordingly. For migratory birds, modeling seasons were derived from the Birds of North America species accounts (BNA; accessed online: http://bna.birds.cornell.edu/bna/) and the Guide to the Birds of Alaska (Armstrong 2008). Modeling season was assigned by inspecting the BNA distribution map for each taxon. We then consulted Armstrong (2008) to ascertain whether the species was a confirmed breeder in the state, or whether their occurrence during the breeding season was casual or accidental. Only taxa identified as confirmed breeders (which included year-round residents) were retained for distribution modeling.

<u>Derivation of final taxa list:</u> Once the initial list was fully attributed, including all seasonal information, we developed seven "taxa inclusion decision rules" to identify the final list of species for modeling. Taxa excluded from the initial list were:

1. Purely marine taxa (e.g. cetaceans, non-breeding seabirds that remain exclusively at sea while foraging along the Alaska continental shelf).
2. Taxa with only incidental, accidental, or vagrant occurrence in Alaska; this also included avian taxa only known to occur in Alaska during migration but do not breed in the state.
3. Taxa for which recent authoritative taxonomic sources eliminated unique standing (i.e., taxa recently lumped with others).
4. Taxa extirpated from Alaska for 20 years or >5 demographic generations, whichever is greater (e.g., Eskimo curlew; *Numenius borealis*).
5. Taxa representing unsuccessful introduction or re-establishment in Alaska.

Exotic (non-native) taxa that persist in primarily urban environments (e.g. Norway rat, *Rattus norvegicus*, Rock Dove, *Columba livia*) and non-native taxa that occupy and persist in wild or semi-wild environments, and merit at least some management concern (e.g., Mule deer, *Odocoileus hemionus*), were retained on the target list.

6. Exotic taxa.
7. Recognized sub-taxa (e.g., subspecies) that do not differ enough in patterns of environmental use to be treated as modeling and mapping entities distinct from other sub-taxa within the same species. Such sub-taxa were lumped at the species level; e.g., all six subspecies of ermine (*Mustela erminea* ssp.) were treated as a single *M. erminea* taxon throughout the project.

Our final list of vertebrate taxa consisted of 6 amphibians, 266 birds, and 75 mammals for a total of 347 species or sub-taxa (see Appendix A; species list by taxonomic group, common name, scientific name, and ITIS code).

Occurrence Data Acquisition and Organization

Occurrence data were acquired from numerous and disparate data sources, many that utilized different observers, survey methods, and objectives. Major sources of information included the Biotics database of the Alaska Natural Heritage Program (http://aknhp.uaa.alaska.edu/maps/biotics/); data from annual bird monitoring efforts (e.g., the North American Breeding Bird Survey and the Alaska Landbird Monitoring Survey, ALMS); nationwide avian databases (e.g. eBird and the Avian Knowledge Network); museum specimens (notably the University of Alaska Museum); global natural history records databases (e.g., Global Biodiversity Information Facility, GBIF); regional avian surveys (e.g., USFWS North Slope Eider Survey); and numerous and varied unpublished data sets from local and regional wildlife biologists and university researchers.

Occurrence records were summarized in a common format and attributed with 39 common fields. A complete list of occurrence database fields is shown in Appendix B. Positional accuracy (if not provided) was estimated based on the record's mapping protocol using standards established by the Natural Heritage Network (http://www.natureserve.org/prodServices/standardsMethods.jsp). All records were stored in a geodatabase that was queried as needed for analysis and modeling.

Range Mapping

We defined a species range 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 (Aycrigg and Beauvais 2007). Range maps were developed for each target taxon to provide the biological context within which to build our distribution models.

We developed a range map for each taxon using 8-digit hydrologic units (HUC8s) as map units, following methods employed by other recent regional GAP range mapping efforts (Boykin et al. 2007, Beauvais et al. 2013). At the time we initiated the range mapping process, 8-digit HUCs were the finest scale state-wide hydrologic unit layer available. This scale was also consistent with the HUC8s used by SWReGAP Program for their species range mapping efforts (Boykin et al. 2007).

We acquired initial polygon range maps for individual taxa from NatureServe (http://www.natureserve.org/getData/animalData.jsp) and from the Alaska Natural Heritage Program. We then tessellated each polygon range map into its constituent HUC8s (Figure 1).

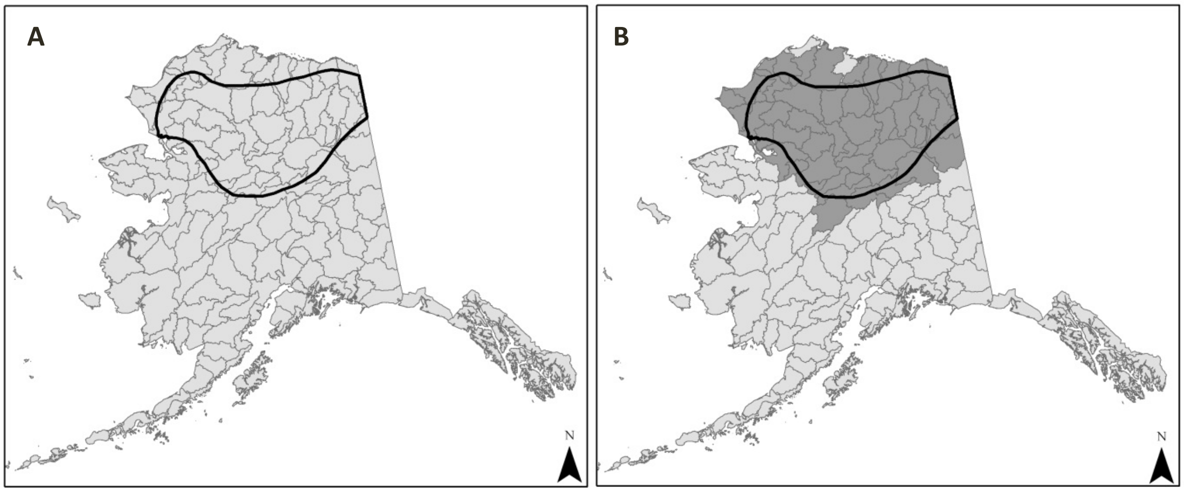


Figure 1. HUC8 range map processing steps. (A) Area outlined in black indicates the original (polygon) range map for the Alaska marmot (*Marmota broweri*) overlaid on HUC8s. (B) Dark gray area indicates all HUC8s that intersected or were included within the original polygon range map, and was considered the final HUC8 range map.

We then assigned initial values for two attributes to each HUC8:

Season: Possible values were Summer, Spring/Fall, Winter, and Year-round. Especially for migratory taxa, the value of the Season attribute was assigned with the specific modeling season (e.g., Breeding equates with Summer) in mind. Seasons were broadly defined as follows: Winter (December - February); Fall/Spring (March - May and August - November); Summer (June or July); Year-round (all months).

Occurrence: Possible values were Known, Suspected, or Historical. “Known” equated to the presence of documented occurrences of the target taxon, or confident expert prediction of occurrence, within a given HUC8. To do so, we overlaid occurrence data for each target taxon with their HUC8 range map in ArcGIS 10.0. New HUC8s were added if there was persistence in the occurrence points (>3 within a 10 year span) that fell outside of the documented range. All HUCs in the range map were then attributed by the most recent date of documented observation of the target taxon.

If occurrence data were lacking for a given HUC8, but the HUC8 was part of the original range map, then it was attributed as “Suspected”. “Historical” indicated the last known record of occurrence for a given HUC8 predated 1910.

Range maps underwent two internal reviews by the species modeling team and a single external review by species experts. Phase I range maps were assessed by the species modeling team and included a HUC-by-HUC review of range attributes for individual taxa. Reviewers could suggest any changes they thought necessary to improve any range map in the set. Recommendations for changes were generally supported with documentation. The species modeling team had access to all occurrence records for all target taxa during this review phase, and thus their edits were informed by patterns of documented observations.

The UAA modeling team collected and compiled the first-phase edits, and re-issued all range maps (including those changed during the first round of editing) for a second round of internal editing. Phase II edits were intended to ensure an adequate degree of consistency across all taxa, as well as ensure all Phase I edits had been applied correctly. The UAA modeling team reviewed and compiled the second-phase edits, resulting in a final range map for each target taxon. These final range maps were then reviewed by outside experts. This assessment was conducted simultaneously with final reviews of distribution models (described below).

Environmental Variables

The AKGAP species modeling team began selection of environmental predictor variables by deciding which factors would potentially affect the distribution of species in each of the three vertebrate classes (i.e. Mammalia, Amphibia, and Aves). General categories considered were geological, hydrological, physiographical, ecological/biological, anthropogenic, and climate factors. We then investigated a suite of data sources and reviewed these for availability of relevant data of reasonable resolution (<1-km) at the statewide scale.

To prepare environmental variables we processed each layer using the following methods:

- Merging tiled subsections of a variable.
- Defining a key attribute (e.g. distance to wet vegetation) and the units (e.g. meters) for each variable.
- Standardizing the coordinate system to datum of NAD1983 and projection of Alaska Albers. In situations where geographic transformations from original datums (i.e. NAD27, Clarke 1860, WGS84) were required, we used the best conventional ESRI transformation methods available for the statewide scale of Alaska. Because these methods uniformly applied a transformation algorithm across the very large longitudinal and latitudinal extent of Alaska, some offsets (~90±60m) were observed at the extreme margins of the state and accepted as inherent biases of these data.
- Vector based data were transformed to raster (ESRI *.grd) format.
- Grid cell size of any grid with cell resolution >60m was resampled to a standard of 60m using a nearest neighbor replacement technique ("Nearest" option of the Arctoolbox Resample tool in ESRI ArcGIS 10.x software).

Variables were run through a filtering process to standardize the modeling extent ("Filter"; Table 1) to a region consisting of the entire mapped land surface of Alaska ("Coast"; Table 1) plus a zone extending 200±50m from the coastline.

Any grid cells (e.g., "holes") with a no-data value in original data or created as a consequence of extending features to the modeling extent (above) were converted to a null (-9999) value using "Null" feature (Table 1).

Table 1. Intermediate features used to process variables used in inductive and deductive modeling.

Feature	Description	Use
Filter	Grid with an extent 200±50m from the coast of Alaska	Defined a common extent and range of inference for all modeling
Null	Grid of background (no-data) values	Defined missing values in model variables
Coast	Extent of landbase in Alaska	Defined the interface of land and marine extents

We processed and derived 81 grids from the environmental variables listed in Table 2 for initial modeling. Variables from within this dataset were ultimately selected for final distribution modeling. Our selection criteria for different modeling procedures are described below.

Table 2. List of all environmental variables (n=81 grids) created and screened for inclusion in species distribution models for the Alaska Gap Analysis Project. Note that three variables (denoted by asterisks) are comprised of 12 individual grids. A subset of the 12 monthly temperature variables (n = 8) were included in the inductive models: tmean01, 02, 03, 04, 05, 09, 11, 12. Environmental variables selected for inclusion were based on permutation importance values from preliminary screening of MaxEnt outputs (inductive models) or relevance to defining habitat associations (deductive models; see text for details). Appendix C contains detailed descriptions for each of the variables selected for inclusion in modeling.

Variable Group	Variable	Description	# Grids	Variable Type	Model Type	Used in Final Model
Geology	Surficial Geology	Type of surficial geology substrate	1	Categorical	Inductive	Yes
Geology	Soils	Value based on soil type	1	Categorical	Inductive	Yes
Hydrology	Flowing-Water Presence	Presence of flowing water	1	Categorical	Deductive	Yes
Hydrology	Flowing-Water Distance	Distance to flowing water	1	Continuous	Inductive	No
Hydrology	Flowing-Water Distance Class	Distance class into/from flowing water	1	Categorical	Deductive	No
Hydrology	Non-Flowing-Water Presence	Presence of non-flowing water	1	Categorical	Deductive	Yes
Hydrology	Non-Flowing-Water Distance	Distance to non-flowing water	1	Continuous	Inductive	Yes
Hydrology	Non-Flowing-Water Distance Class	Distance class into/from non-flowing water	1	Categorical	Deductive	No
Hydrology	All Water	Presence of fresh and salt water	1	Categorical	Deductive	No
Hydrology	Freshwater	Presence of fresh water	1	Categorical	Deductive	No
Hydrology	Saltwater	Presence of salt water	1	Categorical	Deductive	No
Hydrology	Salinity	Presence of saline or non-saline waters	1	Categorical	Inductive	No
Hydrology	Summer Sea-Ice Distance	Distance to sea ice	1	Continuous	Inductive	Yes
Hydrology	Winter Sea-Ice Distance	Distance to sea ice	1	Continuous	Inductive	Yes
Hydrology	Glacier Distance	Distance to glacier	1	Continuous	Inductive	Yes
Hydrology	Permafrost Distance	Distance to permafrost boundary	1	Continuous	Inductive	Yes
Hydrology	Water Table	Depth	1	Continuous	Inductive	No
Hydrology	Water-Wetland Vegetation*	Presence of water-wetland vegetation combinations	12	Categorical	Deductive	Yes
Physiography	Elevation	Elevation	1	Continuous	Inductive	Yes
Physiography	Slope	Percent slope	1	Continuous	Inductive	No
Physiography	Aspect	Degrees from due south	1	Continuous	Inductive	No
Physiography	Terrain	Ruggedness index	1	Continuous	Inductive	No
Boundaries	Coastline Distance	Distance to coastline	1	Continuous	Inductive	Yes
Land cover	Vegetation	Value based on LANDFIRE existing vegetation type (EVT)	1	Categorical	Inductive & Deductive	Yes

Category	Variable	Final Attribute	# Grids	Variable Type	Model Type	Final Model
Land cover	Land cover	Value based on land cover type	1	Categorical	Inductive & Deductive	No
Land cover	Wetland-Vegetation	Presence of wetland vegetation	1	Categorical	Deductive	Yes
Land cover	Wetland-Vegetation Distance	Distance to wetland	1	Continuous	Inductive	No
Land cover	Wetland-Vegetation Distance Class	Distance class into/from wetland vegetation	1	Categorical	Deductive	No
Land cover	Alpine Distance	Distance to alpine cover type	1	Continuous	Inductive	No
Development	Disturbance / Avoidance	Level of anthropogenic development	1	Categorical	Deductive	Yes
Development	Infrastructure Distance	Distance to infrastructure	1	Continuous	Inductive & Deductive	No
Disturbance	Insect Damage History	Year of damage	1	Categorical	Inductive	No
Disturbance	Insect Damage Distance	Distance to insect damage	1	Continuous	Inductive	Yes
Disturbance	Fire History	Year of fire	1	Categorical	Inductive	No
Disturbance	Fire location	Distance to fire	1	Continuous	Inductive	No
Climate	Precipitation Monthly*	Average monthly precipitation	12	Continuous	Inductive	No
Climate	Precipitation Annual	Average annual precipitation	1	Continuous	Inductive	No
Climate	Temperature Monthly*	Average monthly temperature	12 (8)	Continuous	Inductive	Yes
Climate	Temperature Annual	Average annual temperature	1	Continuous	Inductive	No
Climate	First Thaw	Julian date of first thaw	1	Continuous	Inductive	Yes
Climate	First Freeze	Julian date of first freeze	1	Continuous	Inductive	Yes
Climate	Growing-Season Length	Number of days in growing season	1	Continuous	Inductive	No
Climate	Insolation	Incident solar radiation value	1	Continuous	Inductive	No
Climate	Wind	Level of wind exposure	1	Categorical	Inductive	No
Ecological	Forest-Edge Distance Class	Distance class into/from forest edge	1	Categorical	Deductive	Yes
Ecological	Forest-Ecotone Width Class	Ecotone width class from forest edge	1	Categorical	Deductive	Yes
Ecological	Forest/Shrub-Edge Distance Class	Distance class into/from forest and shrub edge	1	Categorical	Deductive	No
Ecological	Forest/Shrub-Ecotone Width Class	Ecotone width class of forest and shrub	1	Categorical	Deductive	No

Distribution Models

We defined a species distribution as the spatial arrangement of environments suitable for occupation by a species (Beauvais et al. 2013). A species' distribution map, at 60 meter resolution, was created using a model to predict areas suitable for occupation within its range.

In keeping with methodologies employed by most state-based GAP projects, we elected to model the distribution of all target taxa using traditional land-cover based deductive techniques (Csuti and Crist 1998). However, we recognized from the start the limitations of this modeling approach for an area as vast as Alaska. Specifically, habitat associations for many target taxa are not well known or described throughout their range across the state. Similarly, expert opinion regarding these habitat associations is lacking. Recognizing these significant data gaps, we opted to explore integrating new inductive techniques, such as the Maximum Entropy Algorithm (MaxEnt, Phillips et al. 2006), to produce alternative species distribution models. Inductive models provide a quantitative and repeatable mechanism to identify suitable environments on continuous and ordinal variables (e.g., elevation, mean annual temperature, terrain ruggedness), and rely less on expert opinion than deductive models. One major limitation to this type of modeling approach, however, is that it works best when there is uniform distribution of occurrence data throughout the species range.

Assuming that deductive modeling would provide more representative distribution models for some species, while inductive modeling would perform better for others, we elected to use a combination of **deductive** and **inductive** modeling techniques to produce our **final distribution models**. Our general modeling approach was to (1) produce a **deductive** model of distribution using categorical land cover types, descriptive habitat associations and expert opinion; (2) produce an **inductive** model of distribution using both categorical and continuous measures of physical parameters and known points of occurrence; and (3) intersecting the maps of the two distribution models to produce a **combined** "hybrid" model (i.e., areas of agreement between the two model types). The model selected as the best overall representation of the species distribution, using one of these three techniques, was defined as the **final distribution model.**

Each of these distinct modeling techniques, as well as the selection criteria for determining the final distribution model, is described separately below.

Deductive Distribution Modeling

The goal of the deductive modeling approach consisted of establishing species habitat associations based on an exhaustive literature review and expert opinion, and then translating those associations into quantifiable parameters on available spatial datasets.

To house the variables for each species needed to produce the deductive models we acquired the Wildlife Habitat Relationships Database (WHRdb) developed for the Southeast Gap Analysis Project (SEGAP) by the Biodiversity and Spatial Information Center (BASIC) at North Carolina State University. The WHRdb contains detailed descriptions of wildlife habitat requirements, a habitat use matrix, and citations for literature used to create the database. Only minor modifications to the database were needed to append the AKGAP species list and Ecological Systems classification for the Alaska LANDFIRE Existing Vegetation Type (EVT) map (http://www.landfire.gov/), which we used as our statewide land cover map. Additional categorical variables that described habitat affinities and were included in the environmental variable selection process included hydrological characteristics, human avoidance characteristics, forest interior and ecotone width, and association with edges (Table 2).

Habitat descriptions for individual taxa were extracted from the NatureServe Explorer (http://www.natureserve.org/explorer/) database, the Alaska Natural Heritage Programs (AKNHP) Biotics database (http://aknhp.uaa.alaska.edu/maps/biotics/#), and through an exhaustive literature review. The descriptive habitat associations from the literature were then cross-walked to Ecological Systems and other associated ancillary variables by the UAA modeling team, with substantial assistance from vegetation ecologists at AKNHP, who were instrumental in developing the Ecological Systems legend for the Alaska LANDFIRE map.

Models were developed to incorporate habitat utilization across the taxon's entire range in Alaska. We found that many wide ranging taxa utilized habitats differently across their range or elevation limits changed due to latitudinal differences over the study area. In an attempt to capture regional variation in habitat utilization, but not produce multiple models for a single taxon, Ecological Systems were filtered by physiographic region (including: Aleutian, Artic, Boreal, Sub-boreal, North American Pacific Maritime and Temperate Pacific) before the associated Ecological Systems were identified as suitable habitat or not for each taxon.

Deductive models were generated using a python script that was used to query the WHRdb that stored the applicable variables for each taxon. The python script invoked a series of geospatial masks and raster calculations in ArcGIS 10.0 to generate a 60-m raster of predicted suitable habitats. The final deductive model for each taxon was an intersection of those Ecological Systems selected as suitable and any additional ancillary variables considered, delimited by the HUC8 range.

Inductive Distribution Modeling

Inductive models were derived using known points of occurrence and their intersection with a suite of environmental variables. The inductive modeling process included compiling and filtering occurrence data, developing and refining environmental variables, applying the Maximum Entropy algorithm (MaxEnt; MAXENT version 3.3.1; www.cs.princeton.edu/ ~schapire/ MAXENT/; see Phillips et al. 2006, Phillips and Dudik 2008) to produce models, and clipping models to HUC8 range limits.

Compiling and Filtering Occurrence Data

We acquired occurrence data from numerous sources of varying quality and quantity. Such disparate data required considerable processing and filtering to lessen potential biases in model output (Beauvais et al. 2013).

Our first step was to eliminate any records that fell outside of the Alaska modeling extent. We then used an MS Access script to eliminate duplicate records. Next, we eliminated all records that did not fall within the taxon's modeling season. For avian species, the primary season of interest was the breeding season, in which case all non-breeding season occurrences were eliminated. Breeding season (which includes nesting, hatching, rearing, and post-breeding) was broadly defined as June, July and August, except for breeding waterfowl, whose breeding season included May through August. For mammals and amphibians, we modeled their year-round distribution, and therefore, did not filter the occurrence dataset by month.

We then eliminated remaining records with mapping precisions >2000 m. Finally, we eliminated any remaining records of observations made before 1990. We selected 1990 as an arbitrary cutoff for two reasons: 1) 87% of the occurrence data were collected between 1990 and 2010, and 2) many of our environmental predictor variables reflect conditions over the past 20 years.

These preliminary datasets were then visually inspected to identify species with highly auto-correlated data, which can sometimes bias environmental niche models (Jimenez-Valverde and Lobo 2006, Johnson and Gillingham 2008). We thinned dense clusters of occurrences resulting from oversampling by applying a stratified sampling method using 12-digit HUCs to spatially separate occurrences. Although we used 8-digit HUCs to develop our range maps, they were too large to provide a useful stratification layer for this data reduction processing step. An equal number of occurrences (at least two, and up to ten, depending on minimum number of records) were randomly selected from each HUC to be included in the modeling procedure.

Preliminary models were run using all occurrence data that met the above criteria. After initial review by the species modeling team, preliminary models for taxa that had poor model results (model extent was not representative of species range) were re-run using alternative data selection procedures. The first alternative data selection method reduced the year restriction to include data from years prior to 1990, as long as the other filtering restrictions were met. This secondary filtering method was generally employed to obtain a more uniform distribution of occurrence records throughout the taxon's range.

The vast majority of the small mammal records were obtained from GBIF (http://data.gbif.org/), for which positional accuracy for many of the records was questionable. For this group of taxa, we relaxed both the accuracy and date restrictions in an attempt to produce a large enough sample to run a model, cognizant of the fact that we were potentially reducing the quality of the modeled output.

All points remaining after the filtering steps described above were considered the final set of modeling records. Taxa with <10 final modeling records were excluded from the inductive modeling process and modeled exclusively using deductive techniques.

Environmental Variable Selection

Although MaxEnt (Phillips et al. 2006) can produce outputs with a large number of environmental variables, even in situations with a high degree of collinearity, we reduced the full set of environmental variables to 20 for use in all inductive modeling (Table 2). This reduced the amount of computing time necessary to generate several hundred models at a 60-m resolution and across an extent that was an order of magnitude larger than almost all other previous state-level GAP projects. It was also desirable to increase parsimony and interpretability in determining which factors commonly affect the distributions of species across the entire state.

We used the MaxEnt algorithm to screen and identify a relevant subset of environmental variables for inductive modeling. To do so, we produced an exploratory MaxEnt model for 50 taxa selected randomly from the full species list, using pre-filtered occurrence records and 10,000 points randomly placed throughout the study area (which also served as background points, referenced below). For each of these 50 taxa modeled, we recorded the permutation importance value of each environmental variable resulting from MaxEnt outputs. The contribution for each variable is determined by randomly permuting the values of that variable among the training points (both presence and background) and measuring the resulting decrease in training AUC. A large decrease indicates that the model depends heavily on that variable (Phillips et al. 2006).

We then compiled a list of the top 10 environmental variables (variables with the highest permutation importance scores) for each the 50 species modeled. For each environmental variable, we tallied the total number of species models that identified that environmental variable as 1 of the top 10 most important environmental variables, and then ranked the environmental variables based on the total number of species. Overall, we selected the top 20 environmental variables with the greatest number of associated species. Specific details about the origin and processing of the 20 selected environmental variables used in the final inductive models are provided in Appendix C.

Spatial overlays of environmental variables were performed in the Geospatial Modeling Environment (www.spatialecology.com). The results of the overlay were converted into a Background SWD (samples with data) file. The SWD file format is very useful for modeling in MaxEnt, especially when environmental grids are very large because MaxEnt does not need to access the entire environmental variable extent to obtain the values at the sample points (Phillips et al. 2006). The environmental variable layers are thus only used to get "background" cells (i.e., cells in which the species has not been found). We created 10,000 background data points. The SWD file was used for all species models and the modeling extent was state-wide regardless of the species range.

Model Generation

We used MaxEnt version 3.3.1 to relate modeling subset occurrence records to the final set of environmental predictor variables to produce our final inductive models. All models were produced using the same 20 environmental variables that were derived from the selection procedures described above. We visually inspected model outputs after each run. For some taxa, multiple iterations were run if the model did not adequately represent the taxon's known range. Additional model runs usually involved relaxing the restrictions on the occurrence data for an individual taxon to increase sample size. Individual variable response curves also influenced model selection. Due to time constraints, and in an effort to retain consistency across all models, we did not adopt an iterative approach to reduce the number of environmental variables used in the model based on variable contribution values.

Model Display

Model outputs included an ASCII file which was converted to a continuous raster grid for import into ArcGIS. We used the MaxEnt logistic output, which gives an estimate between 0 and 1 of probability of presence for each cell in the raster (Phillips et al. 2006). For these models, a binary threshold was applied that divided the continuous raster values into two categories: predicted absence (0) and predicted presence (1). We selected an average probability/suitability approach as our threshold rule (Cramer 2003, Liu et al. 2005). To determine the mean for the threshold value, known points of occurrence were overlain on the probability surface from the modeling output. The probability values were then extracted for the location of each occurrence data point and the mean and standard deviation for each species was calculated. The threshold was then applied to the MaxEnt probability surface to produce a binary grid surface. Similar to the deductive models, HUC8 range maps were then used to delineate the final modeled extent.

Final Distribution Model Overlays and Mapping

As described above, taxa with <10 post-filtering occurrence records were only modeled using deductive techniques. However, for taxa for which there were sufficient data to produce both a deductive and an inductive model, we intersected the results of both models to produce a "combined" model. This process was performed in ArcGIS using the multiplicative function (e.g. 1 * 1 = 1) in the "Raster

Calculator". The combined model only included areas where there was positive agreement between the two models, clipped to the taxon's range boundary (Figure 2).

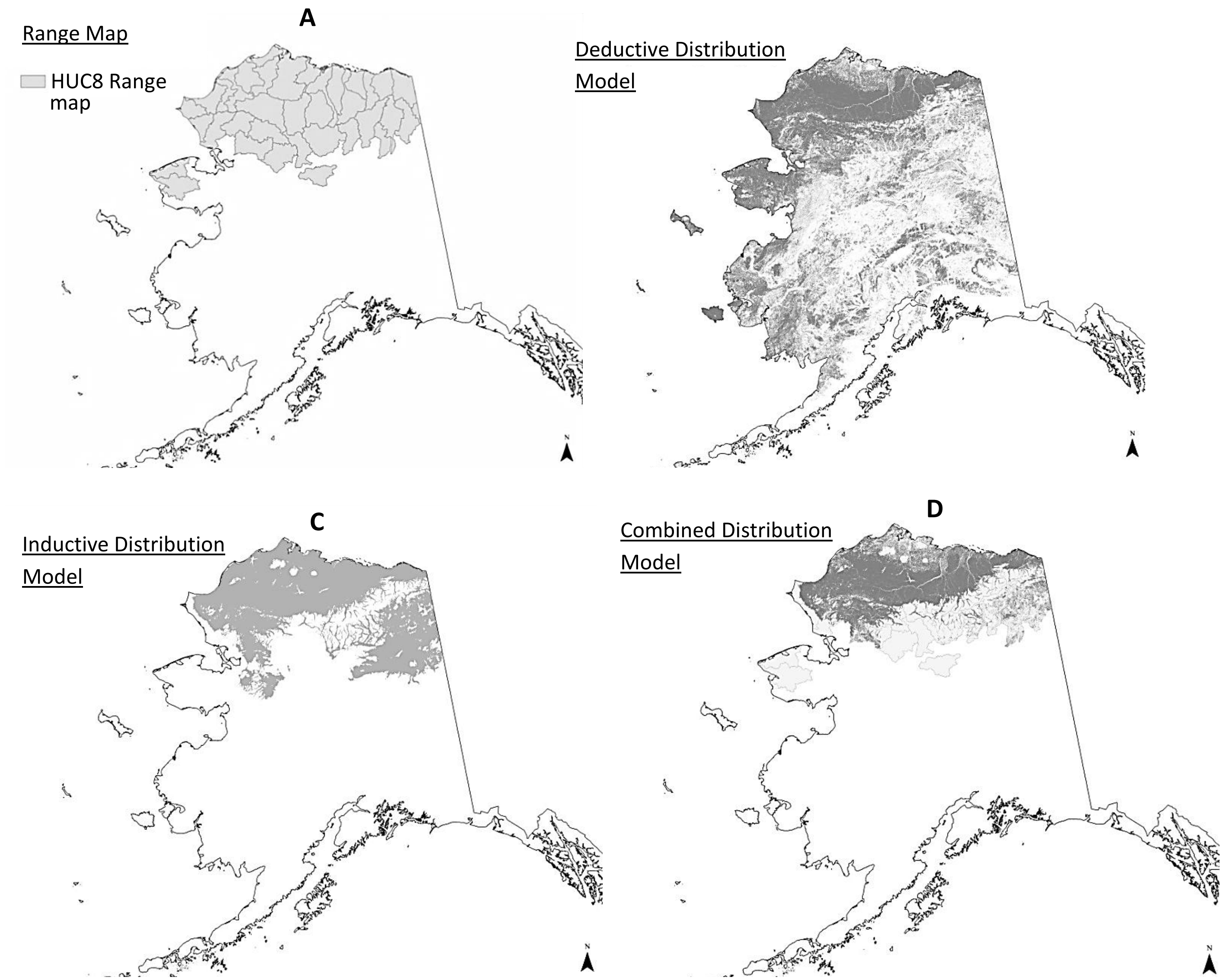


Figure 2. Example of the process used to produce the combined model. Map series is for Barren ground shrew (*Sorex uganak*): **A** is the HUC8 range map; **B** is the deductive model output; **C** is the inductive distribution model output; and **D** is the combined model, the intersection of **B** and **C**, clipped to **A**.

Accuracy Assessment – all model types combined

We used classification success and area-under-curve (AUC) to assess model fit. Classification success is the percent of training points correctly predicted as present. AUC was calculated from a Receiver Operating Characteristic (ROC) plot that was automatically generated as part of the MaxEnt output. The ROC curve is a threshold-independent measure of model accuracy, juxtaposing correct and incorrect predictions over a range of thresholds. It ranges from 0 to 1, with values larger than 0.5 indicating a performance better than random (Fielding & Bell 1997). In our case, 30% of occurrence points were held back for model testing. The MaxEnt derived AUC (or AUC_{po} as suggested by Yakulic et al. 2012) was only applicable to the inductive models. We used classification success as an alternative measure of model performance that could be consistently applied across all model types, and was independent of the MaxEnt AUC.

Assessment datasets varied between the different model types. Since occurrence records were not used directly in the development of the deductive models, all post-filtering occurrence records were used as validation records in the assessment along with an equal number of randomly generated pseudo-absences (drawn from a pool of n=1000) across Alaska. Thus, assessment values calculated from presence and background data describe the probability that the model scores a random presence site higher than a random background site (Phillips et al. 2009). This assessment dataset was also used as validation records for the combined models. Assessment data for the inductive models were the same data held back (30%) to generate the MaxEnt AUC.

Model Review

We conducted both internal and external review of all the range maps and distribution models. The internal review was intended primarily to ensure an adequate degree of consistency across all taxa included in the modeling effort. The purpose of the external review was to evaluate model correctness. External reviewers were solicited from individuals and groups who had expertise with particular species or taxonomic groups.

Internal range map and model review was conducted iteratively, as each product reached a new stage of completion. Similar to the range map review, both deductive and inductive models were reviewed twice by the species modeling team, with changes being incorporated between each review. The combined models were only reviewed once by the species modeling team.

The external review process was undertaken once the final internal review of all mapped products was completed. External review workshops were held in Anchorage (n = 4), Fairbanks (n = 2) and Juneau (n = 2). These workshops discussed the process of modeling, the limitations of the process, and the intent of the species distribution models. At that time, we asked reviewers to evaluate the taxon's range map, wildlife habitat relationships and associated deductive model variable selections, and the three modeled outputs. We asked reviewers to comment on how well they perceived each model type to accurately reflect the taxon's distribution and then asked them to pick the model type that was most representative of the taxon's distribution statewide. See Appendix D for reviewer questionnaire and other supporting documentation provided to expert participants in the review process.

Final Model Determination

To avoid biases associated with any one validation technique, we evaluated models quantitatively and qualitatively using multiple methods, including **classification success** (described above under Accuracy Assessment), the **expert opinion** of biologists regarding how well final models reflected their understanding of species' distributions, and whether or not the modeled output was representative of the species **range extent**.

Taxa for which only a deductive distribution model was generated, the final deductive distribution model was designated as the **final distribution model**. For taxa for which there was a deductive, inductive and combined model produced, final model determination was based on a combination of **range extent**, **expert opinion**, and **classification success values,** respectively.

Both internal and external review indicated that for many wide-ranging taxa, both inductive and combined models tended to under predict presence throughout much of a taxon's range. We visually inspected the output for both the inductive and combined models to assess whether they predicted presence throughout most of the taxon's range (in which case the model was accepted) or left large portions of the taxon's range with no predicted presence (in which case the model was rejected and the deductive model was accepted as the final distribution model).

Final model determination for taxa for which there were two or three different model outputs after range extent screening, was based on expert opinion and classification success values. We asked expert reviewers to select the model type they felt most accurately represented the statewide distribution of the taxon. If expert opinion was available, we used this to make the final model determination. If expert opinion was lacking, we used the highest classification success value to determine the **final distribution model**.

Results

For each of the terrestrial vertebrate species modeled for this project, a species range map and predicted distribution map was created. Graphical representation of each of these mapped products is provided in the Alaska Gap Analysis Project Vertebrate Species Atlas (Gotthardt et al. 2013, provided as a stand-alone document). The atlas includes a complete species report for each taxon, including the following data:

- Species taxonomic information
- Seasonal range map
- Occurrence range map
- Final predicted distribution map, including model type, associated performance statistics, and a general quality rank
- A detailed habitat description
- A list of citations used to develop the habitat description in the WHRdb

Species List

We identified 347 taxa as targets for range mapping and distribution modeling (Table 3). The list was dominated by birds (76% of all taxa; n = 266), followed by mammals (22%; n = 75), and amphibians (1%; n = 6). Of the 347 taxa, 17 (11 birds and 6 mammals) were recognized as sub-species with habitat affinities that were distinctive enough to warrant separate models than their species level equivalent. Twenty-nine taxa had strong associations with the marine environment. Although these taxa spend the majority of their lives at sea, range maps and distribution models included only the terrestrial environments that are utilized at times of the year when they are known to come ashore for breeding, nesting, pupping, molting, etc. The majority of birds on the species list were migratory, of which 81 % were most widespread in Alaska during the summer. The majority of mammals (95%) and amphibians (100%) received year-round designations (Table 3).

Table 3. Summary of 347 vertebrate taxa selected for range mapping and distribution modeling for AKGAP. Columns are not mutually exclusive, as some taxa were scored under multiple criteria.

	No. taxa at subspecies level	No. taxa w/strong marine associations	No. migratory taxa w/summer range predominant	No. non-migratory taxa w/year -round range predominant
Amphibians (n = 6)	0	0	0	6
Birds (n = 266)	11	21	213	53
Mammals (n = 75)	6	8	7	67
All taxa combined (n = 347)	17	29	220	126

Occurrence Data

Occurrence data were acquired from 662 unique data sources, resulting in a total project database of 1,546,532 occurrence records, representing 398 species and subspecies. While our species modeling list only considered 347 taxa, we also collected occurrence records for 51 subspecies that were treated at the species level for modeling. We eliminated all records that fell in the marine environment, which left us with a starting number of 1,527,334 records for further use in the modeling process.

Occurrence records were clipped to the species range leaving approximately 1,174,136 records for secondary filtering by seasonal occurrence, duplication, mapping precision, and year of observation. Of the 1,174,136 records, the overwhelming majority of records (96.0%) were for birds, 3.8% were for mammals, and 0.2% were for amphibians (Table 4).

Due to the disparity between the occurrence data available for modeling birds compared to mammals and amphibians, the secondary filtering process was iterative and not consistently applied across all taxonomic groups. In general, in order to produce mammal datasets with > 10 records, we reduced the temporal filtering restriction for approximately one-third of total mammalian taxa. Following the secondary filtering process, 40 taxa were left with insufficient records to produce a model (< 10), and were therefore excluded from the inductive modeling process. These 40 taxa were modeled exclusively using deductive techniques (see Appendix A).

Table 4. Selection of georeferenced occurrence records for potential use in modeling distributions of 347 target taxa for AKGAP. "Secondary filters" refer to attributes of records that resulted in them being excluded from further use in the modeling process. Filtering categories are not mutually exclusive (some records fell into multiple categories), therefore, values to not always sum across columns.

			SECONDARY FILTERS			
Taxa	Number of starting records	Number of records that fell within taxon's range	Number of records with date outside of modeling season	Number of duplicate records	Mapping precision >2000 m	Number of records prior to 1990
Amphibians (n=6)	3,039	2,348	0	321	1,189	1,212
Birds (n=266)	1,419,192	1,127,171	274,063	93,273	201,051	113,549
Mammals (n=75)	105,103	44,617	0	60,547	73,275	34,299
Total (n=347)	1,527,334	1,174,136	274,063	154,141	275,515	149,060

The secondary and spatial filtering process reduced the record set to 594,061 total modeling records, representing only 39% of the pre-filtering records (Table 5). The occurrence records in the final modeling dataset were divided into two groups: those records used to produce the initial inductive models (n = 454,024), and those used to validate the models (approximately 24% of records held back; n = 140,037) (Table 5). The number of records used to test and train the models for individual taxa are provided in Appendix A.

Table 5. Spatial filtering of georeferenced occurrence records for potential use in modeling distributions of 347 target taxa for AKGAP.

Taxa	Number of starting records	Number of records removed based on spatial filtering	Number of records remaining (% of starting)	Number of records used in modeling	Number of records used to validate models
Amphibians (n=6)	3,039	0	1,121 (37%)	880	241
Birds (n=266)	1,419,192	222,592	566,597 (40%)	432,399	134,198
Mammals (n=75)	105,103	0	26,343 (25%)	20,745	5,598
Total (n=347)	1,527,334	222,592	594,061 (39%)	454,024	140,037

Range Mapping

Seasonal range maps were produced for each of the 347 target taxa. Seventy-one sub-taxa, representing 19 species, were lumped into models at the species level. The majority of these sub-taxa were insular endemic small mammals that do not utilize different habitats among sub-species and therefore did not warrant separate models. From a biodiversity standpoint, however, we feel these sub-taxa are worthy of some level of recognition. As such, we attributed the species level range maps to include the subspecific taxa that they include for graphical outputs only (see Figure 3 for an example). However, the corresponding model was built at the species level, and the range extent used to delineate the model was the compilation of the species range, which was inclusive of all the subspecies ranges.

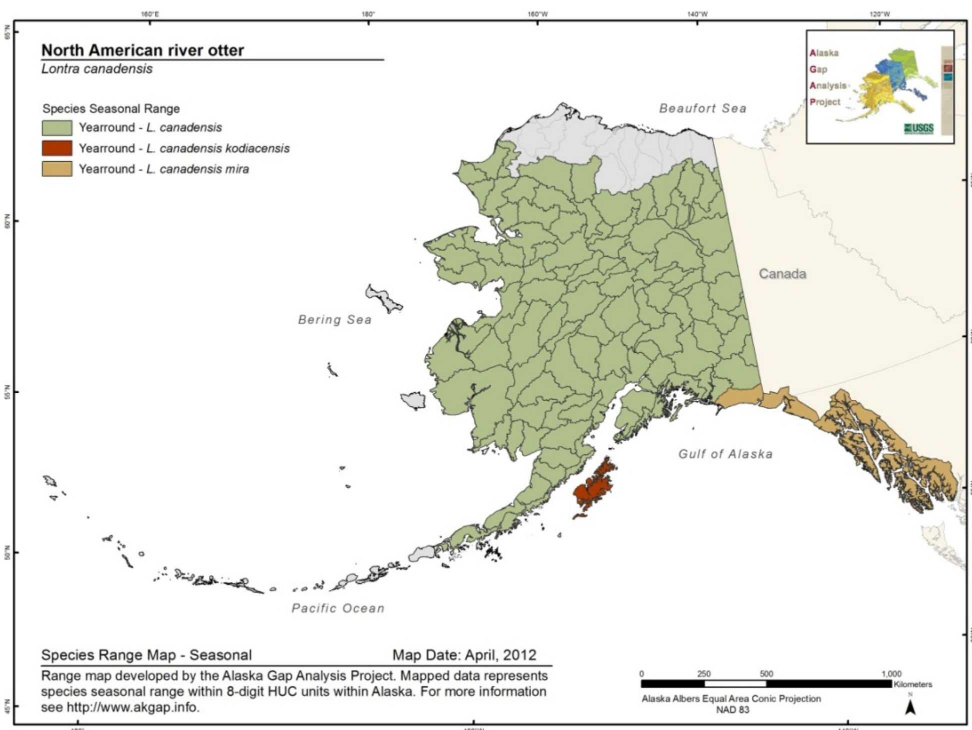


Figure 3. Example of seasonal range map for North American river otter (*Lontra canadensis*), which includes subspecies (*L. c. kodiacensis* and *L. C. mira*).

Range maps were overlaid with occurrence data and attributed as known, suspected, or historical (Figure 4). Overall, 48.1% of HUC8s were designated as known, while 51.8% were designated as suspected (Table 6).

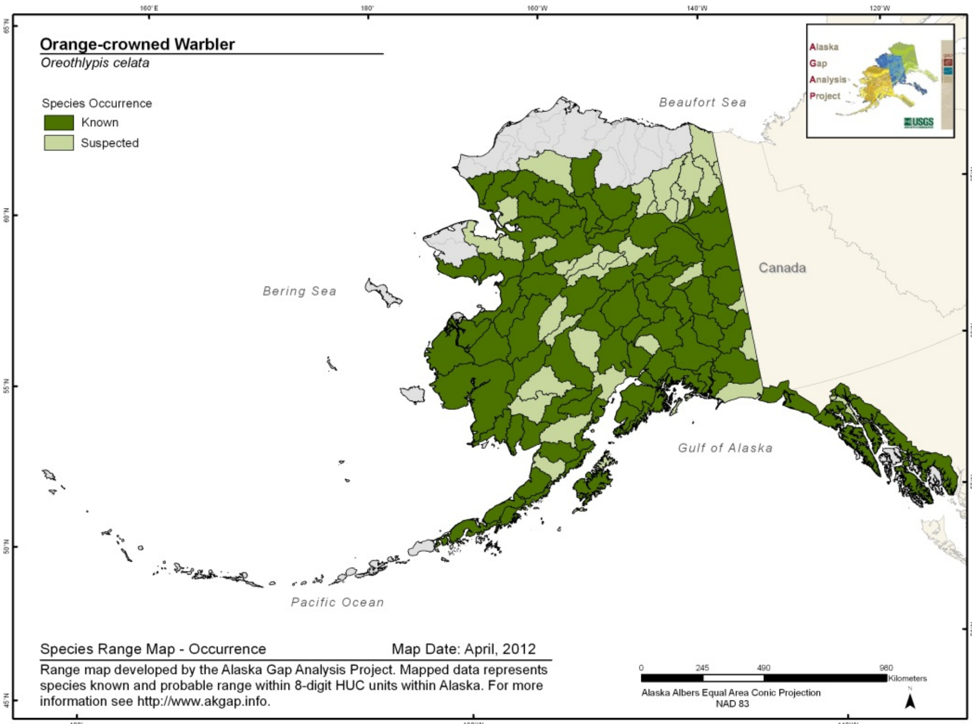


Figure 4. Example of species occurrence range map for Orange-crowned Warbler (*Oreothlypis celata*). Range maps are attributed with occurrence type, including "known", "suspected", or "historical".

Table 6. Summary of final range map attributes for 347 target taxa for AKGAP. For each taxon, a range map was a subset of the total 1,237 8-digit hydrologic units (HUC8s) in the project area. Each HUC8 in each range map was attributed with values for occurrence (i.e., Known, Suspected, or Historical).

	Known	Suspected	Historical
Amphibians (n = 6)	93	56	2
Birds (n = 266)	9,400	8,774	10
Mammals (n = 75)	1,540	3,072	12
All taxa combined (n = 347)	11,033 (48.1%)	11,902 (51.8%)	24 (0.1%)

Environmental Variables

We derived 81 grids related to the 48 environmental variables for initial modeling (see Table 2). Eighteen environmental variables were selected *a priori* for final deductive modeling and 20 environmental variables were used for final inductive modeling (Table 2, Appendix C).

Deductive Distribution Models

We produced deductive models for 338 of the 347 taxa on our target list. Seven seabird species (Slaty-backed Gull, Common Murre, Thick-billed Murre, Cassin's Auklet, Parakeet Auklet, Crested Auklet, Rhinoceros Auklet) with habitat preferences for remote coastal cliffs during the breeding season were eliminated because this landform was not well delineated in the LANDFIRE map (Boggs, pers. comm.). We also did not produce models for Sky Lark and the bushy-tailed woodrat, as we were unable to obtain habitat descriptions for these taxa that could be applied to the Ecological System descriptions in the Alaska LANDFIRE map.

We estimated the accuracy of our final set of deductive distribution models with the models from 269 resident target taxa that had enough modeling records to produce validation subsets. Those models had relatively high assessment values (mean = 0.60 across all taxa; Table 7). There was little difference in classification success values between the taxonomic groups (birds =0.60, mammals = 0.61, and amphibians = 0.61).

Inductive Distribution Models

We produced inductive models for 310 of 347 target taxa that had >10 post-filtering occurrence records. Visual inspection of inductive model outputs by the species modeling team revealed 116 taxa with large portions of their ranges with no modeled presence. These 116 inductive models were removed from further consideration as final models.

When averaged across all taxonomic groups, the inductive models had relatively high fit as measured with validation subset records (mean AUC = 0.97; mean classification success = 0.77; Table 7). Models for amphibians had slightly higher classification success rates (average = 0.85) relative to birds (0.77) and mammals (0.74), while mammals and amphibians had marginally higher AUC values than birds (Table 7).

Combined and Final Distribution Model Selection

The combined models, which were the intersection of the deductive and inductive model results, yielded 299 total models. Similar to results for inductive models, if the combined model inadequately represented the species distribution, then the deductive model was selected as the final distribution model. After this initial filtering step, we then used expert opinion and classification success to help decide the remaining final model types. Experts suggested rejecting all model outputs for five taxa (Snowy Owl, Gray-headed Chickadee, Song Sparrow, Gray-crowned Rosy-finch, and Arctic fox), for which there was little to no agreement between model types.

Classification success values for the combined models were similar to those of the deductive models because they used the same assessment data. The combined models had relatively high assessment values (mean = 0.60 across all taxa; Table 7), with little difference between the taxonomic groups (birds =0.60, mammals = 0.61, and amphibians = 0.58).

Overall, 222 (64%) deductive, 74 (21%) inductive, and 37 (11%) combined models were selected as the final models (Figure 5). By taxonomic group, final model selection was fairly consistent with the overall results, with the majority of final models for birds (68%) and mammals (64%) being deductive. The exception to this rule was for amphibians, for which the majority of final models (66%) were inductive (Figure 5). See Appendix A for final model determinations and selection criteria for individual taxa.

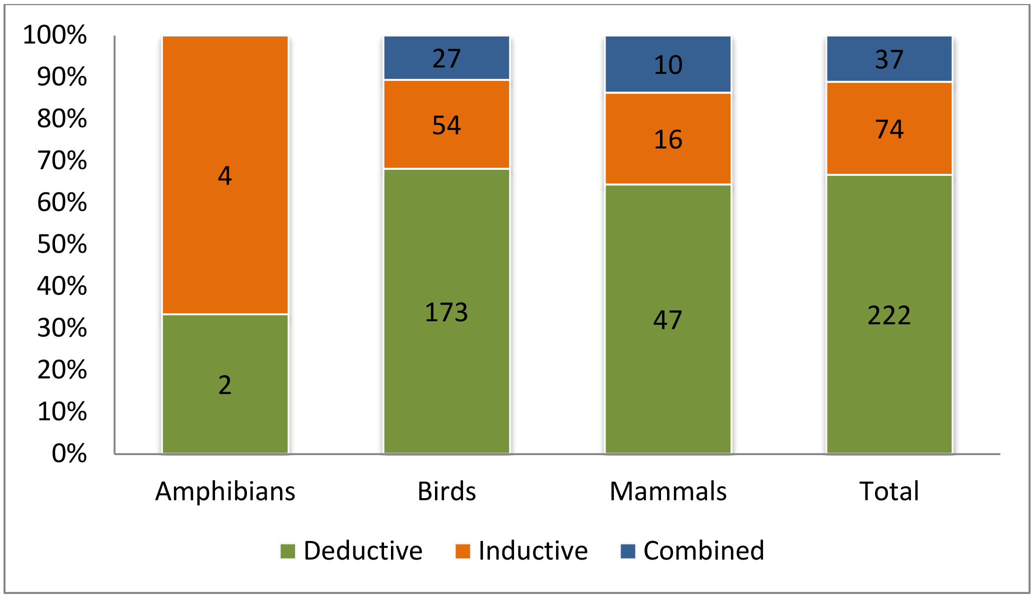


Figure 5. Final model selection by taxonomic group and for all taxa combined.

Models for 14 (4%) taxa were not considered acceptable and removed from further consideration (as described above, these include the nine taxa not modeled using deductive techniques and five models rejected by experts).

Accuracy Assessment

Quantitative prediction accuracy is one measure of model validity (others include expert assessment, traditional knowledge, habitat matching, etc.). This form of assessment relies on the model prediction surface (the predicted distribution) and testing data (occurrence data held back for validation) (Manel et al. 2001, Franklin 2009). We used the AUC metric and classification success as quantitative measurements of prediction accuracy. Model fit of inductive models was assessed using the Maxent AUC value based on the modeling records. Model predictive quality was assessed using classification success.

We found that across taxa, inductive models had higher performance metrics than the deductive or combined models. Generally, the classification success values for the deductive and the combined models averaged around 0.60 for all taxa; inductive models had higher overall performance metrics, both before thresholding (Maxent derived AUC, average 0.97) and after thresholding (classification success, average 0.77) for all taxa (Table 5). The bounding metric for the deductive and combined models seldom reached 90.0% or <50.0%, whereas inductive models averaged 0.77 with some values as high as 0.98 (Figure 6). While these metrics are good trends of model prediction accuracy, they should not be interpreted as more than that. These assessment metrics provide us with relative values for comparing model performance, but we did not use them to establish thresholds for determining whether one model or model type was "superior" to another. Furthermore, the specific assessment values should be approached with some caution, as different validation datasets were used to validate the different model types. The deductive and combined models used the full set of filtered occurrence points that was applied in our inductive modeling efforts, while the inductive models used a subset of the filtered occurrence points.

Table 7. Assessment of accuracy for all final inductive, deductive, and combined models. All values are means across taxa or individual taxa except number of taxa. Model fit of inductive models was assessed using the Maxent AUC value based on the modeling records. Model predictive quality was assessed using the classification success (CS), which is the percent of records of know occurrence predicted by the model to fall in suitable environments. Standard deviation (SD) and number of taxa (n) are shown parenthetically.

	Inductive models		Deductive models	Combined models	Final models
Taxa	Maxent AUC (SD; number of species): before thresholding	CS (SD; number of species) after thresholding	CS (SD; number of species)	CS(SD; number of species)	CS (SD; number of species)
Amphibians	0.99 (0.01; n=6)	0.85 (0.06; n=4)	0.61 (0.11; n=6)	0.58 (0.08; n=6)	0.81 (0.08; n=6)
Birds	0.97 (0.07; n=239)	0.77 (0.10; n=197)	0.60 (0.10; n=202)	0.60 (0.10; n=226)	0.65 (0.13; n=203)
Mammals	1.0 (0.02; n=67)	0.74 (0.11; n=58)	0.61 (0.11; n=63)	0.61 (0.10; n=66)	0.65 (0.12; n=60)
All species	0.97 (0.03; n=312)	0.77 (0.10; n=259)	0.60 (0.11; n=278)	0.60 (0.10; n=298)	0.65 (0.12; n=276)

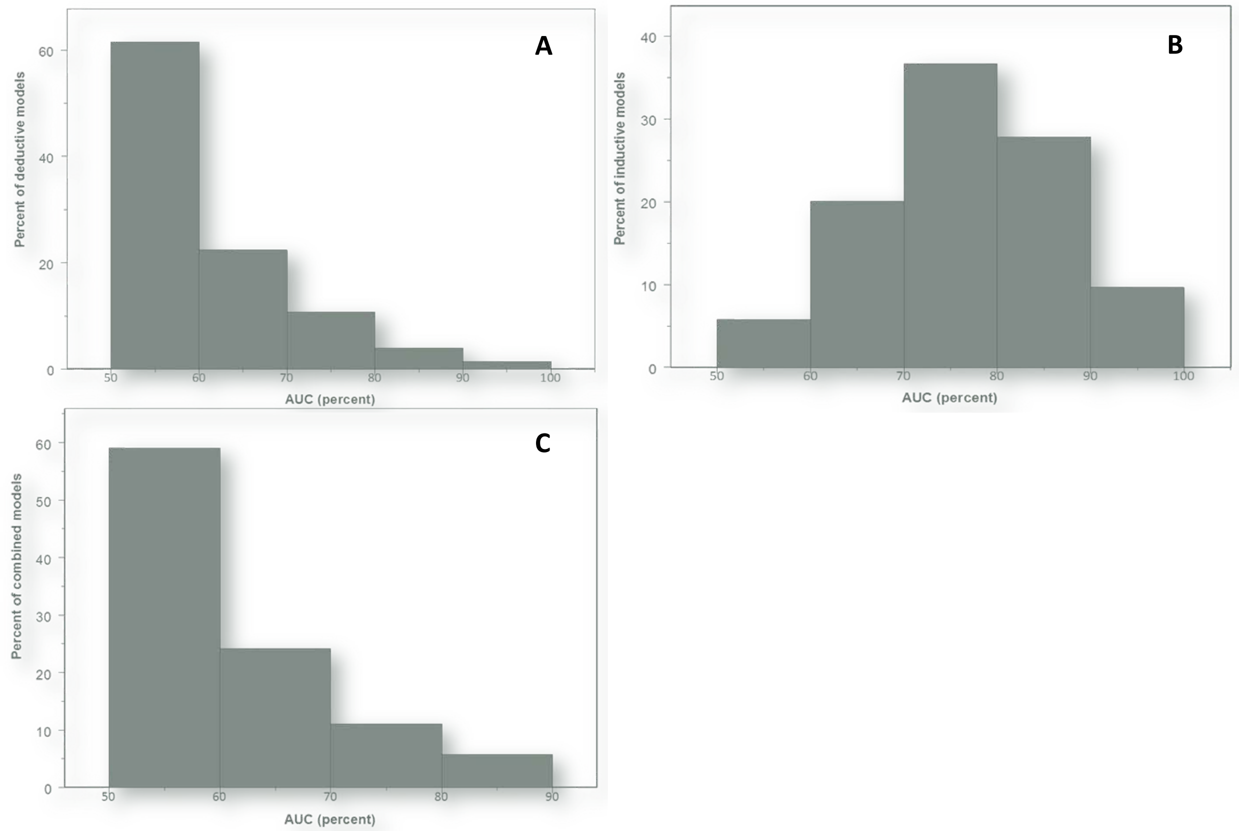


Figure 6. Frequency distributions for classification success values for species distribution models based on deductive (A), inductive (B), and combined (C) distribution modeling approaches.

Expert Review

Although the external model review process generated wide interest throughout the state, attendance at review sessions was relatively low. Overall, 22 external reviewers submitted critiques of 101 species range maps and models. A list of all internal and external reviewers with associated affiliations and taxa reviewed is provided in Appendix E. All reviewer comments were recorded, although not all were incorporated into model revisions. Recommended changes that were not supported by references or verifiable data, for example, were not included in the final models. Expert reviews resulted in relatively few edits to both distribution models and HUC8 range maps. One inductive model was improved with the addition of new occurrence data (Kittlitz's Murrelet) and 17 deductive models were altered based on expert opinion and associated reference information. Deductive model modification consisted of adding or removing land cover types or altering associations with hydrological variables. Expert review also resulted in modifications to HUC8 ranges of 38 taxa (25 birds and 13 mammals). Model modification was an iterative process as modelers reviewed and incorporated expert information, as it was received.

Species Richness

GAP has often been associated with the mapping of species-rich areas or "hotspots." Species richness maps identify where species co-occur in the same geographic locations. For AKGAP, species richness is the total number of animal species per 60 m pixel across the state. The resultant maps are color coded or shaded in intensity from the highest numbers of known or possible co- occurrence (richness) to the lowest. Richness maps provide a useful starting point, in combination with other types of information, to examine conservation opportunities.

We believe the individual species models are of greater value than just the richness summaries. Having distribution models for all species allows more detailed analysis of species habitat overlap by looking at the complementarity of different species' ranges. Aggregating individual models offers the opportunity to evaluate the spatial assemblages of species and to compare and contrast habitat values across the landscape. We present species richness maps for selected taxonomic groups to illustrate potential use of the data.

The individual species models contributing to richness metrics should be considered in the different spatial locales that have similar richness values, in that those locales may support predominantly different assemblages of species. Species richness was calculated for all mapped taxa (Figure 7) and by taxonomic groups (Figures 8 to 10). Richness is presented by 60 m grid cell with ramped colors from light (low richness) to dark green (high richness). Natural breaks within the data are used to provide classification within these maps. Each richness map is displayed with different breaks so comparisons between taxa are not valid. Seasonality and reproductive use are not included.

Total Species Richness

Based on the intersection of distribution maps, total species richness is highest in central interior Alaska with total number of species reaching 127 in some 60 m grid cells (Figure 7). This area is largely comprised of the Intermontane Boreal Forest Ecoregion, which is characterized by vast expanses of boreal forests of both needleleaf and deciduous species dissected by broad, flat river floodplains and a diversity of wetlands. There are also areas of high species richness in southeastern Alaska in coastal areas and along major rivers; and in western Alaska in areas adjacent to the Yukon and Kuskokwim River Deltas. As would be expected, lower species richness occurs in the large mountain ranges of southcentral Alaska, mainland southeastern Alaska, and in the Brooks Range.

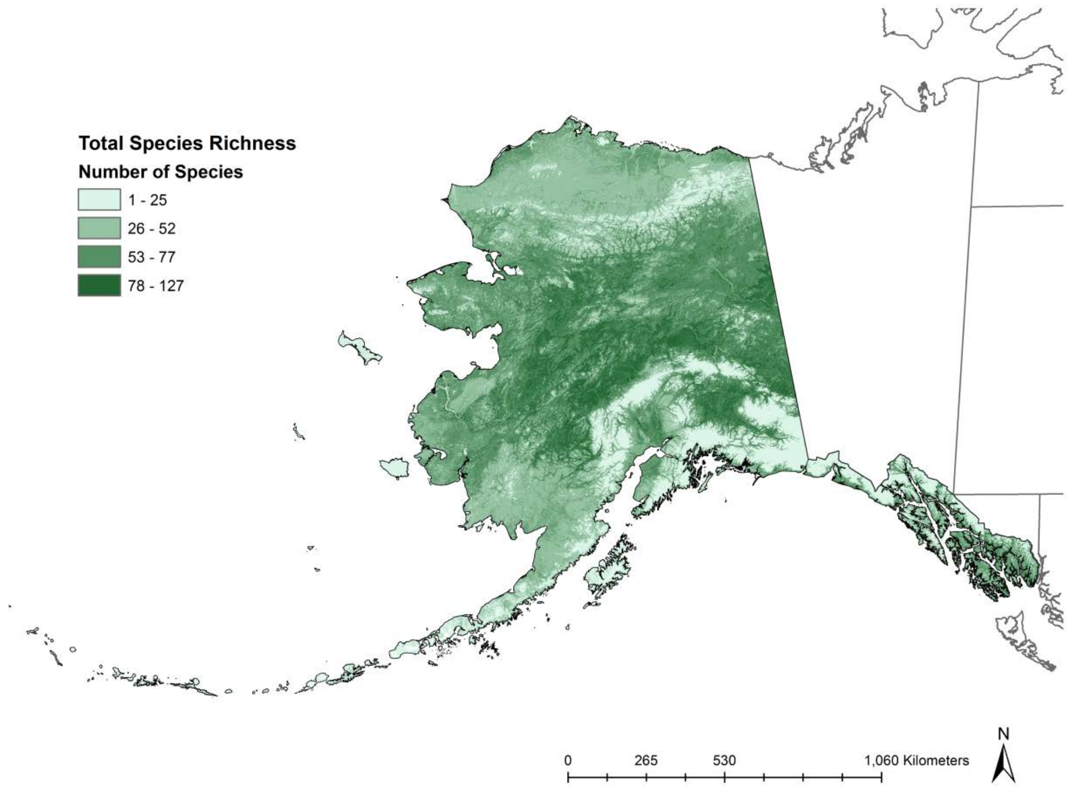


Figure 7. Total species richness by 60 m grid cell for 347 modeled amphibian, bird, and mammal species in the Alaska Gap Analysis Project area.

Amphibian Richness

Amphibian species richness is highest in Southeast Alaska (Figure 8). Richness values range from 0 to 6 species. Many amphibian taxa are at the northern distributional limit of their range in the temperate rainforest of southeastern Alaska. Only one amphibian taxon, the wood frog, is found throughout the interior of Alaska. Amphibians have not been documented in northern and southwestern Alaska.

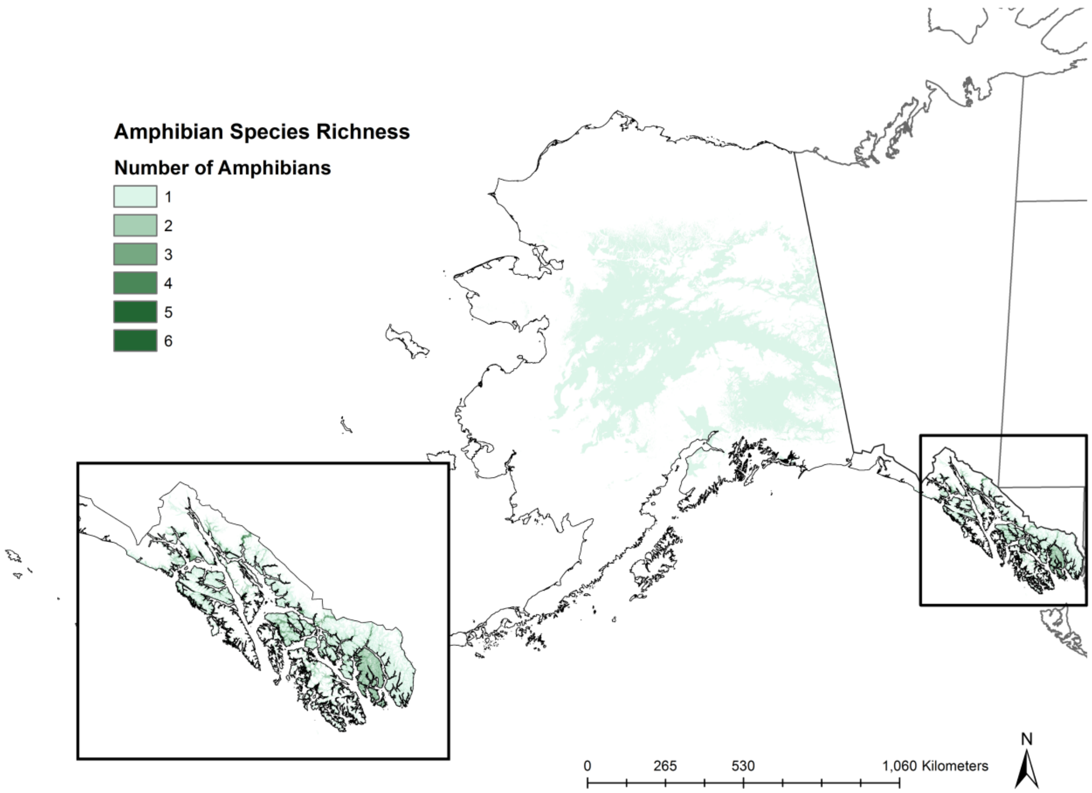


Figure 8. Species richness by 60 m grid cell for 6 modeled amphibian species in the Alaska Gap Analysis Project area.

Bird Richness

Bird richness values range from 0 to 97 species and follows a similar pattern to overall taxa richness. Highest values are observed in central interior Alaska, in southeastern Alaska in coastal areas and along major rivers, and in western Alaska in areas adjacent to the Yukon and Kuskokwim River Deltas (Figure 9). The mainland region of Southeast Alaska has several unique species that are at their northern range limit, which add to the richness count in that region. In western Alaska richness is highest in several localized areas including in the Yukon-Kuskokwim Delta wetlands and estuaries, the southern half of the Seward Peninsula, and the Nulato Hills region. Bird richness decreases from interior Alaska northwards onto the arctic coastal plain. Similarly, richness decreases from the Alaska Peninsula and westward out the Aleutian chain.

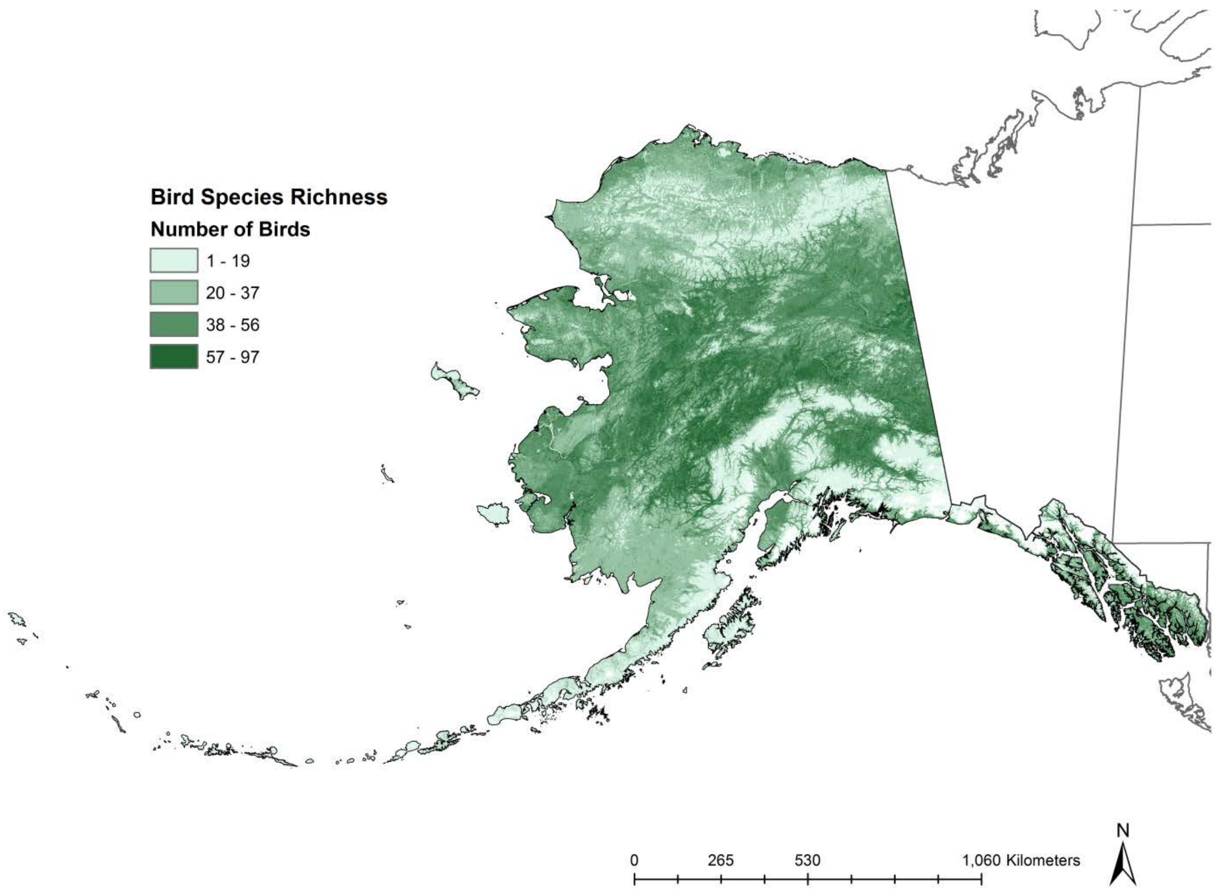


Figure 9. Species richness by 60 m grid cell for 6 modeled bird species in the Alaska Gap Analysis Project area.

Mammal Richness

Mammal richness is highest in the southeastern, southcentral, and interior regions of Alaska (Figure 10). Richness values range from 0 to 36 species. Islands tend to have a lower diversity of mammals compared to the mainland, as seen by the lower values on islands in the Bering Sea, Gulf of Alaska, and Pacific Ocean.

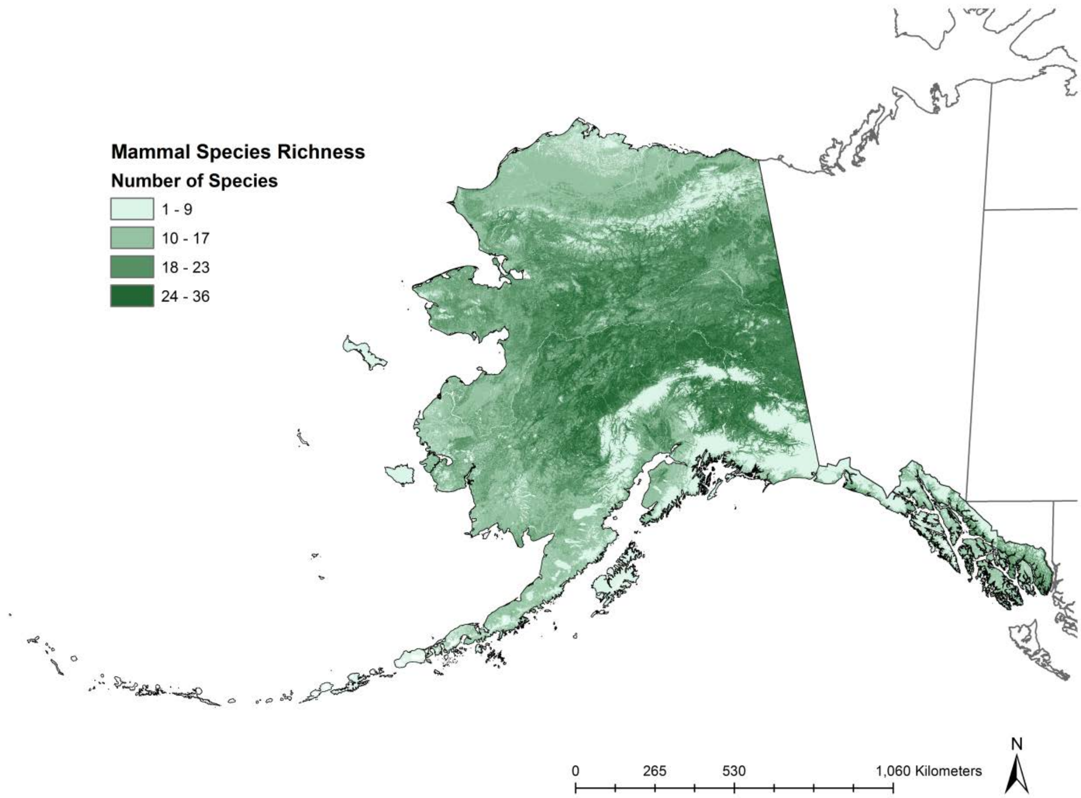


Figure 10. Species richness by 60 m grid cell for 6 modeled mammal species in the Alaska Gap Analysis Project area.

Discussion

The primary goal of the Alaska Gap Analysis Project was to develop species range maps and distribution models using the best available contemporary and historical data to inform conservation planning and research. Developing range maps and distribution models for 347 terrestrial vertebrate taxa at the scale of the state of Alaska presented significant challenges due to sparse or patchily available occurrence data, the resolution and validity of available vegetation maps, and the scale and scope of climatological and other environmental data. Despite these considerable obstacles, we feel that this first generation of Alaska GAP distribution maps and models represents a major advance in our understanding of the distribution of terrestrial vertebrate taxa across the state. These mapped results provide a base from which we can iteratively improve as new data and resources become available. They will also provide the basis for a statewide gap analysis.

Developing the spatial data needed to produce range maps and distribution models was an enormous task that required a massive cooperative effort among academic, state, federal, and non-governmental institutions. This activity has resulted in positive changes in institutional relationships by helping to foster data sharing beyond jurisdictional boundaries. The synthesis of consolidated biogeographic data [occurrence database, the wildlife habitat relationships database (WHRdb), and environmental data layers] are of fundamental utility to resource planners, managers, and researchers, and have not been previously available.

The centralized repository of occurrence data will allow researchers and land managers to identify gaps in existing knowledge and coordinate survey efforts to target particular species and or particular habitats. The WHRdb is the first effort, to our knowledge, to compile literature and expert-based habitat associations for all resident vertebrate taxa across their ranges in Alaska, and then equate them spatially to existing vegetation types. The WHRdb provides landscape level habitat information that is also useful at regional and local scales, and can be used to help guide field inventories in key habitats. Lastly, the processing and development of the environmental data layers used to produce models cannot be understated. This synthesis of climatic, hydrologic, physiographical, and anthropogenic data has enormous value to researchers and modelers alike for statewide planning and basic research.

Range Maps

Range limits depicted using 8-digit hydrologic units (e.g., HUC8s) tend to overpredict species ranges. However, HUC8s were the finest scale state-wide hydrologic unit layer available at the time we initiated the range mapping process. Ranges for species varied and because of the coarse nature of HUC8s, we likely over-generalized these ranges. We suggest our range maps be used as a baseline for coarse level analysis and modified as needed based on project or research objectives.

By using different attributes to designate HUCs within a species range we were able to represent seasonality as well as known or suspected occurrence. While we recognize that gathering occurrence data for over 340 taxa was likely far from comprehensive, attribution of HUC8s by known occurrence was helpful in identifying gaps in the current knowledge of taxa and under-surveyed areas within a species range. We also found value in incorporating expert opinion into our range maps, which greatly improved their accuracy for many taxa.

More recently, HUC-10 and -12s for Alaska have become available, and the Gap Analysis Program at the University of Idaho has re-scaled the Alaska HUC8 range maps to HUC12. These finer scale range maps, attributed by season and occurrence type, are accessible at the GAP Species Viewer portal (http://gapanalysis.usgs.gov/species/viewer/). The HUC12 ranges may provide a more representative delineation of a species range, but accurate attribution by seasonal use and occurrence type may not be as reliable as in the HUC8 range maps due to a general lack of comprehensive occurrence data necessary to make those determinations. We suggest consulting these finer scale range maps and make determinations regarding the most appropriate scale for your particular needs.

Environmental Variables

The species distribution models were limited by the accuracy, resolution, and general availability of statewide ancillary data layers. We used the LANDFIRE Existing Vegetation Layer (EVT) as our primary land-cover map for our deductive models. An accuracy assessment for seven locations across Alaska reported relatively low accuracy values (Boucher et al. 2009). While there have been numerous attempts to develop a statewide vegetation map for Alaska (Fleming 1998, LANDFIRE, NLCD), none have produced a map that contains both high accuracy and a fine-scale vegetation classification, with the exception of Boggs et al. (2013), which was not available when this project was initiated. For our purpose, which was to develop range-wide distribution models at a coarse- scale, we felt that LANDFIRE captured the general vegetation patterns across the landscape and appeared accurate and generally suitable for portraying vertebrate distributions at these scales.

Describing detailed species distributions over a large biogeographic area was one of the main incentives for The AKGAP project, but the statewide mapping aspect of the project was limited, in many cases, by the lack of available statewide datasets. Specific habitat features that would have greatly improved our deductive models, but were not available at the scale or quality required included:

- Riparian and coastal cliffs: principal habitat features for cliff nesting seabirds and many raptor taxa. As such, we were unable to model the distribution of many cliff-nesting seabirds, such as auklets and murres, and we have fairly low confidence in many of the raptor models.
- Forest structure and presence of snags/cavities: principal habitat features for wildlife species that depend on snags, large trees or cavity trees for survival and reproduction such as woodpeckers and forest owls;
- Sandy beaches and spits and other coastal features: important foraging habitat for numerous shorebirds as well as important habitats for marine mammals that haulout on land; these were especially lacking definition in the arctic.
- Microhabitats such as caves and buildings: important habitat for hibernacula (bats) and roosting and nesting (birds).

Our intent was to model species distributions over the last two to three decades. Some environmental variables, such as climate and geology (see Appendix C), reflected conditions during this period, but others originated from more specific time frames or from prior periods. In most situations, variables with temporal components were either not included in our final models or the mismatch in time frame was deemed insufficient to significantly affect our coarse-scale modeling efforts. Temporal biases in such variables, including sea ice, permafrost, insect damage, and glaciers, should be considered on a case-by-case basis for other modeling applications that have more specific spatio-temporal constraints.

There are some caveats associated with the processing of variables. For instance, climate variables (see Appendix C) were resampled from original grid cell sizes that were much larger than 60-m (e.g., 2 km). Likewise, some of our final grids, such as geology, originated from vector based data mapped at variable scales. In both these situations, we assumed that attributes (e.g., geological types or climate grid cells) were uniform across original cell sizes. Although our modeling products were published with 60-m grid cell sizes, this is not the actual data resolution and interpretation of cell-by-cell values (e.g. presence, absence) is not valid.

Known issues arose while deriving a uniform coordinate system. Some of our original data were produced with older datums, such as NAD27 and Clarke 1866. Region-specific transformation methods could have minimized the effects of geographic transformations, but this was not possible because datasets had to cover the entire area of Alaska. Some products resulted in an offset (up to 120-m) at the margins of the state (i.e., islands in Southeast Alaska, the Aleutians). This offset could have affected ranges of individual taxa by as much as 0.5%, with very localized error.

Distribution Models

As a means to advance the traditional methods of species distribution modeling for GAP, we opted to produce distribution models using a combination of deductive and inductive modeling techniques. These two modeling approaches produced very distinct types of distribution models. In general, the deductive models tended to overpredict species distributions across their range, but failed to identify regional patterns of range restriction – thus, they performed better in avoiding omission errors. Conversely, the inductive models honed in on particular regions, which tended to underpredict species presence over the entire state. We recognized from the start of the project the limitations associated with each of these modeling approaches, but elected to move forward with this combined methodology in an attempt to improve our overall predictive abilities, as suggested by Peterson and Kluza (2003). For both model types we found that the accuracy of each modeling approach relied on comprehensive data.

For the deductive models, we did not have specific habitat descriptions for many taxa across their entire range in Alaska. For some species, habitat associations were not well-defined because of limited research. Other species have been well-studied, but not in geographic regions similar to Alaska; while still others have been well-studied only regionally or locally in the state. Furthermore, many species utilize habitats very differently throughout their Alaskan range and we were not able to consistently capture these regional differences with this type of modeling approach. Thus, the ecological systems selected to describe a taxon's preferred habitats were oftentimes broadly interpreted and selected, and therefore tended to generalize the taxon's distribution. For example, many species were described as occurring in "dwarf shrub" habitats with no further qualification. In such a case, all of the available "dwarf shrubland" ecological systems (n = 18) were selected for model inclusion unless we were able to limit the selection by physiographic region based on known range of the taxon. Selection of all dwarf shrubland classes would likely result in an overestimation of habitat use by the taxon. Even for taxa whose habitat use was well documented across its' range, habitat associations could not always be well-represented by our environmental variables on a spatial basis. These limitations are some of the inherent criticisms of traditional habitat-based GAP models and one of the major reasons why we also elected to explore alternative modeling techniques.

Inductive models have become increasingly easy to use and are a topic of numerous publications in the ecological literature. MaxEnt, the modeling algorithm we selected, has been widely accepted by the ecological community as one of the most accurate algorithms for distribution modeling, and has proven to be effective with small sample sizes and presence only occurrence data from disparate sources (Graham and Elith 2005, Hijmans and Graham 2006, Graham et al. 2008, Wisz et al. 2008). It is also commonly accepted that inductive modeling techniques work best when there is uniform distribution of occurrence data throughout the species range. We attribute the high rate of omission error (i.e.

underprediction) in our inductive models to two things: poor quantity or quality occurrence data and the extreme range of variation in habitats and climates associated with a landmass the size of Alaska.

Similar to the findings of Beauvais et al. (2013) for NWGAP, comprehensive occurrence data were extremely rare for a study area as large as Alaska, and for the number of taxa included. Occurrence records were compiled from over 600 unique sources and were collected using diverse survey methods, study areas, and target taxa. Although the overall occurrence dataset consisted of approximately 1.5 million records, surprisingly few of the occurrence points were for the more common taxa (e.g., common raven, arctic ground squirrel, red fox). Additionally, game species records in the state are currently not consolidated into a single repository. Obtaining records for game taxa such as for caribou or moose from individual biologists across the various management agencies in Alaska would have entailed extensive time and resources, which was beyond the scope of this project. Although we did obtain occurrence records for many game animals, they were generally included within other multi-species datasets or were from fur-sealing (trapping) records, which had generally poor positional accuracy.

Even though we went through extensive data filtering and thinning exercises to attain a more even distribution of occurrence points across a taxon's range, this was rarely attainable. Much of the occurrence data was clustered in the most accessible areas, primarily along roads, rivers, and near human settlements. In such cases, the resulting localities for a taxon often reflected this sampling bias and less likely reflected the full taxon's niche, which can produce unrepresentative models (Anderson and Gonzalez 2011). There were, however, exceptions to this observed pattern: waterfowl, which are surveyed by aerial techniques extensively throughout the state by the U.S. Fish and Wildlife Service, had well distributed occurrence records; shorebirds, for which there are a number of regional datasets available that, once combined, provided generally good coverage throughout many species ranges; and amphibians, which are restricted to only a small part of the state and modeled well with small datasets.

We expended considerable effort in preparing and producing our inductive models. In the end, however, we rejected 64% of models generated using inductive techniques because they did not adequately represent a species distribution across its entire range. In many cases, the rejected models failed to predict occurrence in >50% of the taxon's range. Many of the rejected inductive models had relatively high quantitative estimates of accuracy, which were misleading, but were likely the result of overfitting the models in MaxEnt, which would have resulted in higher AUC values. Beauvais et al. (2013) reported similar results for the NW REGAP, rejecting over 59% of their inductive models for similar reasons. Overall, we found that quantity and quality of occurrence data for model development was a limiting factor in our inductive models and that independent and adequate data for evaluation was even more difficult to obtain.

Modeling species whose distributions span numerous environmental gradients or large variations in habitat may be problematic, resulting in distribution models with high rates of omission error in the predicted outputs (Guisan and Thuiller 2005, Hernandez et al. 2006). In such cases, the models may indicate regional specialization, peripheral, or isolated populations (Gonzalez et al. 2011). This was especially true of inductive models for taxa whose ranges included habitat on the mainland and also in the archipelagos of southeastern and southwestern Alaska. In general, if a species range spanned the mainland and extremities, the modeled output was almost always more representative of the species distribution in areas of more heterogeneous environmental space (mainland), but was unable to detect local environmental conditions in the extremities of the species range (southeast and southwest). Thereby, resulting in high rates of omission error, and ultimately, in the modeled output being rejected.

Some of the more obvious environmental gradients included mountains sharply contrasted to shrubland/meadow landscapes while a north-south gradient was evident in the data for date of first thaw, date of first freeze, and average monthly temperature. Additional gradients were southeast to northwest for distance to permafrost and exterior to interior for distance to winter sea ice and distance to coastline. When designing our modeling methods, we explored the idea of spatial partitioning of the data and hence, the modeled outputs, geographically (i.e., by ecoregion), which might have helped overcome some of the limitations to extrapolating across areas with such large environmental or habitat variations (Gonzalez et al. 2011). However, we deemed this method too labor intensive and beyond the scope of the project. Furthermore, we are uncertain if spatial partitioning of the modeled output and then re-combining the different outputs would have produced any higher quality models.

Final Model Selection and Assessment

Our initial goal was to combine the results of the deductive and inductive models to produce a final combined model. However, due to the disparity in modeled outputs generated by the different modeling techniques, we only selected the combined model option for 11% (n = 37) of our final models. Sixty-four percent (n = 222) of final models were deductive models, and 21% (n = 74) were inductive models. Overall, the traditional habitat-derived deductive models provided the backbone for most species models by producing the most consistent results, and were chosen as suitable more often than the inductive or combined models.

Because of broad variation in each taxon's use of the environment and the availability (or lack of) of comprehensive occurrence data, no single modeling approach, including the combined models, best represented all taxa within Alaska. As previously described, amphibians modeled best using inductive techniques. These taxa are restricted to Southeast Alaska, are niche specific, and we were able to obtain relatively good quality and quantity of occurrence data to support the modeling. Conversely, four species of bats are also restricted to Southeast Alaska, and these modeled best using deductive techniques, largely due to a lack of adequate occurrence data to produce representative inductive models. Marine mammals associated exclusively with coastal features (e.g., Steller sea lion, northern fur seal, harbor seal), such as beaches and spits, modeled best using inductive techniques, simply because these features were not adequately classified in the LANDFIRE map, which the deductive models relied heavily upon. Deductive modeling appeared to represent the remaining terrestrial mammals, wide ranging ungulates, carnivores, and small mammals, while inductive modeling appeared to best represent most medium-sized herbivores. We expected inductive models would better represent avian taxa given that 96% of occurrence records were for birds, and, as previously described, spatial distribution of waterfowl and shorebird data was generally good. However, of the 266 birds modeled, only 20% (n = 54) of models selected were produced using inductive techniques, with no observable pattern by Order or Family.

We expected that the quantitative techniques used to assess model accuracy would provide us with clear patterns with which to make our final model determinations. However, this was not the case. Instead, we found the ROC/AUC and classification success estimates were not a consistently reliable measure of model quality. In general, inductive models had higher quantitative estimates of accuracy than either the deductive or combined models, yet over 60% were rejected because the modeled extent was not representative of the taxon's range. The high assessment values are likely a result of significant overfitting of occurrence records, and the biases introduced by using different assessment data to evaluate the different model types, which collectively produced misleading results. Reliance on this single form of evaluation could have produced a final set of models for AKGAP with of very poor quality.

Fortunately, we also relied heavily on qualitative assessment measures, such as expert opinion and range extent to make our final model determinations. We feel that this combination of evaluation factors helped produce a set of final models with the highest quality possible.

Assessing the accuracy of GAP-predicted vertebrate distribution models is subject to many of the same problems as assessing land cover maps, as well as a host of more serious challenges related to both the behavioral aspects of species and the logistics of detection (Csuti and Crist 1998). It is, however, necessary to provide some measure of confidence in the results for each species and to allow users to judge the suitability of the distribution models for their own uses. For some species, no modeling method may be suitable for the project area and available digital data. We acknowledge that distribution maps are never finished products, but are continually updated as new information is gathered. However, we feel that assessing the accuracy of the current iteration provides useful information about their reliability to potential users and the suitability of the modeling process for particular species. Thus, we have attempted to provide users with a statement about the accuracy of our predicted vertebrate distributions within the limitations of available resources and practicalities of such an endeavor. The techniques we used to assess model accuracy would likely be greatly improved if we tested the models with independent data collected with some statistical rigor that were not included in the model derivation. However, this was not the plausible for this iteration of models.

Limitations and Conclusions

The main purpose of our species range maps and distribution models are to serve as practical tools and sources of sound information on which resource managers can rely to provide regional context for conservation research and management. The maps of species habitat distributions may be used to answer a wide variety of management, planning, and research questions on individual species or groups of species. In addition to the maps, great utility may be found in the compiled occurrence data and the habitat associations established for each species and stored in the WHRdb database.

Alaska's large area compares more closely to a regional GAP project than to a state-based GAP project. To our knowledge these models represent the first range-wide habitat models for vertebrate species at this resolution for Alaska. Keeping the issue of scale in mind, we believe that our models performed reasonably well over large geographic areas (>20,000 ha), and that the range maps produced for over 340 taxa is invaluable for future conservation and planning efforts. For smaller areas, however, model performance and range maps at HUC8 levels are likely to become more uncertain or potentially less useful.

We attempted to address the issues associated with occurrence data, environmental variables, habitat associations, and modeling approaches, which allowed us to produce a large set of valuable range maps and models for about 340 taxa. Prior to using Alaska GAP data, we encourage users to become familiar with the modeling efforts described in this report and note the limitations of range maps, distribution models, and all associated model variables.

Range maps and distribution models improve as the data upon which they are built improves. We present here preliminary results based on the wealth of data produced by the Alaska GAP Project. These data provide baseline information for conservation in Alaska, particularly when combined with other current efforts. A major contribution of the species ranges and models is the availability of the input data and model outputs for informing conservation management and strategic planning. The compilation of occurrence data for such a large number of taxa from an extensive number of sources will provide the basis for future modeling efforts, as will the standardized environmental data layers, all neatly packaged in a common projection and spatial resolution. Further, these data provide researchers and managers with a tool for understanding the distribution of vertebrates within the context of these species habitats in Alaska. These models and all the associated data mentioned above are available to natural resource managers, planners, and researchers for future conservation and management (see aknhp.uaa.alaska.edu or gapanlysis.usgs.gov).

Acknowledgements

Funding for this project was provided by the U.S. Geological Survey, National Gap Analysis Program. We are especially grateful to Jocelyn Aycrigg, University of Idaho, who served as the vertebrate species modeling coordinator; and to Kevin Gergely and Alexa McKerrow, USGS, who served as project managers. We are also grateful to Jeff Lonneker and Thomas Laxson, University of Idaho, who assisted with QA/QC and data delivery.

We would also like to thank Keith Boggs, Lindsey Flagstad and Tina Boucher, Alaska Natural Heritage Program, for assistance with the crosswalk of habitat associations to land cover classes. Julie Nielsen, UAS, assisted with data discovery and developing code to automate several GIS mapping tasks. Matt Callahan and Kim Homan assisted with ancillary data development and expert review.

We would like to thank the following reviewers for providing advice to improve and help select our final range maps and models: Andy Baltensperger, Gwen Baluss, Mary Ann Benoit, Karen Blejwas, Travis Booms, Brad Griffith, Julie Hagelin, Chris Harwood, Jessica Ilse, Judy Jacobs, Ellen Lance, Steve Lewis, Jim MacCraken, Steve Matsuoka, Marilyn Myers, Thomas Paragi, Bob Platte, Gretchen Roffler, Jason Schamber, John Shook, and Audrey Taylor.

Lastly, but equally as importantly, we would like to extend and enormous thank you to all the individuals that provided occurrence data to assist with model development and accuracy assessment: Amal Amji, Brad Andres, Gene Augustine, Andy Baltensperger, Mary Ann Benoit, Karen Blejwas, Travis Booms, Craig Cardner, Heather Coletti, Chris Gabriele, Debbie Groves, David Gustine, Colleen Handel, Chris Harwood, Christie Haupert, Falk Huettmann, Jennifer Jenkins, Bud Johnson, Kurt Kamletz, Karen Kozie, Denny Lassuy, Joe Liebezeit, Tom Lohuis, Carol McIntyre, Terri McMillan, Katja Mocnik, Dorothy Mortenson, Keith Pardieck, Laura Phillips, Bob Platte, Judy Putera, Sanjay Pyare, Gretchen Roffler, Dan Ruthrauff, Phil Schempf, Dave Schirokauer, Susan Sharbaugh, Cuyler Smith, Melanie Smith, Cara Staab, Shawn Stephensen, Dave Swanson, Miranda Terwilliger, David Tessler, Bill Thompson, Lee Tibbitts, and Cyndie Wolfe.

Literature Cited

Alaska Department of Fish and Game (ADFG). 2006. Our wealth maintained: a strategy for conserving Alaska's diverse wildlife and fish resources. Alaska Department of Fish and Game, Juneau, Alaska, xvii + 824 pp.

Armstrong, R.H. 2008. Guide to the Birds of Alaska. 5th Edition. Alaska Northwest Books.

Arujo, M.B. and P.H. Williams. 2000. Selecting areas for species persistence using occurrence data. Biological Conservation 96:331-345.

Anderson, R. P. and I. Gonzalez Jr. 2011. Species-specific tuning increases robustness to sampling bias in models of species distributions: An implementation with Maxent. Ecological Modelling 222:2796-2811.

Aycrigg, J. and G.P. Beauvais. 2007. Novel approaches to mapping vertebrate occurrence for the Northwest Gap Analysis Project. Gap Analysis Bulletin 15:27-33.

Beauvais, G., M. Andersen, D. Keinath, J. Aycrigg, and J. Lonneker. 2013. Predicted vertebrate species habitat distributions and species richness. Chapter 3 in J. Aycrigg, et al., eds. Ecoregional Gap Analysis of the Northwestern United States: Northwest Gap Analysis Project Draft Report. U.S. Geological Survey, Gap Analysis Program.

Boggs, K., Personal communication, Alaska Natural Heritage Program, University of Alaska Anchorage 2013.

Boggs, K., T. Boucher, T. Kuo, D. Fehringer and S. Guyer. 2013. Vegetation Map and Classification-Northern, Western, and Interior Alaska. http://aknhp.uaa.alaska.edu/ecology/vegetation-map-and-classification-northern-western-and-interior-alaska (Oct 2013).

Boucher, T., K. Boggs, L. Flagstad, and M. Duffy. 2009. Alaska LANDFIRE Application Project: map and classification review in seven locations across Alaska. Alaska Natural Heritage Program, University of Alaska Anchorage. 44 pp.

Boykin, K. G., B. C. Thompson, R. A. Deitner, D. Schrupp, D. Bradford, L. O'Brien, C. Drost, S. Propeck-Gray, W. Rieth, K. Thomas, W. Kepner, J. Lowry, C. Cross, B. Jones, T. Hamer, C. Mettenbrink, K.J. Oakes, J. Prior-Magee, K. Schulz, J. J. Wynne, C. King, J. Puttere, S. Schrader, and Z. Schwenke. 2007. Predicted animal habitat distributions and species richness. Chapter 3 in J.S. Prior-Magee t al. (eds). Southwest Regional Gap Analysis Final Report. U.S. Geological Survey, Gap Analysis Program. Moscow, Idaho.

Brugnach,M., J. Bolte, and G.A Bradshaw. 2003. Determining the significance of threshold values uncertainty in rule-based classification models, Ecological Modelling 160:63-76.

Cassidy, K. M., C. E. Grue, M. R. Smith, and K. M. Dvornich, eds. 1997. Washington State Gap Analysis - Final Report. Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle, Volumes 1-5.

Cramer, J.S. 2003. Logit models: from economics and other fields. Cambridge Univ. Press, 66-67 pp.

Csuti, B. 1994. Methods for developing terrestrial vertebrate distribution maps for Gap Analysis. Pages Data Layers 2.1-2.52 in J.M. Scott and M.D. Jennings, editors. A handbook for Gap Analysis. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Idaho.

Csuti, B. and P. Crist. 1998. Methods for Assessing Accuracy of Animal Distribution Maps, Gap Analysis Program, University of Idaho, Moscow, Idaho. http://www.gap.uidaho.edu/ Date Accessed: 02 July 2003.

Fairbanks, D.H.K., and G.A. Benn. 2000. Identifying regional landscapes for conservation planning: a case study from KwaZulu-Natal, South Africa. Landscape and Urban Planning 50: 237-257.

Fielding, A.H., J.F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environ. Conserv. 24:38-49.

Fleming, M. 1998. Statewide vegetation/land cover. [Vegetation map of Alaska, 23 classes, 19 vegetated, raster format.] http://agdc.usgs.gov/data/projects/fhm/#G. (Oct 2013).

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

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

Gonzalez, S.C., J.A. Soto-Centeno, and D.L. Reed. 2011. Population distribution models: species distributions are modeled better using biologically relevant data partitions. BMC Ecology 11:20.

Gotthardt, T., S. Pyare, F. Huettmann, K. Walton, M. Spathelf, K. Nesvacil, A. Baltensperger, G. Humphries and T.L. Fields. 2012. Alaska Gap Analysis Project Terrestrial Vertebrate Species Atlas. The Alaska Gap Analysis Project. University of Alaska.

Graham, C. and J. Elith. 2005. Testing alternative methodologies for modeling species' ecological niches and predicting geographic distributions. 2005 Annual Meeting of the Ecological Society of America. Ecological Society of America, Montreal Canada.

Graham, C. H., J. Elith, R. J. Hijmans, A. Guisan, A. T. Peterson, B. A. Loiselle and the NCEAS Predicting Species Distributions Working Group. 2008. The influence of spatial errors in species occurrence data used in distribution models. Journal of Applied Ecology 45:239-247.

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

Hernandez, P.A., C.H. Graham, L.L. Master, and D.L. Albert. 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography 29:773-785.

Hijmans, R. J. and C. H. Graham. 2006. The ability of climate envelope models to predict the effect of climate change on species distributions. Global Change Biology 12:2272-2281.

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

Jimenez-Valverde, A. and J. M. Lobo. 2006. The ghost of unbalanced species distribution data in geographical model predictions. Diversity and Distributions 12:521-524.

Johnson, C. J. and M. P. Gillingham. 2008. Sensitivity of species-distribution models to error, bias, and model design: an application to resource selection functions for woodland caribou. Ecological Modeling 213:143-155.

Lui, C., P.M. Berry, T.P. Dawson, and R.G. Pearson. 2005. Selecting thresholds of occurrence in the prediction of species distributions. Ecography 28:385-393.

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

Mackey, B.G., H.A. Nix, M.F. Hutchinson, J.P. Macmahon, and P.M. Fleming. 1988. Assisting representatives of places for conservation reservation and heritage listing. Environmental Management 12: 501-514.

Manel, S., H.C. Williams, and S.J. Ormerod. 2001. Evaluating presence-absence models in ecology: the need to account for prevalence. Journal of Applied Ecology, 38, 921-931.

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

Maxted, N. and E. Dulloo. 2008. Gap analysis: a tool for complimentary genetic conservation assessment. Diversity and Distributions 14: 1018-1030.

Parker, D.I., B.E. Lawhead, and J.A. Cook. 1997. Distributional limits of bats in Alaska. Arctic 53(3):256-265.

Pearce, J. and S. Ferrier. 2000. Evaluating the predictive performance of habitat models developed using logistic regression, Ecological Modelling, 133: 225-245.

Penhollow, M.E. and D. F. Stauffer. 2000. Large-scale habitat relationships of neotropical migratory birds in Virginia. Journal of Wildlife Management 64:362-373.

Peterson, A.T. and D.A. Kluza. 2003. New distributional modeling approaches for gap analysis. Animal Conservation 6:47-54.

Phillips, S. J. and M. Dudik. 2008. Modeling of species distributions with MaxEnt: new extensions and a comprehensive evaluation. Ecography 31:161-175.

Phillips, S. J., R. P. Anderson and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190:231-259.

Phillips, S.J., M. Dudik, J. Elith, C. H. Graham, A. Lehmann, J. Leathwick, J.and S. Ferrier.2009. Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. Ecological Applications 19:181-197.

Rodriguez, J.P., L. Brotons, J. Bustamante, and J. Seoane. 2007. The application of predictive modeling of species distribution to biodiversity conservation. Diversity and Distributions 13: 243-251.

Scott, M.J., F. Davis, B. Csuti, 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

U.S. Geological Survey Gap Analysis Program. 2011. National GAP vertebrate species distribution model. http://gapanalysis.usgs.gov/species

Wisz, M. S., R. J. Hijmans, J. Li, A. T. Peterson, C. H. Graham, A. Guisan and the NCEAS Predicting Species Distributions Working Group. 2008. Effects of sample size on the performance of species distribution models. Diversity and Distributions 14:763-773.

Yackulic, C.B., R. Chandler, E.F. Zipkin, J.A. Royle, J.D. Nichols, E.H. Campbell Grant, and S. Veran. 2012. Presence-only modeling using MAXENT: when can we trust the inferences? Methods in Ecology and Evolution 1-8.

Appendix A: Full species list and accuracy statistics for models of the distribution of terrestrial vertebrates in Alaska

Alaska
Gap
Analysis
Project

Full species list and accuracy statistics for models of the distribution of terrestrial vertebrates in Alaska. Table includes common name, scientific name, ITIS code, MaxEnt AUC_{PO}, and classification success values (CS; the percent of records of known occurrence predicted by the model to fall in suitable environments) for inductive, deductive, and combined models. Cells highlighted in gray indicate the final model that was selected, which is summarized in the "Final Models CS" column. Final Model Selection Criteria includes: CS (classification success), EX (expert opinion), and RE (range extent). Modeling records indicate the number of filtered occurrence records used to build the inductive model. These records also functioned as the assessment dataset for the deductive and combined models. Assessment records indicate the number of records that were used in accuracy assessment of inductive models.

Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
Amphibia										
Northwestern Salamander	*Ambystoma gracile*	173597	1.000	-	71.4	64.3	71.4	CS	6	1
Long-toed Salamander	*Ambystoma macrodactylum*	173601	0.999	-	77.3	72.7	77.3	CS	10	3
Roughskin Newt	*Taricha granulosa*	173620	0.994	89.8	56.1	55.4	89.8	CS	109	32
Western Toad	*Anaxyrus boreas*	173482	0.986	91.3	52.1	52.1	91.3	CS	340	86
Wood Frog	*Lithobates sylvaticus*	173440	0.986	77.9	54.2	53.9	77.9	CS	382	111
Columbia Spotted Frog	*Rana luteiventris*	550546	0.998	81.3	52.4	52.4	81.3	CS	33	8
Aves										
Greater White-fronted Goose	*Anser albifrons*	175020	0.950	84.0	77.3	79.3	77.3	EX	1562	456
Tule White-fronted Goose	*Branta hutchinsii leucopareia*	714722	-	-	-	-	-	EX	N/A	N/A
Emperor Goose	*Chen canagica*	175042	0.995	92.0	73.0	72.8	92.0	EX	152	44
Snow Goose	*Chen caerulescens*	175038	0.972	94.3	70.2	71.0	71.0	EX	774	180
Brant	*Branta bernicla*	175011	0.697	97.3	63.5	64.3	97.3	EX	21171	5920
Cackling Goose	*Branta hutchinsii*	714068	0.612	74.2	90.5	73.3	90.5	RE	48804	14484
Taverners Cackling Goose	*Anser albifrons elgasi*	714728	-	-	-	-	-	EX	N/A	N/A
Cackling Cackling Goose	*Branta hutchinsii taverneri*	714727	-	-	-	-	-	EX	N/A	N/A
Aleutian Cackling Goose	*Branta hutchinsii minima*	714726	-	-	-	-	-	EX	N/A	N/A
Canada Goose	*Branta canadensis*	174999	0.604	54.8	52.4	50.8	52.4	RE	52543	14829
Trumpeter Swan	*Cygnus buccinator*	174992	0.857	93.0	54.6	55.2	54.6	EX	5527	1576
Tundra Swan	*Cygnus columbianus*	174987	0.599	80.8	73.8	69.7	73.8	EX	57084	16973
Whooper Swan	*Cygnus cygnus*	174990	-	-	-	-	-	EX	N/A	N/A
Gadwall	*Anas strepera*	175073	0.998	75.0	52.0	52.0	52.0	RE	38	11
American Wigeon	*Anas americana*	175094	0.940	79.9	66.4	70.8	66.4	RE	1918	564
Mallard	*Anas platyrhynchos*	175063	0.940	79.3	61.6	66.5	61.6	RE	1889	558
Blue-winged Teal	*Anas discors*	175086	0.999	83.3	56.4	56.9	56.4	RE	20	6
Northern Shoveler	*Anas clypeata*	175096	0.946	77.3	67.7	66.1	67.7	RE	1706	502
Northern Pintail	*Anas acuta*	175074	0.643	89.3	76.0	85.0	76.0	RE	34922	10215
Green-winged Teal	*Anas crecca*	175081	0.967	71.9	61.7	64.7	61.7	RE	968	281
Canvasback	*Aythya valisineria*	175129	0.982	88.0	62.4	64.8	62.4	EX	517	154

Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
Redhead	*Aythya americana*	175125	0.999	78.1	-	57.9	78.1	CS	30	8
Ring-necked Duck	*Aythya collaris*	175128	0.995	80.0	-	-	80.0	CS	139	40
Tufted Duck	*Aythya fuligula*	175135	1.000	-	50.1	50.0	50.1	RE	4	1
Greater Scaup	*Aythya marila*	175130	0.990	61.7	52.3	53.9	52.3	EX	219	60
Lesser Scaup	*Aythya affinis*	175134	0.996	78.8	61.0	52.7	61.0	EX	115	33
Steller's Eider	*Polysticta stelleri*	175153	0.994	77.5	88.3	73.1	73.1	EX	175	50
Spectacled Eider	*Somateria fischeri*	175161	0.981	88.7	82.4	79.3	79.3	EX	558	163
King Eider	*Somateria spectabilis*	175160	0.977	94.3	78.9	79.5	79.5	EX	646	172
Common Eider	*Somateria mollissima*	175155	0.809	86.5	54.7	54.6	86.5	CS	6725	588
Harlequin Duck	*Histrionicus histrionicus*	175149	0.978	60.7	54.4	53.9	54.4	RE	466	28
Surf Scoter	*Melanitta perspicillata*	175170	0.963	71.9	55.9	53.1	55.9	EX	884	90
White-winged Scoter	*Melanitta fusca*	175163	0.957	-	52.1	54.6	52.1	EX	1131	202
Black Scoter	*Melanitta americana*	175171	0.873	82.6	69.8	72.6	69.8	EX	4711	1367
Long-tailed Duck	*Clangula hyemalis*	175147	0.686	91.2	72.2	82.2	72.2	EX	22996	6226
Bufflehead	*Bucephala albeola*	175145	0.986	81.7	61.0	62.7	61.0	EX	399	109
Common Goldeneye	*Bucephala clangula*	175141	0.991	81.9	73.7	75.0	73.7	EX	258	76
Barrow's Goldeneye	*Bucephala islandica*	175144	0.992	75.0	50.2	50.4	50.2	EX	178	24
Hooded Merganser	*Lophodytes cucullatus*	175183	0.999	-	50.0	50.0	-	EX	7	2
Common Merganser	*Mergus merganser*	175185	0.987	68.0	63.2	53.5	63.2	EX and RE	230	50
Red-breasted Merganser	*Mergus serrator*	175187	0.951	73.1	-	55.2	-	RE	1302	245
Ruffed Grouse	*Bonasa umbellus*	175790	0.996	74.2	55.7	60.6	55.7	EX	109	32
Spruce Grouse	*Falcipennis canadensis*	553896	0.995	62.5	53.2	50.9	53.2	RE	42	12
Willow Ptarmigan	*Lagopus lagopus*	175804	0.950	71.9	52.4	54.9	52.4	RE	1547	463
Rock Ptarmigan	*Lagopus muta*	677542	0.993	81.8	56.6	56.0	56.6	RE	199	59
White-tailed Ptarmigan	*Lagopus leucura*	677541	-	-	-	-	-	EX	N/A	N/A
Sooty Grouse	*Dendragapus fuliginosus*	175776	0.995	87.5	96.0	88.2	96.0	CS	101	28
Sharp-tailed Grouse	*Tympanuchus phasianellus*	175841	1.000	-	77.5	77.5	77.5	RE	7	2
Red-throated Loon	*Gavia stellata*	174474	0.893	84.3	-	71.9	-	EX	3767	1072
Arctic Loon	*Gavia arctica*	174471	1.000	-	56.3	-	56.3	CS	6	1
Pacific Loon	*Gavia pacifica*	174475	0.670	87.3	-	82.8	-	RE	27469	8179
Common Loon	*Gavia immer*	174469	0.956	85.8	70.5	72.2	70.5	RE	1316	386
Yellow-billed Loon	*Gavia adamsii*	174470	0.974	86.9	81.2	79.3	79.3	EX	742	201
Horned Grebe	*Podiceps auritus*	174482	0.996	77.9	51.7	53.5	51.7	EX	99	26
Red-necked Grebe	*Podiceps grisegena*	174479	0.984	77.9	-	-	-	EX	413	112

Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
Double-crested Cormorant	*Phalacrocorax auritus*	174717	0.996	66.7	50.2	50.4	66.7	CS	77	6
Red-faced Cormorant	*Phalacrocorax urile*	174728	0.995	-	51.0	50.3	-	EX	106	3
Pelagic Cormorant	*Phalacrocorax pelagicus*	174725	0.995	89.5	53.2	52.9	89.5	CS	119	19
American Bittern	*Botaurus lentiginosus*	174856	-	-	-	-	-	EX	N/A	N/A
Great Blue Heron	*Ardea herodias*	174773	0.997	70.8	64.4	69.8	64.4	RE	52	12
Osprey	*Pandion haliaetus*	175590	0.995	81.1	54.2	59.1	54.2	EX and RE	151	45
Bald Eagle	*Haliaeetus leucocephalus*	175420	0.863	83.9	56.0	59.7	56.0	EX	4674	982
Northern Harrier	*Circus cyaneus*	175430	0.993	61.9	50.2	51.0	50.2	EX	149	44
Sharp-shinned Hawk	*Accipiter striatus*	175304	0.992	61.5	64.5	62.7	64.5	EX	96	26
Northern Goshawk	*Accipiter gentilis*	175300	0.990	69.3	67.6	70.8	67.6	EX and RE	212	61
Queen Charlotte Goshawk	*Accipiter gentilis laingi*	175302	0.994	81.8	66.9	64.5	64.5	EX	63	11
Swainson's Hawk	*Buteo swainsoni*	175367	1.000	-	50.0	50.0	50.0	EX	6	1
Red-tailed Hawk	*Buteo jamaicensis*	175350	0.992	63.6	-	50.5	63.6	EX	192	57
Rough-legged Hawk	*Buteo lagopus*	175373	0.984	82.5	-	54.4	-	EX and RE	453	133
Golden Eagle	*Aquila chrysaetos*	175407	0.982	65.5	52.8	52.5	65.5	EX	520	156
American Kestrel	*Falco sparverius*	175622	0.996	70.5	53.6	52.0	70.5	EX	42	11
Merlin	*Falco columbarius*	175613	0.994	64.5	56.1	52.2	56.1	EX	129	38
Gyrfalcon	*Falco rusticolus*	175599	0.989	80.6	50.5	60.3	50.5	EX	306	90
Peregrine Falcon	*Falco peregrinus*	175604	0.993	76.8	-	55.2	-	EX	188	55
American Peregrine Falcon	*Falco peregrinus anatum*	175605	-	-	-	-	-	EX	N/A	N/A
Peale's Peregrine Falcon	*Falco peregrinus pealei*	175606	-	-	-	-	-	EX	N/A	N/A
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	175608	-	-	-	-	-	EX	N/A	N/A
Sora	*Porzana carolina*	176242	0.997	-	64.0	66.0	64.0	EX	9	2
American Coot	*Fulica americana*	176292	0.993	-	60.5	-	60.5	CS	12	3
Sandhill Crane	*Grus canadensis*	176177	0.978	78.1	55.5	55.8	55.5	RE	626	184
Black-bellied Plover	*Pluvialis squatarola*	176567	0.998	75.0	59.5	62.3	59.5	RE	47	12
American Golden-Plover	*Pluvialis dominica*	176564	0.986	73.8	62.5	64.0	62.5	EX	413	123
Pacific Golden-Plover	*Pluvialis fulva*	554381	0.996	73.8	-	50.2	-	RE	80	21
Semipalmated Plover	*Charadrius semipalmatus*	176506	0.993	66.0	51.5	53.1	51.5	EX	180	53
Killdeer	*Charadrius vociferus*	176520	0.993	-	50.0	50.0	-	EX	11	3
Eurasian Dotteral	*Charadrius morinellus*	176545	-	-	-	-	-	EX	N/A	N/A
Black Oystercatcher	*Haematopus bachmani*	176475	0.976	92.9	50.0	50.0	92.9	CS	529	39
Greater Yellowlegs	*Tringa melanoleuca*	176619	0.984	70.9	50.9	51.1	50.9	EX	294	85

Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
Lesser Yellowlegs	*Tringa flavipes*	176620	0.973	70.3	51.1	53.2	51.1	RE	802	237
Wood Sandpiper	*Tringa glareola*	176618	-	-	50.0	-	50.0	CS	N/A	N/A
Solitary Sandpiper	*Tringa solitaria*	176615	0.982	76.8	51.6	50.1	76.8	CS	515	150
Wandering Tattler	*Tringa incana*	176635	0.997	70.8	66.5	66.9	66.5	RE	84	24
Spotted Sandpiper	*Actitis macularius*	726049	0.980	74.7	56.1	59.2	56.1	RE	545	155
Upland Sandpiper	*Bartramia longicauda*	176610	0.997	84.3	58.7	53.5	84.3	CS	93	27
Whimbrel	*Numenius phaeopus*	176599	0.989	65.6	64.1	65.4	65.4	EX	315	93
Bristle-thighed Curlew	*Numenius tahitiensis*	176604	0.994	78.6	63.5	59.9	59.9	EX	187	56
Hudsonian Godwit	*Limosa haemastica*	176690	0.994	60.7	51.5	50.4	50.4	EX	105	28
Bar-tailed Godwit	*Limosa lapponica*	176687	0.995	84.0	53.4	51.0	51.0	EX	141	36
Beringian Marbled Godwit	*Limosa fedoa beringiae*	176686A	0.999	-	75.4	73.3	75.4	RE	19	5
Ruddy Turnstone	*Arenaria interpres*	176571	0.999	-	-	50.4	-	EX	18	3
Black Turnstone	*Arenaria melanocephala*	176574	0.999	-	71.9	66.7	71.9	EX and RE	23	4
Surfbird	*Aphriza virgata*	176673	0.998	78.8	60.9	66.8	60.9	EX	48	13
Red Knot	*Calidris canutus*	176642	0.997	-	-	51.1	-	EX	13	3
Sanderling	*Calidris alba*	176669	0.999	60.0	50.0	50.0	60.0	CS	20	5
Semipalmated Sandpiper	*Calidris pusilla*	176667	0.997	83.8	56.9	59.9	56.9	EX and RE	72	20
Western Sandpiper	*Calidris mauri*	176668	0.996	76.9	65.4	66.2	65.4	RE	92	26
Red-necked Stint	*Calidris ruficollis*	176659	1.000	-	-	50.2	-	EX	6	1
Least Sandpiper	*Calidris minutilla*	176656	0.989	65.8	50.8	53.4	65.8	CS	291	84
White-rumped Sandpiper	*Calidris fuscicollis*	176654	1.000	-	52.6	51.3	51.3	EX	5	1
Bairds Sandpiper	*Calidris bairdii*	176655	0.999	70.5	76.2	75.6	76.2	CS	37	11
Pectoral Sandpiper	*Calidris melanotos*	176653	0.998	86.5	-	80.1	-	EX	46	13
Rock Sandpiper	*Calidris ptilocnemis*	176647	0.997	95.0	-	50.3	95.0	CS	48	10
Pribilof Rock Sandpiper	*Calidris ptilocnemis ptilocnemis*	176650	0.999	50.0	-	57.5	57.5	CS	33	9
Aleutian Rock Sandpiper	*Calidris ptilocnemis couesi*	176651	-	-	-	-	-	EX	N/A	N/A
Dunlin	*Calidris alpina*	176661	0.997	77.9	62.6	66.1	62.6	RE	59	17
Stilt Sandpiper	*Calidris himantopus*	554145	0.999	-	50.0	50.0	-	EX	13	3
Buff-breasted Sandpiper	*Tryngites subruficollis*	176684	1.000	-	62.5	64.6	64.6	CS	8	2
Short-billed Dowitcher	*Limnodromus griseus*	176675	0.994	73.0	53.7	54.0	53.7	RE	129	38
Long-billed Dowitcher	*Limnodromus scolopaceus*	176679	0.998	82.9	77.5	80.4	77.5	EX	66	19
Wilson's Snipe	*Gallinago delicata*	726048	0.926	65.2	56.2	51.6	56.2	RE	2402	701
Common Snipe	*Gallinago gallinago*	176700	-	-	-	-	-	EX	N/A	N/A

	Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
	Red-necked Phalarope	*Phalaropus lobatus*	176735	0.991	69.3	-	-	-	RE	205	53
	Red Phalarope	*Phalaropus fulicarius*	176734	-	-	-	-	-	EX	N/A	N/A
	Bonaparte's Gull	*Chroicocephalus philadelphia*	176839	0.991	81.5	58.9	63.5	58.9	RE	215	58
	Mew Gull	*Larus canus*	176832	0.855	76.1	66.9	68.3	66.9	RE	5646	1614
	Ring-billed Gull	*Larus delawarensis*	176830	-	-	51.3	-	51.3	CS	N/A	N/A
	Herring Gull	*Larus argentatus*	176824	0.991	78.9	58.0	59.7	58.0	RE	211	51
	Iceland Gull	*Larus glaucoides*	176811	-	-	51.6	-	51.6	CS	N/A	N/A
	Slaty-backed Gull	*Larus schistisagus*	176816	-	-	-	-	Reject all	EX	N/A	N/A
	Glaucous winged Gull	*Larus glaucescens*	176814	0.973	88.1	51.9	51.5	88.1	CS	599	88
	Glaucous Gull	*Larus hyperboreus*	176808	0.960	83.7	66.1	65.1	65.1	EX	1190	333
	Sabines Gull	*Xema sabini*	176866	0.772	82.1	84.4	76.0	84.4	RE	11839	3485
	Black-legged Kittiwake	*Rissa tridactyla*	176875	0.977	88.3	-	-	88.3	CS	504	30
	Red-legged Kittiwake	*Rissa brevirostris*	176845	0.999	-	-	-	-	EX	22	2
	Caspian Tern	*Sterna caspia*	176924	0.993	-	56.3	56.3	56.3	EX	10	1
	Arctic Tern	*Sterna paradisaea*	176890	0.952	75.8	52.6	52.5	52.6	EX	1453	414
	Aleutian Tern	*Sterna aleutica*	176893	0.994	85.0	-	-	85.0	CS	79	15
	Pomarine Jaeger	*Stercorarius pomarinus*	176792	0.999	92.9	-	89.3	-	RE	33	7
	Parasitic Jaeger	*Stercorarius parasiticus*	176793	0.995	77.5	-	55.0	-	RE	104	20
	Long-tailed Jaeger	*Stercorarius longicaudus*	176794	0.985	75.8	55.8	57.9	55.8	RE	429	126
	Dovekie	*Alle alle*	176982	1.000	-	50.0	50.0	50.0	EX	5	1
	Common Murre	*Uria aalge*	176974	0.998	75.0	50.0	50.0	Reject all	EX	51	6
	Thick-billed Murre	*Uria lomvia*	176978	0.999	-	50.0	50.0	Reject all	EX	18	2
	Black Guillemot	*Cepphus grylle*	176985	0.999	-	50.0	50.0	-	EX	13	1
	Pigeon Guillemot	*Cepphus columba*	176991	0.972	96.3	55.2	52.4	96.3	RE	629	47
	Marbled Murrelet	*Brachyramphus marmoratus*	176996	0.981	83.8	60.1	57.1	83.8	CS	407	37
	Kittlitz's Murrelet	*Brachyramphus brevirostris*	176998	0.997	60.0	50.0	50.0	60.0	CS	71	5
	Ancient Murrelet	*Synthliboramphus antiquus*	177008	-	-	50.0	-	50.0	CS	N/A	N/A
	Cassin's Auklet	*Ptychoramphus aleuticus*	177013	1.000	-	57.1	50.0	Reject all	EX	5	0
	Parakeet Auklet	*Aethia psittacula*	554029	0.998	-	-	-	Reject all	EX	39	4
	Least Auklet	*Aethia pusilla*	177020	0.999	-	53.3	53.3	53.3	EX	11	0
	Whiskered Auklet	*Aethia pygmaea*	177021	0.998	-	54.5	50.0	50.0	EX	35	4

Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
Crested Auklet	*Aethia cristatella*	177019	0.999	-	-	-	Reject all	EX	11	0
Rhinoceros Auklet	*Cerorhinca monocerata*	177023	0.999	-	-	50.1	Reject all	EX	30	4
Horned Puffin	*Fratercula corniculata*	177029	0.989	80.0	-	-	80.0	CS	229	10
Tufted Puffin	*Fratercula cirrhata*	177032	0.988	91.7	-	-	91.7	CS	250	12
Western Screech-Owl	*Megascops kennicotti*	686659	-	-	53.3	-	53.3	EX	N/A	N/A
Great Horned Owl	*Bubo virginianus*	177884	0.994	72.5	62.1	67.3	62.1	EX and RE	172	50
Snowy Owl	*Bubo scandiacus*	686683	0.962	81.5	52.5	50.0	Reject all	EX	1120	310
Northern Hawk Owl	*Surnia ulula*	177898	0.996	77.4	52.0	51.3	77.4	CS	77	21
Northern Pygmy-Owl	*Glaucidium gnoma*	177902	0.996	-	92.6	85.8	85.8	EX	12	3
Barred Owl	*Strix varia*	177921	-	-	-	-	-	EX	N/A	N/A
Great Gray Owl	*Strix nebulosa*	177929	0.999	62.5	59.8	56.9	59.8	EX and RE	29	8
Short-eared Owl	*Asio flammeus*	177935	0.991	66.4	55.7	51.4	55.7	EX	233	67
Boreal Owl	*Aegolius funereus*	177938	0.998	86.7	64.8	69.8	64.8	RE	53	15
Northern Saw-whet Owl	*Aegolius acadicus*	177942	0.997	92.9	66.7	64.6	66.7	RE	75	21
Common Nighthawk	*Chordeiles minor*	177979	0.979	-	50.0	50.0	-	EX	5	1
Black Swift	*Cypseloides niger*	177997	0.999	-	50.0	50.0	-	EX	8	1
Vaux's Swift	*Chaetura vauxi*	178002	0.999	-	50.0	59.1	59.1	EX	5	0
Rufous Hummingbird	*Selasphorus rufus*	178040	0.992	83.7	-	54.4	83.7	CS	169	43
Belted Kingfisher	*Megaceryle alcyon*	178106	0.989	76.8	57.2	57.0	57.2	RE	242	69
Yellow-bellied Sapsucker	*Sphyrapicus varius*	178202	-	-	84.4	-	84.4	CS	6	1
Red-breasted Sapsucker	*Sphyrapicus ruber*	178212	0.991	96.9	-	85.4	85.4	EX	209	57
Downy Woodpecker	*Picoides pubescens*	178259	0.993	75.6	52.4	52.5	75.6	CS	159	45
Hairy Woodpecker	*Picoides villosus*	178262	0.991	71.3	70.7	63.0	70.7	RE	208	61
American Three-toed Woodpecker	*Picoides dorsalis*	178251	0.992	71.6	58.8	57.1	58.8	RE	199	59
Black-backed Woodpecker	*Picoides arcticus*	178250	0.994	75.0	58.1	52.2	75.0	CS	17	5
Northern Flicker	*Colaptes auratus*	178154	0.996	86.2	67.4	74.7	67.4	RE	100	29
Olive-sided Flycatcher	*Contopus cooperi*	554221	0.974	73.2	55.1	53.4	55.1	RE	753	221
Western Wood-Pewee	*Contopus sordidulus*	178360	0.994	81.3	64.3	67.2	64.3	RE	143	40
Yellow-bellied Flycatcher	*Empidonax flaviventris*	178338	0.999	92.5	52.1	52.6	52.6	EX	35	10
Alder Flycatcher	*Empidonax alnorum*	178340	0.936	73.1	52.7	54.3	73.1	EX and	2029	596

	Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
									RE		
	Hammond's Flycatcher	*Empidonax hammondii*	554254	0.987	83.0	60.2	57.1	60.2	RE	383	112
	Pacific-slope Flycatcher	*Empidonax difficilis*	178348	0.987	95.5	-	60.6	-	EX	338	95
	Say's Phoebe	*Sayornis saya*	178333	0.997	67.1	68.9	60.9	68.9	CS	67	19
	Northern Shrike	*Lanius excubitor*	178511	0.996	57.1	50.3	50.6	50.3	RE	52	14
	Warbling Vireo	*Vireo gilvus*	179023	0.997	81.8	52.6	54.9	81.8	CS	83	22
	Red-eyed Vireo	*Vireo olivaceus*	179021	0.999	-	-	50.0	-	EX	5	1
	Gray Jay	*Perisoreus canadensis*	179667	0.945	70.9	53.4	53.1	53.4	RE	1732	518
	Steller's Jay	*Cyanocitta stelleri*	179685	0.992	88.0	84.0	82.3	84.0	EX	165	46
	Black-billed Magpie	*Pica hudsonia*	726117	0.992	79.1	57.2	65.5	57.2	RE	178	49
	American Crow	*Corvus brachyrhynchos*	179731	-	-	50.4	-	50.4	CS	N/A	N/A
	Northwestern Crow	*Corvus caurinus*	179736	0.990	87.5	76.8	71.4	87.5	CS	232	36
	Common Raven	*Corvus corax*	179725	0.955	56.7	53.7	52.5	53.7	RE	1283	372
	Sky Lark	*Alauda arvensis*	178398	-	-	-	-	Reject all	EX	N/A	N/A
	Horned Lark	*Eremophila alpestris*	554256	0.992	86.1	64.7	60.8	64.7	RE	235	70
	Tree Swallow	*Tachycineta bicolor*	178431	0.960	78.7	64.1	61.1	64.1	RE	1177	336
	Violet-green Swallow	*Tachycineta thalassina*	178427	0.992	75.5	50.4	51.2	50.4	RE	190	55
	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	178443	1.000	-	50.0	50.0	50.0	EX	4	1
	Bank Swallow	*Riparia riparia*	178436	0.974	76.9	50.4	54.7	50.4	RE	745	210
	Cliff Swallow	*Petrochelidon pyrrhonota*	178455	0.995	66.4	64.8	62.3	64.8	RE	122	35
	Barn Swallow	*Hirundo rustica*	178448	0.997	63.6	51.2	51.2	63.6	CS	40	11
	Black-capped Chickadee	*Poecile atricapillus*	554382	0.978	73.8	55.7	56.2	55.7	RE	601	173
	Chestnut-backed Chickadee	*Poecile rufescens*	554387	0.987	92.8	79.9	80.5	79.9	RE	321	90
	Boreal Chickadee	*Poecile hudsonicus*	726112	0.979	72.2	58.5	57.5	57.5	EX	601	180
	Gray-headed Chickadee	*Poecile cinctus*	726111	-	-	-	-	Reject all	EX	N/A	N/A
	Red-breasted Nuthatch	*Sitta canadensis*	178784	0.994	72.6	59.7	60.4	72.6	CS	75	21
	Brown Creeper	*Certhia americana*	178803	0.992	84.2	77.6	72.3	77.6	EX	136	38
	Pacific Wren	*Troglodytes pacificus pacificus*	178559	0.979	93.9	83.7	83.1	83.7	RE	513	140
	American Dipper	*Cinclus mexicanus*	178536	0.997	50.0	55.5	61.4	55.5	RE	28	7
	Golden-crowned Kinglet	*Regulus satrapa*	179865	0.986	85.9	77.7	74.6	85.9	CS	322	92
	Ruby-crowned Kinglet	*Regulus calendula*	179870	0.941	69.0	-	63.5	-	RE	1825	530
	Arctic Warbler	*Phylloscopus borealis*	179843	0.982	78.0	55.9	50.4	50.4	EX	506	148
	Bluethroat	*Luscinia svecica*	179818	0.996	81.3	73.1	66.2	66.2	EX	109	32

	Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
	Northern Wheatear	*Oenanthe oenanthe*	179814	0.996	75.8	61.1	57.6	57.6	EX	104	31
	Mountain Bluebird	*Sialia currucoides*	179811	0.995	-	56.5	51.9	56.5	EX	10	3
	Townsends Solitaire	*Myadestes townsendi*	179824	0.997	65.0	50.2	50.5	50.2	RE	86	25
	Gray-cheeked Thrush	*Catharus minimus*	179793	0.928	69.2	52.5	51.4	52.5	RE	2354	685
	Swainson's Thrush	*Catharus ustulatus*	179788	0.910	76.7	55.4	56.1	55.4	RE	3091	920
	Hermit Thrush	*Catharus guttatus*	179779	0.943	79.6	67.6	67.6	67.6	EX	1583	455
	American Robin	*Turdus migratorius*	179759	0.913	64.0	51.0	53.6	51.0	EX and RE	2903	859
	Varied Thrush	*Ixoreus naevius*	179773	0.905	69.3	60.7	60.1	60.7	RE	3189	920
	Eastern Yellow Wagtail	*Motacilla tschutschensis*	726116	0.997	90.6	66.2	63.0	66.2	EX	82	24
	White Wagtail	*Motacilla alba*	178476	1.000	-	50.7	50.0	50.7	CS	8	2
	Red-throated Pipit	*Anthus cervinus*	178498	1.000	-	-	50.5	-	EX	5	1
	American Pipit	*Anthus rubescens*	554127	0.982	75.0	52.1	53.6	52.1	EX and RE	485	145
	Bohemian Waxwing	*Bombycilla garrulus*	178529	0.990	73.5	60.1	60.2	60.1	RE	281	83
	Cedar Waxwing	*Bombycilla cedrorum*	178532	0.998	83.3	69.7	66.3	69.7	EX	32	6
	Tennessee Warbler	*Oreothlypis peregrina*	178855	0.995	-	56.8	52.3	56.8	CS	13	3
	Orange-crowned Warbler	*Oreothlypis celata*	178856	0.907	65.2	51.1	51.9	51.1	EX	3081	894
	Yellow Warbler	*Dendroica petechia*	178878	666.000	69.5	55.6	59.6	69.5	CS	19189	17546
	Magnolia Warbler	*Dendroica magnolia*	178886	-	-	-	-	-	EX	N/A	N/A
	Yellow-rumped Warbler	*Dendroica coronata*	178891	0.912	77.6	64.7	67.2	64.7	RE	2988	886
	Townsend's Warbler	*Dendroica townsendi*	178897	0.972	84.3	68.6	62.9	68.6	EX	791	232
	Blackpoll Warbler	*Dendroica striata*	178913	0.945	79.8	50.6	53.8	50.6	RE	1728	499
	American Redstart	*Setophaga ruticilla*	178979	0.998	81.8	54.0	55.0	81.8	CS	44	11
	Northern Waterthrush	*Parkesia noveboracensis*	178931	0.937	79.2	51.5	51.9	51.5	RE	1982	568
	Macgillivray's Warbler	*Oporornis tolmiei*	178940	0.998	75.0	54.6	54.3	75.0	CS	57	14
	Common Yellowthroat	*Geothlypis trichas*	178944	0.996	88.9	51.0	51.0	88.9	CS	79	18
	Wilson's Warbler	*Wilsonia pusilla*	178973	0.917	64.4	51.9	51.4	51.9	RE	2688	793
	Western Tanager	*Piranga ludoviciana*	179882	0.998	91.7	61.9	62.7	91.7	CS	49	12
	American Tree Sparrow	*Spizella arborea*	179432	0.935	67.1	58.2	55.9	58.2	EX	2084	616
	Chipping Sparrow	*Spizella passerina*	179435	0.996	78.2	62.0	64.0	62.0	EX and RE	107	31
	Brewer's Sparrow	*Spizella breweri*	179440	1.000	-	71.4	57.1	71.4	RE	4	1
	Savannah Sparrow	*Passerculus sandwichensis*	179314	0.932	63.4	52.1	51.8	52.1	RE	2164	634
	Fox Sparrow	*Passerella iliaca*	179464	0.905	64.1	56.7	54.5	56.7	RE	3210	923
	Song Sparrow	*Melospiza melodia*	179492	0.992	81.4	50.6	50.2	Reject	EX	160	43

	Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
								all			
	Lincoln's Sparrow	*Melospiza lincolnii*	179484	0.962	76.3	55.1	55.1	55.1	RE	1119	332
	White-crowned Sparrow	*Zonotrichia leucophrys*	179455	0.918	69.1	51.5	50.9	51.5	RE	2769	830
	Golden-crowned Sparrow	*Zonotrichia atricapilla*	179461	0.973	69.5	56.6	50.9	56.6	RE	688	204
	Dark-eyed Junco	*Junco hyemalis*	179410	0.925	78.9	69.4	77.0	69.4	RE	2474	740
	Lapland Longspur	*Calcarius lapponicus*	179526	0.971	76.8	58.4	61.8	58.4	EX	853	251
	Smith's Longspur	*Calcarius pictus*	179529	0.998	86.1	-	51.9	86.1	EX	63	18
	Snow Bunting	*Plectrophenax nivalis*	179532	0.996	61.3	51.1	50.9	61.3	CS	68	20
	Mckay's Bunting	*Plectrophenax hyperboreus*	179535	1.000	-	50.4	50.0	50.4	EX and RE	4	1
	Red-winged Blackbird	*Agelaius phoeniceus*	179045	0.999	87.5	-	57.8	87.5	CS	36	10
	Rusty Blackbird	*Euphagus carolinus*	179091	0.978	84.6	-	53.6	-	RE	626	178
	Brown-headed Cowbird	*Molothrus ater*	179112	1.000	-	52.6	-	52.6	CS	7	1
	Brambling	*Fringilla montifringilla*	179167	-	-	-	-	-	EX	N/A	N/A
	Gray-crowned Rosy-Finch	*Leucosticte tephrocotis*	179215	0.996	64.3	50.3	50.3	Reject all	EX	50	14
	Pine Grosbeak	*Pinicola enucleator*	179205	0.976	76.1	50.8	54.9	50.8	EX and RE	650	187
	Red Crossbill	*Loxia curvirostra*	179259	0.991	93.4	83.6	78.7	83.6	EX	180	49
	White-winged Crossbill	*Loxia leucoptera*	179268	0.969	78.2	54.2	53.2	54.2	RE	915	273
	Common Redpoll	*Acanthis flammea*	179230	0.942	63.9	52.2	50.7	52.2	RE	1838	547
	Hoary Redpoll	*Acanthis hornemanni*	179231	0.999	77.5	50.2	52.8	50.2	RE	35	10
	Pine Siskin	*Spinus pinus*	179233	0.984	84.3	-	59.3	84.3	CS	368	105
Mammalia											
	Cinereus (Masked) Shrew	*Sorex cinereus*	179929	0.958	62.1	50.2	59.2	59.2	EX	1074	311
	American Pygmy Shrew	*Sorex hoyi*	179946	0.994	74.0	71.1	71.4	71.1	EX and RE	162	48
	Pribilof Island Shrew	*Sorex pribilofensis*	179930	1.000	-	96.5	88.0	88.0	EX	13	3
	St. Lawrence Island Shrew	*Sorex jacksoni*	179931	-	-	51.3	-	51.3	CS	N/A	N/A
	Dusky Shrew	*Sorex monticolus*	179950	0.966	58.7	50.4	51.0	51.0	EX	738	210
	American Water Shrew	*Sorex palustris*	179933	0.998	78.6	67.4	68.1	67.4	RE	25	7
	Tundra Shrew	*Sorex tundrensis*	179957	0.989	65.5	51.1	56.4	51.1	EX and RE	277	82
	Barren Ground Shrew	*Sorex ugyunak*	552509	0.998	73.4	70.6	60.2	60.2	EX	61	16
	Alaska Tiny Shrew	*Sorex yukonicus*	555663	0.998	73.2	67.1	72.8	67.1	EX and RE	49	14

Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
Silver-haired Bat	*Lasionycteris noctivagans*	180014	-	-	56.3	-	56.3	CS	N/A	N/A
California Myotis	*Myotis californicus*	179991	0.998	-	69.4	58.8	69.4	CS	15	4
Keen's Myotis	*Myotis keenii*	179989	0.997	91.7	90.0	84.5	90.0	RE	24	6
Little Brown Myotis	*Myotis lucifugus*	179988	0.989	80.8	75.4	75.9	75.4	EX	210	60
Long-legged Myotis	*Myotis volans*	179990	0.998	-	50.0	50.0	50.0	EX	9	2
Arctic Fox	*Vulpes lagopus*	622025	0.996	87.9	56.0	50.6	Reject all	EX	121	31
Pribilof Island Arctic Fox	*Vulpes lagopus pribilofensis*	622088	1.000	-	51.4	51.4	51.4	EX	5	1
Coyote	*Canis latrans*	180599	0.998	78.8	55.8	71.2	55.8	RE	45	13
Wolf	*Canis lupus*	180596	0.959	57.7	53.7	55.1	53.7	EX	1165	346
Alexander Archipelago Wolf	*Canis lupus ligoni*	726831	0.996	-	63.0	56.5	63.0	EX	15	2
Red Fox	*Vulpes vulpes*	180604	0.997	73.4	56.4	68.6	56.4	RE	54	16
Canadian Lynx	*Lynx canadensis*	180585	0.987	73.8	56.2	52.3	73.8	CS	350	104
River Otter	*Lontra canadensis*	180549	0.971	62.1	60.7	62.4	60.7	RE	518	149
Kodiak River Otter	*Lontra canadensis kodiacensis*	727010	0.999	-	60.7	60.7	-	EX	7	0
Prince of Wales River Otter	*Lontra canadensis mira*	727012	-	-	-	-	-	EX	N/A	N/A
Wolverine	*Gulo gulo*	180551	0.989	66.3	51.2	59.0	51.2	RE	310	89
American Marten	*Martes americana*	180559	0.939	80.5	58.9	61.6	58.9	EX	1722	471
Pacific Marten	*Martes caurina*	727088	-	-	-	-	-	EX	N/A	N/A
Ermine	*Mustela erminea*	180555	0.990	59.7	59.0	52.8	59.0	RE	166	44
Least Weasel	*Mustela nivalis*	180554	0.999	63.6	54.5	54.5	54.5	RE	37	11
American Mink	*Neovison vison*	180553	0.990	70.7	55.5	55.3	55.5	EX and RE	157	35
Black Bear	*Ursus americanus*	180544	0.990	70.3	61.4	64.0	61.4	EX	178	48
Brown Bear	*Ursus arctos*	180543	0.975	55.2	65.1	64.6	65.1	CS	475	106
Moose	*Alces americanus*	180703	0.985	72.7	52.2	61.5	52.2	RE	409	119
Mule Deer	*Odocoileus hemionus*	180698	0.995	95.5	74.7	61.1	74.7	EX	42	11
Caribou	*Rangifer tarandus*	180701	0.909	83.0	57.4	69.5	57.4	RE	3116	918
Mountain Goat	*Oreamnos americanus*	180713	0.950	97.0	64.7	66.9	64.7	EX	1539	461
Muskox	*Ovibos moschatus*	180708	0.998	83.9	75.8	73.5	73.5	EX	56	14
Dalls Sheep	*Ovis dalli*	180710	0.990	84.2	57.0	59.3	59.3	EX	283	84
Alaska Marmot	*Marmota broweri*	180138	0.999	77.8	64.9	62.8	77.8	CS	32	9
Hoary Marmot	*Marmota caligata*	180139	0.993	77.1	60.8	56.5	60.8	EX	49	12
Woodchuck	*Marmota monax*	180137	0.999	91.7	54.3	55.2	91.7	CS	21	6
Arctic Ground Squirrel	*Spermophilus parryii*	180146	0.992	56.3	53.1	55.3	56.3	CS	204	60

	Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
	Red Squirrel	*Tamiasciurus hudsonicus*	180166	0.987	77.3	60.9	58.9	77.3	CS	263	77
	Northern Flying Squirrel	*Glaucomys sabrinus*	180169	0.996	73.9	-	62.6	73.9	CS	77	22
	Beaver	*Castor canadensis*	180212	0.970	63.2	53.1	55.6	53.1	EX	636	190
	Admiralty Beaver	*Castor canadensis phaeus*	180212 A	-	-	50.0	-	50.0	CS	N/A	N/A
	Meadow Jumping Mouse	*Zapus hudsonius*	180386	0.994	74.2	52.2	50.9	52.2	RE	113	33
	Western Jumping Mouse	*Zapus princeps*	180387	0.998	-	50.0	50.0	-	EX	11	3
	Southern Red-backed Vole	*Myodes gapperi*	180294	0.995	86.6	87.4	84.5	87.4	CS	98	28
	Northern Red-backed Vole	*Myodes rutilus*	180293	0.961	69.2	-	66.4	-	EX and RE	1126	335
	Nearctic Collared Lemming	*Dicrostonyx groenlandicus*	180328	0.999	53.1	-	51.3	-	EX and RE	27	8
	Nearctic Brown Lemming	*Lemmus trimucronatus*	180320	0.994	70.0	-	61.1	-	RE	151	40
	Insular Vole	*Microtus abbreviatus*	180303	-	-	-	-	-	EX	N/A	N/A
	Long-tailed Vole	*Microtus longicaudus*	180299	0.987	61.3	71.1	64.1	71.1	EX	242	62
	Singing Vole	*Microtus miurus*	180309	0.993	69.3	62.8	56.1	62.8	EX	192	57
	Root vole formerly Tundra vole	*Microtus oeconomus*	180298	0.977	59.5	54.4	50.0	54.4	EX and RE	591	174
	Meadow Vole	*Microtus pennsylvanicus*	180297	0.988	78.7	51.0	51.2	78.7	CS	343	101
	Admiralty Meadow Vole	*Microtus pennsylvanicus admiraltiae*	180291 A	-	-	-	-	-	EX	N/A	N/A
	Yellow cheeked Or Taiga Vole	*Microtus xanthognathus*	180301	0.996	86.1	59.4	65.0	59.4	EX	121	36
	Muskrat	*Ondatra zibethicus*	180318	0.999	54.2	51.7	50.6	51.7	EX	21	6
	Northern Bog Lemming	*Synaptomys borealis*	180323	0.993	75.0	-	63.8	-	EX and RE	178	53
	Bushy-tailed Woodrat	*Neotoma cinerea*	180371	-	-	-	-	Reject all	EX	N/A	N/A
	Northwestern Deermouse	*Peromyscus keeni*	552497	0.976	-	-	-	-	EX	560	130
	North American Porcupine	*Erethizon dorsatum*	180393	0.998	68.2	-	51.5	-	RE	38	11
	Collared Pika	*Ochotona collaris*	180108	0.996	85.8	50.2	50.0	85.8	CS	100	30
	Snowshoe Hare	*Lepus americanus*	180112	0.996	83.3	64.5	80.9	80.9	EX	121	36
	Alaskan Hare	*Lepus othus*	552513	0.998	90.0	87.1	74.3	87.1	RE	53	15
	Pacific Walrus	*Odobenus rosmarus*	180639	0.993	67.2	52.0	52.0	67.2	EX and RE	178	32
	Northern Fur Seal	*Callorhinus ursinus*	180627	1.000	-	50.0	50.0	-	EX	7	2
	Steller Sea Lion	*Eumetopias jubatus*	180625	0.979	61.0	50.9	50.3	61.0	RE	478	75

	Common Name	Scientific Name	ITIS CODE	MaxEnt Training AUC	Inductive CS	Deductive CS	Combined CS	Final Model CS	Final Model Selection Criteria	Modeling records	Assess. records
	Bearded Seal	*Erignathus barbatus*	180655	0.995	88.2	65.4	65.4	65.4	EX	104	17
	Ringed Seal	*Pusa hispida*	622018	0.990	65.2	63.6	63.7	63.7	EX	222	28
	Spotted Seal	*Phoca largha*	180642	0.995	79.2	73.5	72.6	79.2	CS	89	12
	Harbor Seal	*Phoca vitulina*	180649	0.962	76.0	51.4	50.4	76.0	CS	819	49
	Polar Bear	*Ursus maritimus*	180542	0.998	88.5	50.0	50.0	88.5	CS	53	13

Appendix B: AKGAP occurrence database record attributes

Alaska
Gap
Analysis
Project

Description of 39 fields attributed to each occurrence record in the AKGAP occurrence database. The 11 field names followed by as asterisk(*) were required for records to be used in the AKGAP project; other attributes were not mandatory, but retained from the source data if available.

No.	Field Name	Field Description
1	Record_ID*	Unique identifier for each record. Auto- generated number assigned by Alaska Natural Heritage Program.
2	Kingdom	Taxonomic kingdom
3	Phylum	Taxonomic phylum
4	Class	Taxonomic class
5	Order	Taxonomic order
6	Family	Taxonomic family
7	Sci_Name*	Scientific name (in Latin) of taxon, including the genus, species, and infra species (if applicable).
8	Comm_Name*	Common name of taxon
9	Infra_Spp	Infraspecific name (in Latin) of the subspecies or population, if applicable.
10	G_Rank	Global NatureServe conservation status rank. This alphanumeric rank, assigned by NatureServe, characterizes the rarity of each taxon.
11	S_Rank	State NatureServe conservation status rank. This alphanumeric rank, assigned by the Alaska Natural Heritage Program, characterizes the rarity of each taxon.
12	Elcode	Heritage Program's element species code. This alphanumeric code is unique for each species.
13	ITIS_Code*	Integrated Taxonomic Information System code, a six digit taxonomic serial number.
14	1_Source	Primary data source. This refers to which group of the modeling team received and formatted the record for entry into the occurrence data, and thus in each case will be the name of the relevant university campus name. *Allowable entries:* *UAA [University of Alaska Anchorage]* *UAF [University of Alaska Fairbanks]* *UAS [University of Alaska Southeast]*
15	2_Source	Secondary data source. This refers to where the record was acquired from, which may or may not be the ultimate, original source of the data.
16	Reliability*	Certainty/ reliability of taxon identification. This field indicates any available assessment of confidence indicating if the taxon was correctly identified in the field by the observer. *Allowable entries:* *Y [high confidence that identification is correct]* *Q [questionable; indicates reason to suspect identification]* *N [high confidence that identification is incorrect]* *U [unknown confidence in identification]*
17	Record_Type	Description of the record type *Allowable entries:*

No.	Field Name	Field Description
		Museum record_vouchered specimen *Survey data_professional researcher* *Survey data_citizen science or students*
18	Obs_Name	Observer name, if available.
19	Obs_Affil	Observer affiliation, if available.
20	Year*	Year of observation. The 4-digit year in which the target taxon was observed. If a record was dated within a range of years (e.g., observation made sometime between the 1965 and 1987), the midpoint year was used.
21	Month*	Month of Observation. The 1 or 2 digit number corresponding to the month in which the target taxon was observed. If a record was dated within a range of months (e.g., observation made sometime between May and September), the midpoint month was used. If a record was dated only to a particular season, the season was translated into a month as follows: winter = 1, spring = 4, summer = 7, and fall = 10.
22	Date	Date of Observation. The 1 or 2 digit number corresponding to the day in which the target taxon was observed. If a record was dated to within a range of dates (e.g., observation made sometime between the 15th and 30th), the midpoint was used.
23	Other_Date	Other dates a particular record was observed or collected.
24	Count	Number of animals observed at this location.
25	Life_Stage	Indication of the life stage of species *Allowable entries:* *Juvenile(s)* *Adult(s)* *Nest* *Empty Nest* *Adult(s) with young* *Egg mass* *Colony* *Den site*
26	Season	Season of observation. This refers to the season the observation was made. *Allowable entries:* *Winter [December – February]* *Summer [June or July]* *Fall/Spring [March - May and August – November]*
27	Obs_Type	Observation type based on species life history. This field indicates the type of observation, condition, or life history stage of the observation. *Allowable entries:* *Observation* *Breeding* *Probable breeding* *Migratory* *Staging*

No.	Field Name	Field Description
		Wintering *Hibernacula* *Molting*
28	Site_Name	Name of location of the occurrence, if provided.
29	Directions	Directions to occurrence location, if provided
30	Lat_DD*	Latitude. The latitudinal coordinates of the location of the observation, as expressed in decimal degrees (to 5 decimal places).
31	Long_DD*	Longitude. The longitudinal coordinates of the location of the observation, as expressed in decimal degrees (to 5 decimal places).
32	Coord	Coordinate source. Description of how the coordinates were obtained, specifically if coordinates were provided in the source data or obtained from external sources based on geographic descriptions in the source data. *Allowable entries:* *Coord [coordinates provided]* *Map [obtained from map in source]* *Description [mapped in ArcGIS or TopoZone using directions]* *AK Places [assigned from AK place names dataset]* *Shapefile [received from an existing shapefile]*
33	Accuracy*	This refers to the accuracy of the reported point maps to the actual location of the observation. This value is a radius (in meters) that defines the smallest circle, centered on the mapped point that confidently encompasses the location of the actual field observation. *Allowable entries:* *S [Seconds- within 100 m]* *M [Minutes- within 2,000 m]* *G [General- within 10 km]*
34	Point_Type*	This field denotes whether the reported point was originally recorded and reported as a point observation, or represents the centroid of an observation originally recorded and reported as a line or polygon. *Allowable entries:* *Original point of observation* *Centroid of line* *Centroid of polygon*
35	Data_Sens	Data sensitivity. Indicates if the data is sensitive to public use.
36	Source_ID	Numerical unique identifier of the source of the data.
37	Datum	Map datum of the coordinate source.
38	Voucher_ID	Voucher record identifier. GBIF or other museum record voucher number.
39	3_Source	Secondary source for museum specimen data downloaded from large databases, such as GBIF.

Appendix C: Ancillary Data Component

Alaska Gap Analysis Project

Ancillary Data Variables

Processing information and modeling uses

Version 1.0

Alaska Natural Heritage Program
University of Alaska Anchorage

Spatial Ecosystem Analysis Lab
University of Alaska Southeast

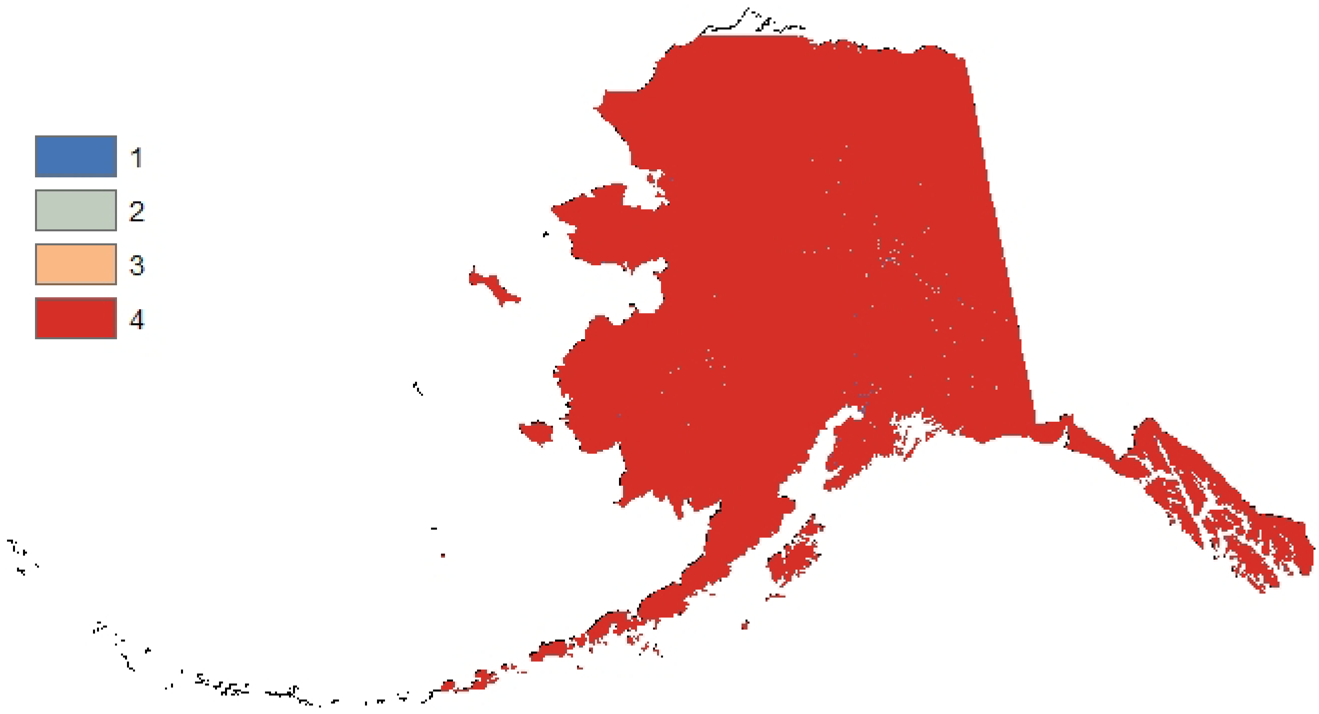
Background

The ancillary data component of the project included creation of a core dataset of 58 variables, of which 24 variables were ultimately used and presented in this document, to support deductive and inductive modeling efforts. This was handled primarily by an ancillary-data team at the University of Alaska. These variables represented geological, hydrological, physiographical, ecological, land cover, disturbance, infrastructure, and climate characteristics; as well as a subset of data to support processing. Activities included:

- Collating and organizing original and raw datasets (e.g. national hydrography data) and their metadata from a variety of sources
- Defining criteria and key attributes of source data
- Developing a processing workflow to help address data consistency and help track data processing
- Spatial processing of data including conversion to grid formats, standardizing coordinate systems, resampling resolutions, and merging tiled datasets
- The extent of each raw datasets was modified using a "filter" – a grid with an extent 200+50m from the coast of Alaska – to define a common range of inference for modeling.
- Final variables were created with a cell size resolution of 60-m; each representing approximately $2.19*10^8$ cells and 7.5gb of data; resulting in a total of about 0.5TB total data.
- Final variables were published in an ESRI grid (*.grd) format.
- All data were published to a standardized coordinate system with Datum of NAD1983 and Projection of Alaska Albers.

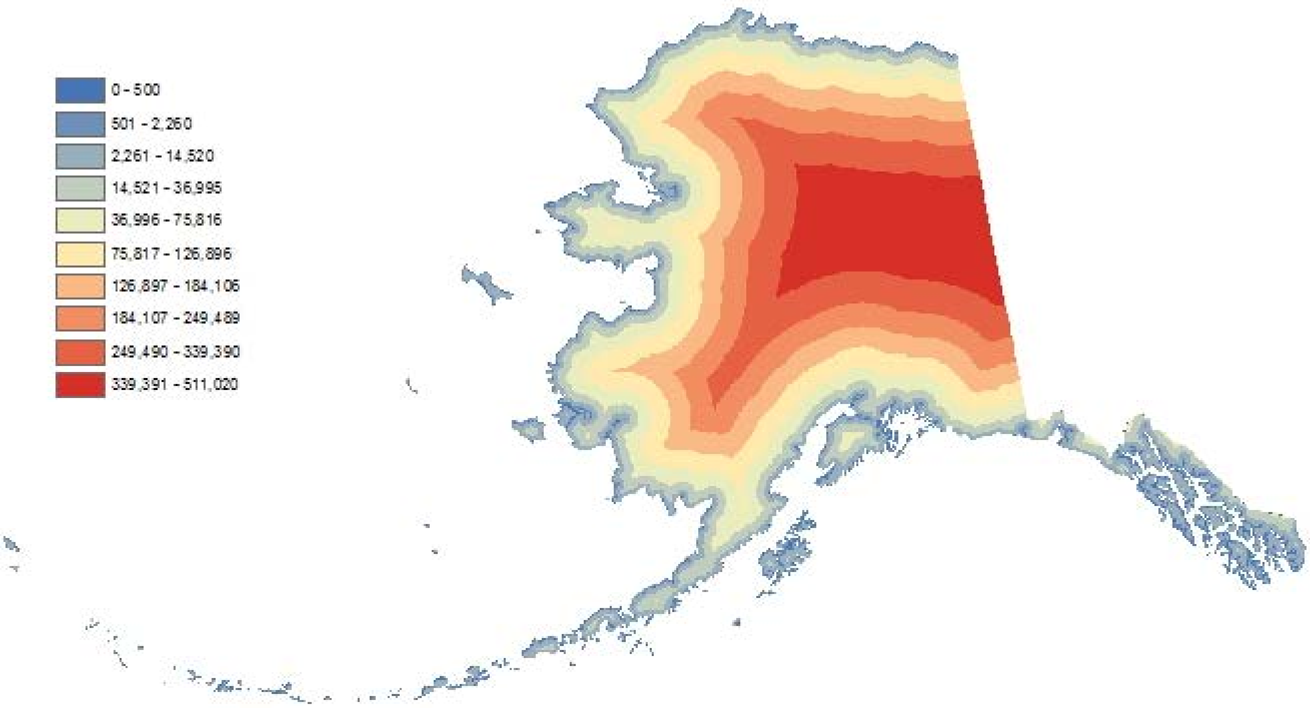
For more information contact:
Sanjay Pyare, Ph.D.
Associate Professor
Environmental Science & Geography Programs
& Spatial Ecosystem Analysis Lab (SEALAB)
http://sealab.uas.alaska.edu/

University of Alaska Southeast
11120 Glacier Hwy
Juneau AK 99801
(907) 796-6007
sanjay.pyare@uas.alaska.edu



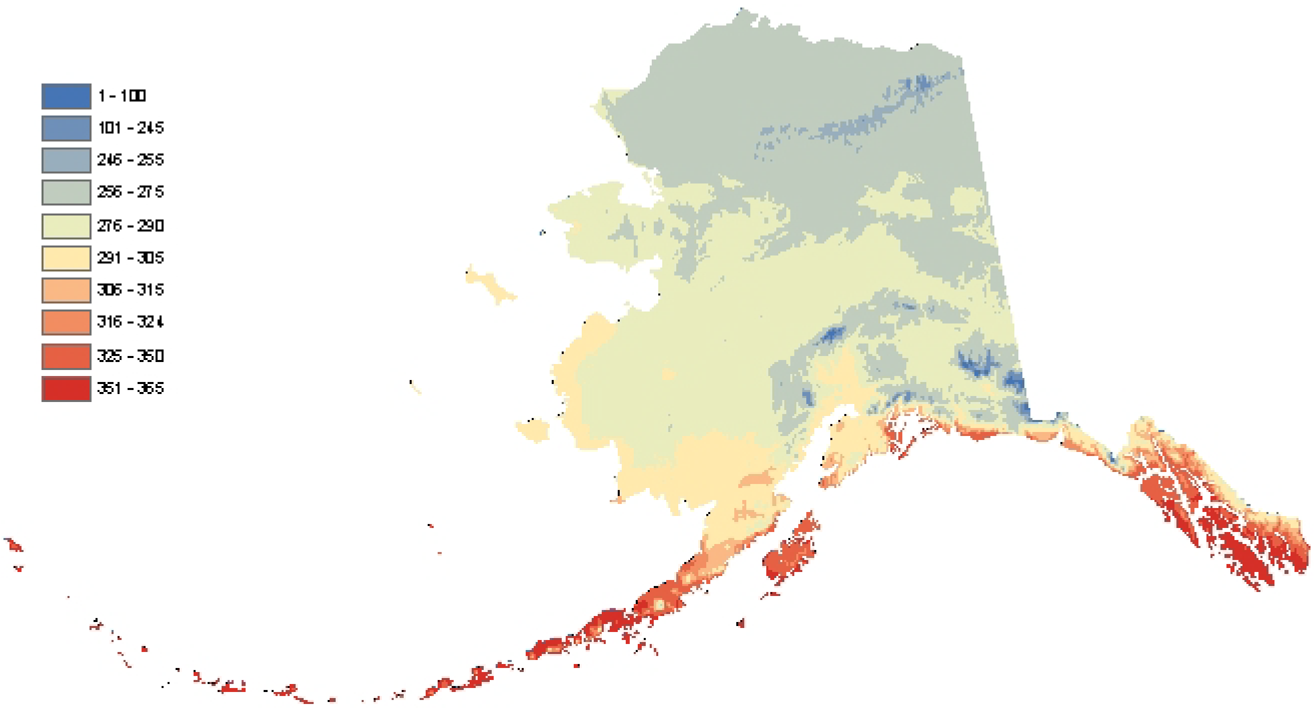
Dataset Name:	Anthropogenic Disturbance	*Variable Type:*	Categorical
File Name:	avoidance	*GAP Model Type (s):*	Deductive
Attribute:	Disturbance Level (1-4)	*Data Source:*	Landfire

Processing Notes: Select attributes relating to anthropogenic disturbance activity were selected from the 2008 Landfire Existing Vegetation Type (EVT, USGS EROS) and reclassified into one of four values: 1 – low disturbance, 2 – medium disturbance, 3 – high disturbance, and 4 - no disturbance. Data were resampled from 30-m cell resolution and reprojected from NAD83 Albers Conical Equal Area. Landfire EVT classifications were as follows: Low - 20 Developed-General, 21 Developed-Open Space, or 22 Developed-Low Intensity; Medium - 23 Developed-Medium Intensity; and High - 24 Developed-High Intensity, 31 Barren 32 Quarries/Strip Mines/Gravel Pits, 80 Agriculture-General, 81 Agriculture-Pasture/Hay, 82 Agriculture-Cultivated Crops and Irrigated Agriculture, 83 Agriculture-Small Grains, 84 Agriculture-Fallow, or 85 Agriculture-Urban/Recreational Grasses



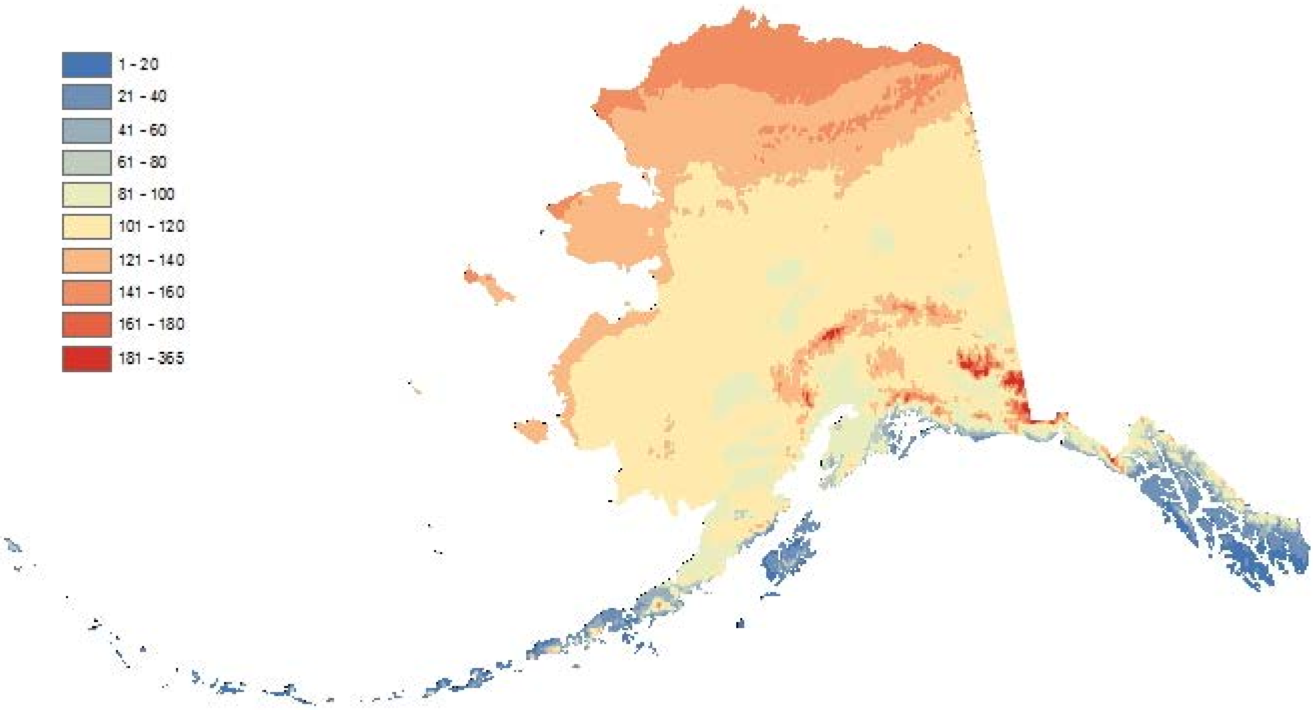
Dataset Name:	Distance to Coastline	*Variable Type:*	Continuous
File Name:	coast_dist	*GAP Model Type (s):*	Inductive
Attribute:	Distance (m)	*Data Source:*	DNR Alaska Coastline, USGS NHD coastline

Processing Notes: Alaska Department of Natural Resources' 1998 Alaska Coastline 1:63,360 (See: http://dnr.alaska.gov/SpatialUtility/SUC?cmd=vmd&layerid=56), supplemented with select features from USGS National Hydrography Data where coastline data were missing, e.g. Aleutians, were used to calculate planar distances to the interior land surface from the coastline using standard ESRI raster processing methods.



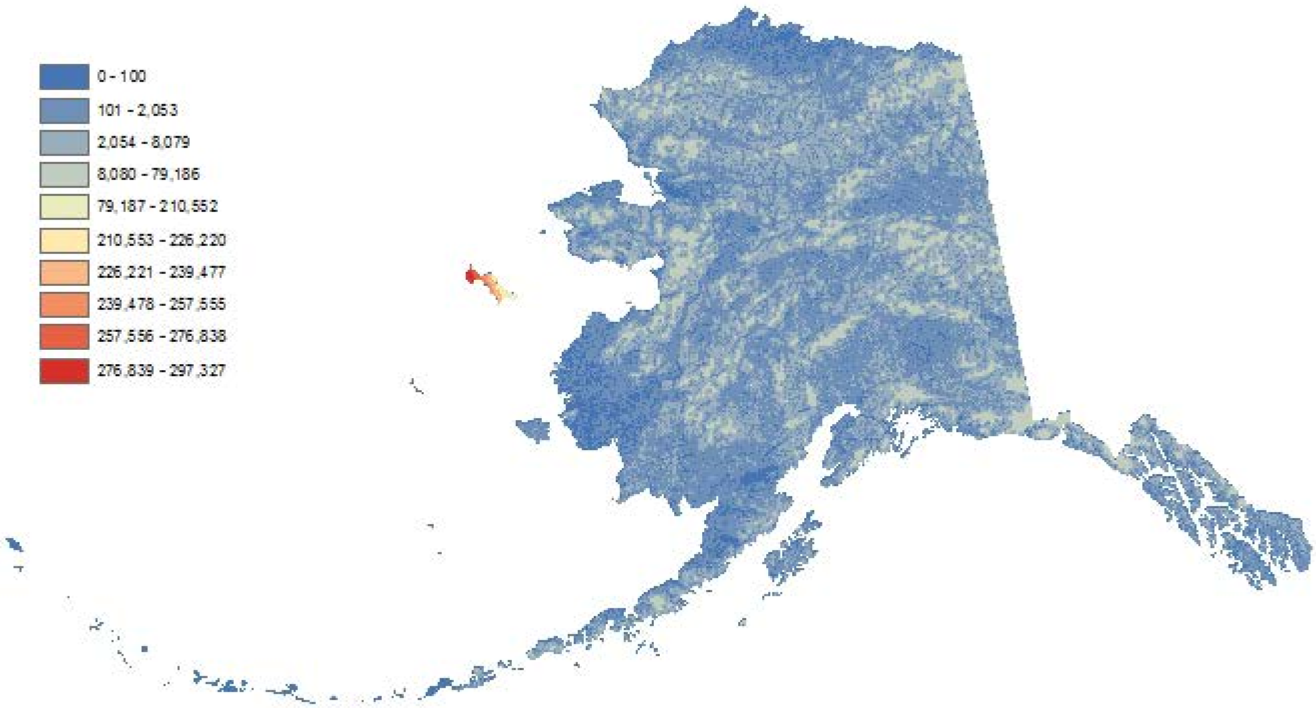
Dataset Name:	First Day of Freeze	*Variable Type:*	Categorical
File Name:	dayfrz	*GAP Model Type (s):*	Inductive
Attribute:	Julian date (day)	*Data Source:*	SNAP temperature-derivative

Processing Notes: Estimated Julian day of the first freeze date of the year was derived from historical derived temperature products published circa 2010 by Scenarios Network for Alaska Planning (SNAP). See: http://www.snap.uaf.edu/data.php. These data were derived from 1961-1990 PRISM temperature reference data, and calculated by assuming a linear change in temperature between the 15th day of consecutive months, with mean monthly temperatures representing temperature on the 15th day. Data were resampled (not downscaled) from grids with 2-km cell-size resolution.



Dataset Name:	First Day of Thaw	*Variable Type:*	Categorical
File Name:	daythaw	*GAP Model Type (s):*	Inductive
Attribute:	Julian date (day)	*Data Source:*	SNAP temperature-derivative

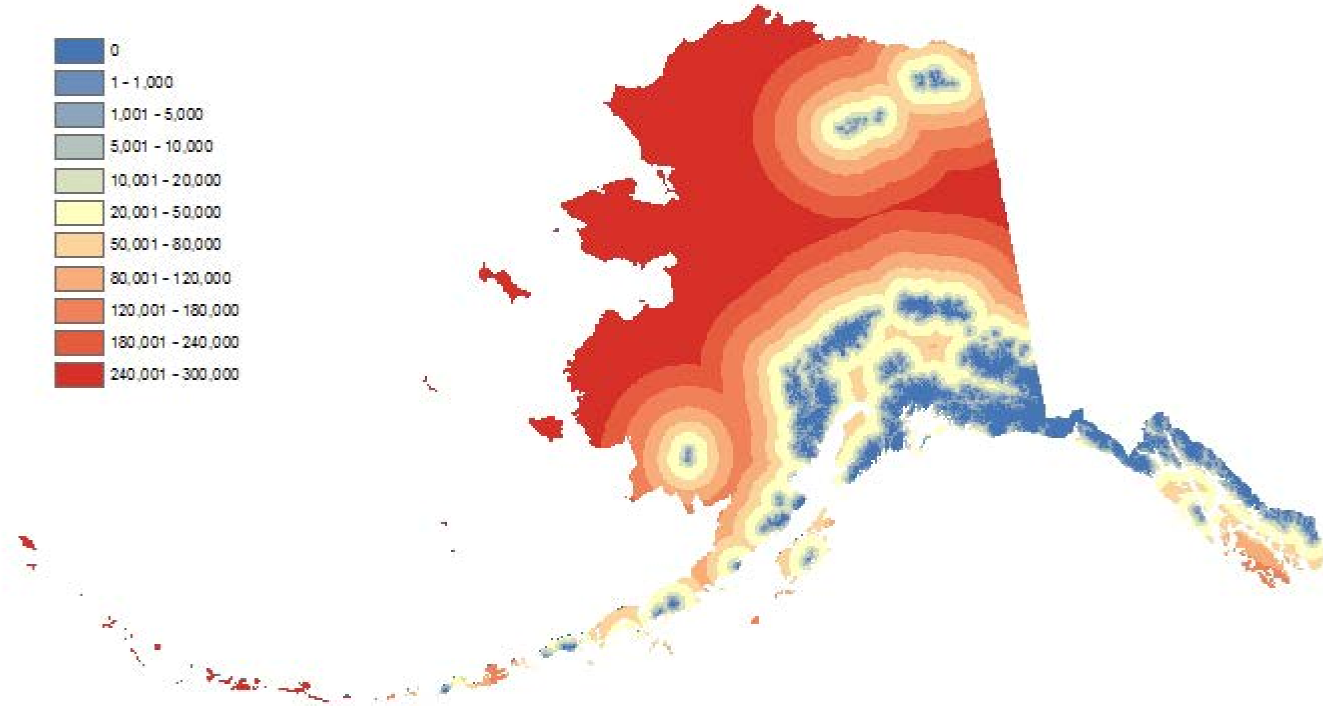
Processing Notes: Estimated Julian day of the first thaw date of the year was derived from historical derived temperature products published circa 2010 by Scenarios Network for Alaska Planning (SNAP). See: http://www.snap.uaf.edu/data.php. These data were derived from 1961-1990 PRISM temperature reference data, and calculated by assuming a linear change in temperature between the 15th day of consecutive months, with mean monthly temperatures representing temperature on the 15th day. Data were resampled (not downscaled) from grids with 2-km cell-size resolution.



Dataset Name:	Distance to Non-Flowing	*Variable Type:*	Continuous
File Name:	lentic	*GAP Model Type (s):*	Inductive and Deductive
Attribute:	Distance (m)	*Data Source:*	USGS National Hydrography Data

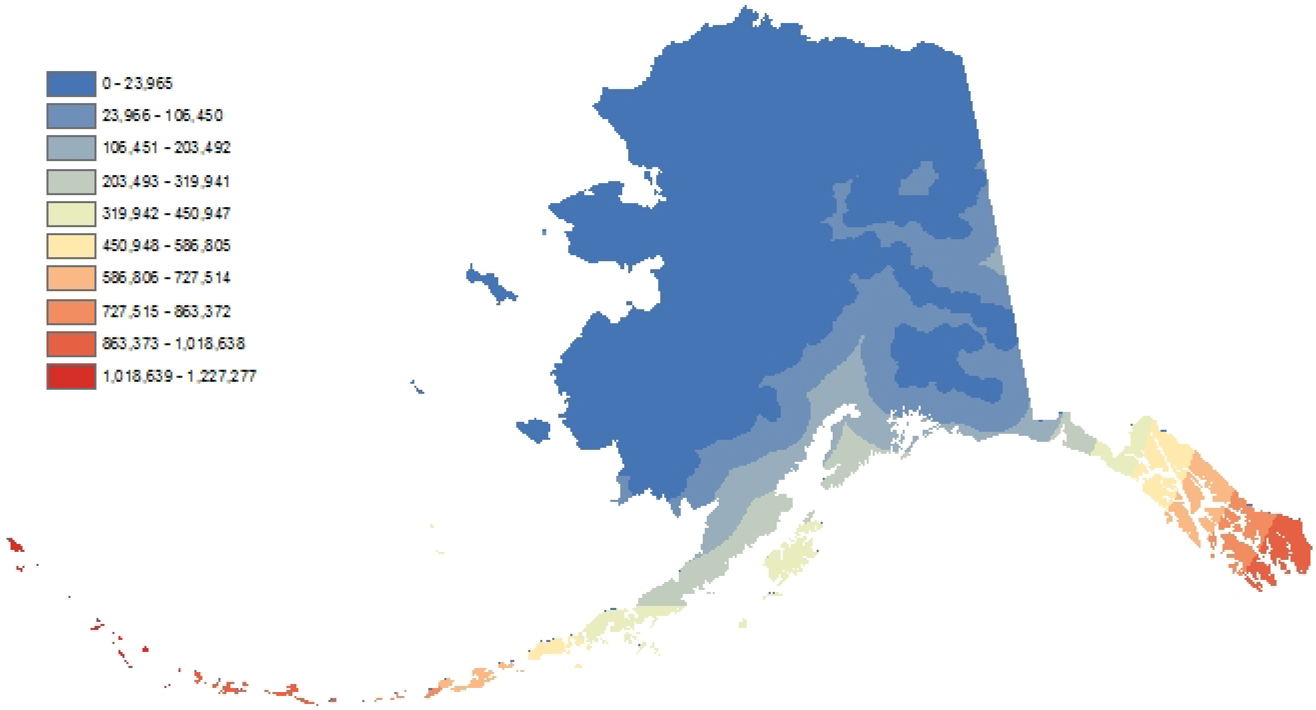
Processing Notes: Non-lotic water features were selected from a merged USGS National Hydrography Dataset consolidated from six subregional datasets, and planar distances both interior and exterior to these features were calculated using standard ESRI raster processing methods. For inductive modeling, only exterior distances were retained. For deductive modeling (not shown), interior and exterior distances were retained, and these data were further classified into 1 of 17 possible classes of distance range-categories from 0 to > 4000m (0, 60, 120, 250, 500, 1000, 2000, 4000, >4000).

In addition, for use in deductive modeling, similar variables were created for flowing water, but not shown explicitly in this document.



Dataset Name:	Distance to Glacier	*Variable Type:*	Continuous
File Name:	dist2glacier	*GAP Model Type (s):*	Inductive
Attribute:	Distance (m)	*Data Source:*	ADNR glacier coverage

Processing Notes: Glacier data were derived from ADNR LRIS data, mapped in 1998 at a 1:1,000,000 scale. See: http://dnr.alaska.gov/SpatialUtility/SUC?cmd=extract&layerid=27 . The glacier data were combined from drainage network (DNNET) coverages comprising 5 degree by 5 degree tiles for Alaska. Planar distances exterior to these features were calculated using standard ArcGIS Spatial Analyst toolbox.



Dataset Name:	Distance to Permafrost	*Variable Type:*	Continuous
File Name:	dist2pfrost	*GAP Model Type (s):*	Inductive
Attribute:	Distance(m)	*Data Source:*	USGS EROS

Processing Notes: Permafrost occurrence was derived from USGS-EROS historical data mapped at a 1:2,500,000 scale. See http://agdcwww.wr.usgs.gov/agdc/agdc.html. Source information for this feature was based on a Permafrost of Alaska Map (circa 1965) and therefore this variable was used only to delineate general permafrost occurrence areas across the state without reference to permafrost categorization due to ambiguity about current conditions. Planar distances exterior to these features were calculated using ArcGIS Spatial Analyst toolbox.

Dataset Name: Elevation

Variable Type: Continuous

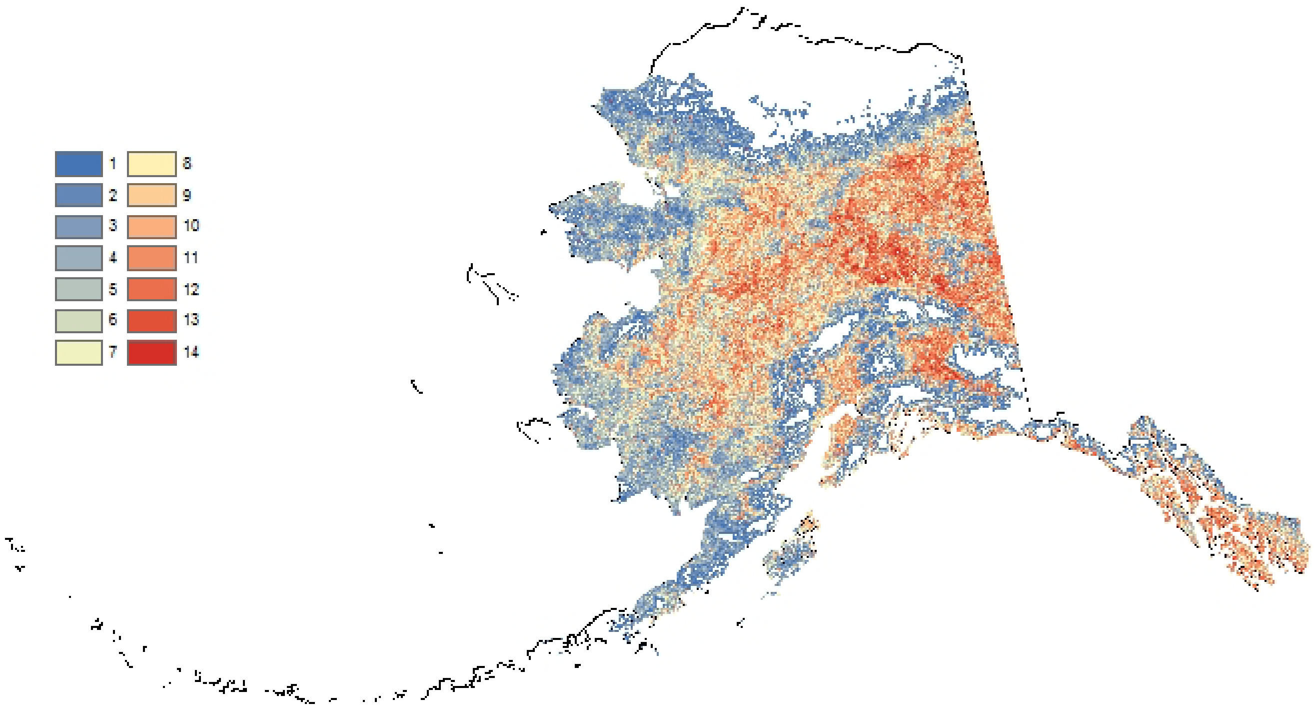
File Name: ak_ned_60

GAP Model Type (s): Inductive and Deductive

Attribute: Elevation (m)

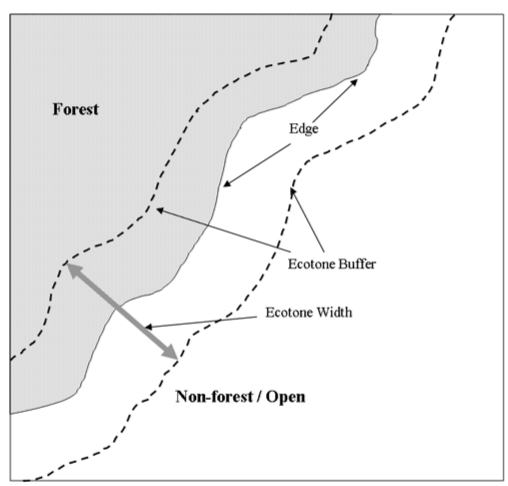
Data Source: USGS National Elevation Data

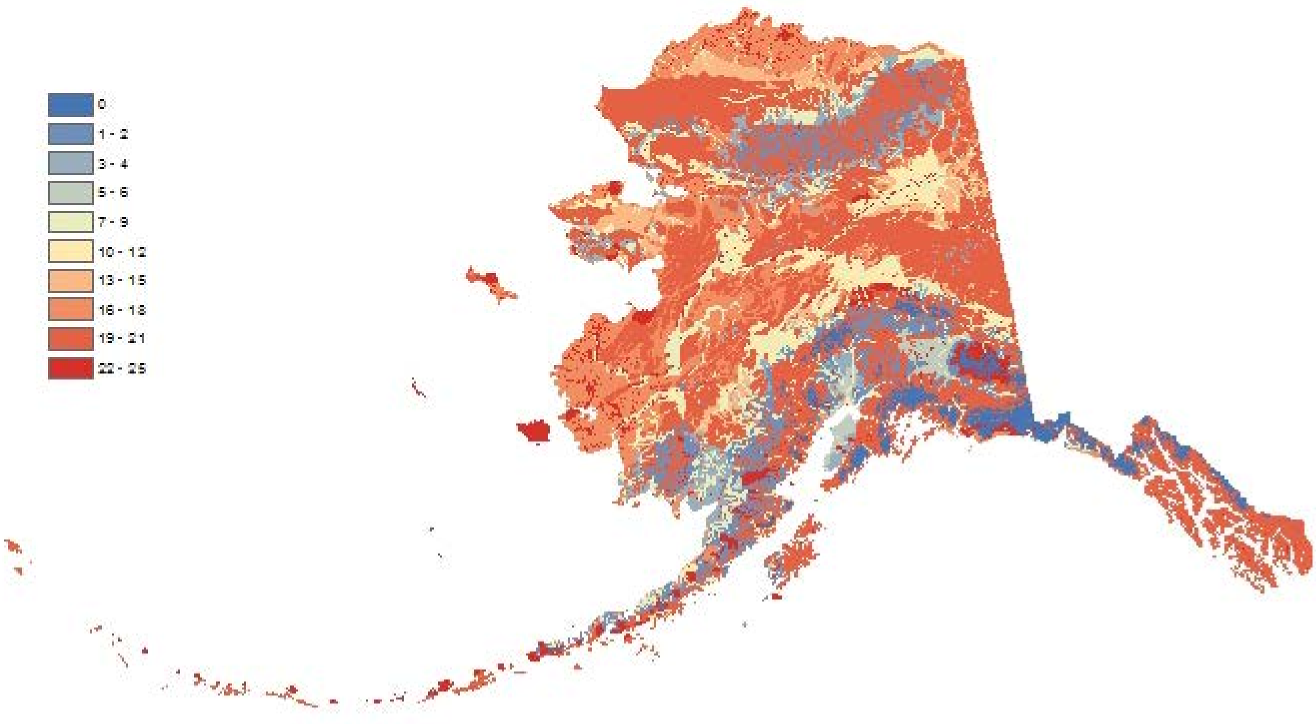
Processing Notes: These data were minimally processed and derived from USGS National Elevation Data (NED) with a cell size resolution of 60m.



Dataset Name:	Forest Edge & Ecotone	*Variable Type:*	Categorical
File Name:	forest_buffer, ecotn_forest	*GAP Model Type (s):*	Deductive
Attribute:	Distance class (1-17)	*Data Source:*	NLCD

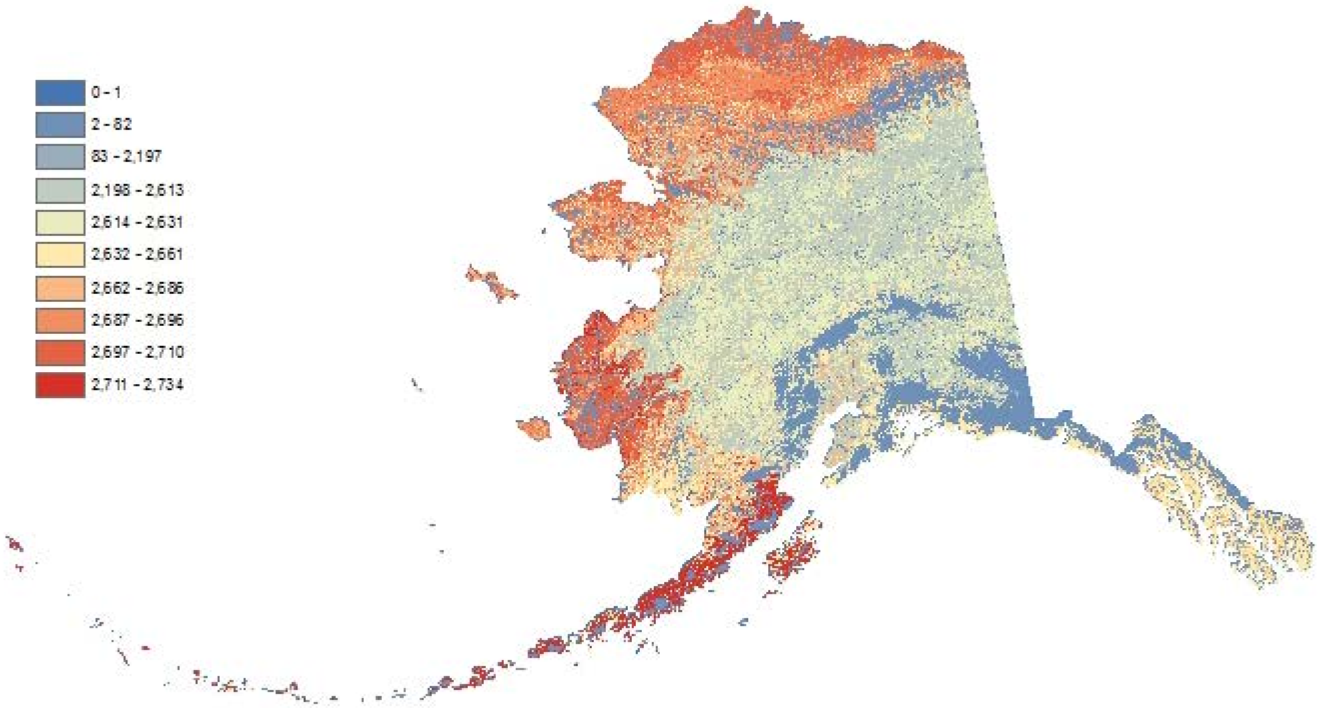
Processing Notes: Forest cover data were derived from select land cover classes of the 2001 National Land cover Dataset (NLCD) for Alaska. Land cover classes were 41 - Deciduous Forest, 42 - Evergreen Forest, and 43 - Mixed Forest, as well as class 91 - Palustrine Forested Wetland, which includes mesic forest types found throughout coastal and interior Alaska. All other classes were treated as non-forest cover, and edges were defined as all forest/non-forest boundaries. Planar distances both interior (i.e. from forest/non-forest edge into forest) and exterior (i.e. from forest/non-forest edge into non-forest) to edge features were calculated using standard ESRI raster processing methods and these data were further classified into 1 of 15 possible classes of distance range-categories from 0 to 4000m (0, 60, 120, 250, 500, 1000, 2000, 4000). The Ecotone variable was a closely related derivative and represented the swath of forest/non-forest spanning across the interior and exterior portions of edges calculated above, as classified into 1 of 6 possible width classes (0, 60, 120, 250, 500, 1000 meters).





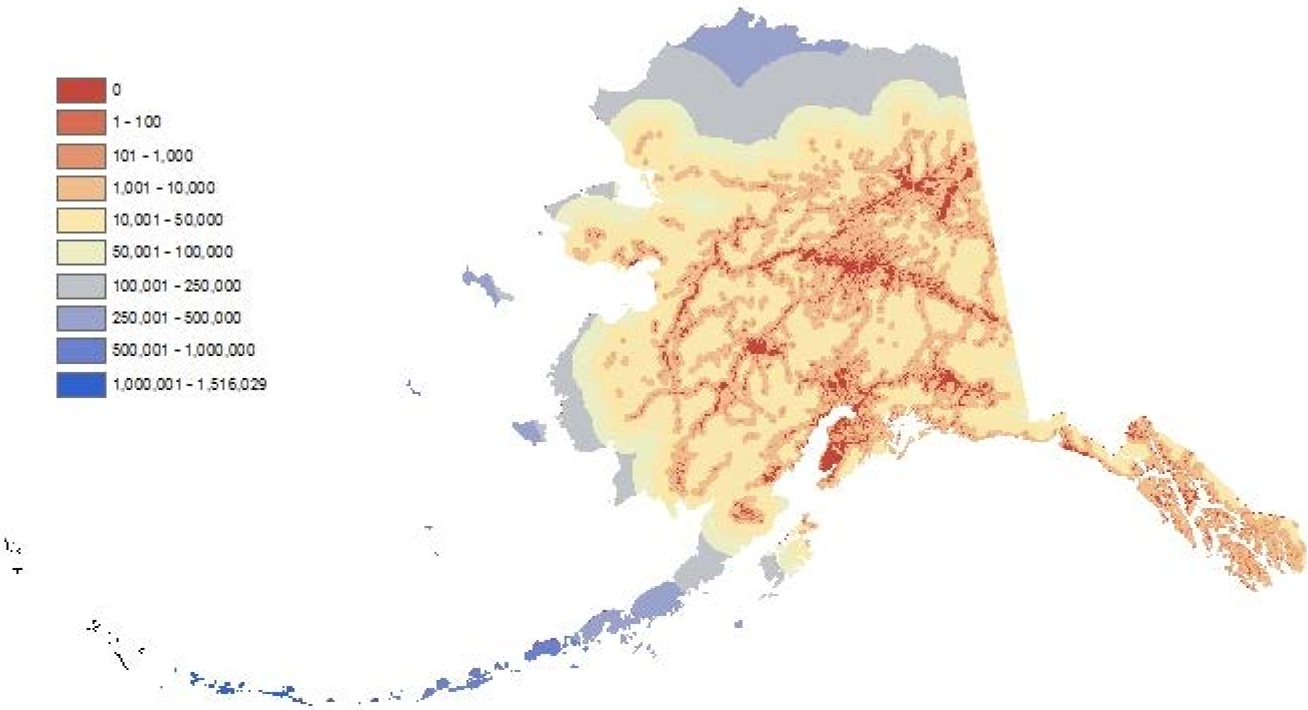
Dataset Name:	Geology	*Variable Type:*	Categorical
File Name:	geology	*GAP Model Type (s):*	Inductive
Attribute:	Class	*Data Source:*	USGS Surficial Geology

Processing Notes: Surficial geology classes of Alaska were derived from a map compiled by N.V. Karlstrom et. al. 1964 and published as a georeferenced dataset in 1999 by the USGS as a Miscellaneous Geologic Investigations Map I-357 at 1:1,584,000. These data were rasterized and each unique surficial geology type (i.e. Qc code) was designated an arbitrary class value. See: http://agdc.usgs.gov/data/usgs/geology/metadata/beikman.html



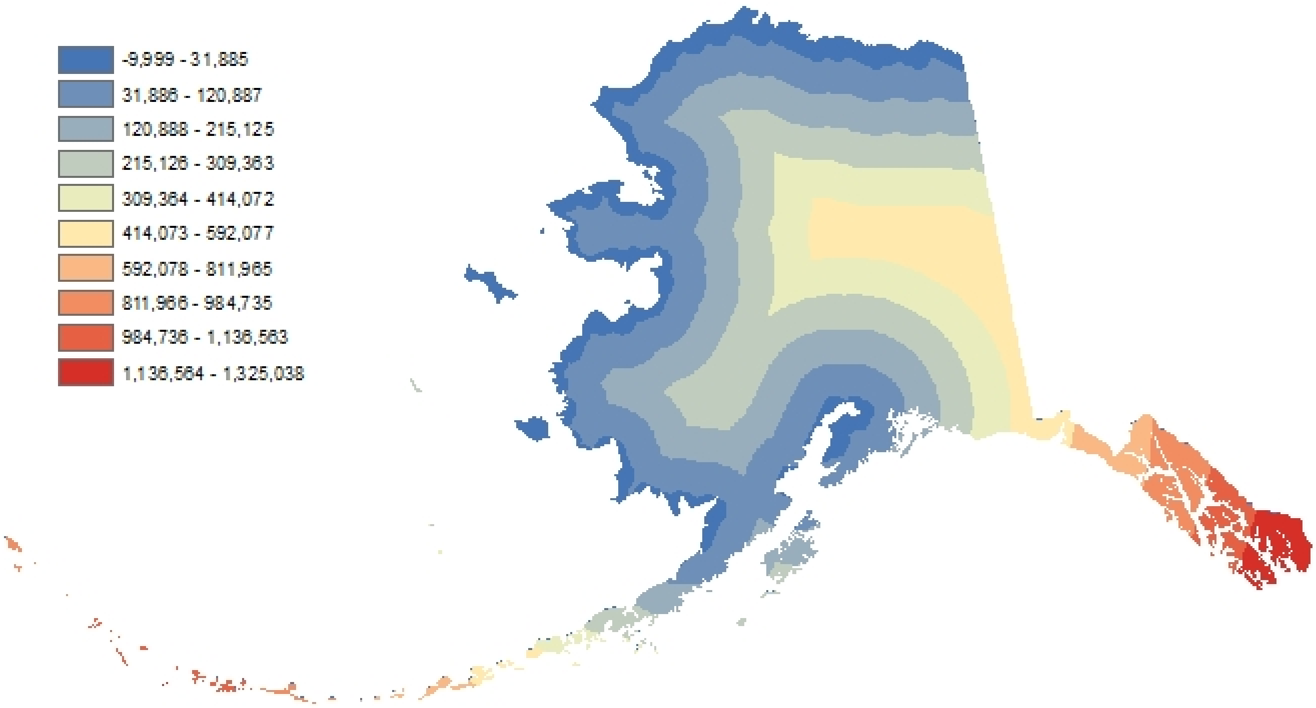
Dataset Name:	Vegetation	*Variable Type:*	Categorical
File Name:	lf_60	*GAP Model Type (s):*	Deductive
Attribute:	Vegetation type	*Data Source:*	Landfire EVT

Processing Notes: Vegetation types were derived from the first (2009) iteration of Landfire existing vegetation types (EVT). Data were merged from several subregions and resampled (not upscaled) from grids with 30m cell-size resolution to 60m cell-size. In some cases, EVT values were collapsed across subregions into broader categories to remove purely regional categories.



Dataset Name:	Distance to Insect Damage	*Variable Type:*	Continuous
File Name:	insect_dist	*GAP Model Type (s):*	Inductive
Attribute:	Distance (m)	*Data Source:*	ADNR Forestry

Processing Notes: Data were derived from mapped areas of forest damaged by insect irruptions (i.e., spruce budworm, larch sawfly, aspen leaf miner, and Ips/ engraver beetles) between 1989 and 2003. Planar distances exterior to these features were calculated using ArcGIS Spatial Analyst toolbox.



Dataset Name: Distance to Sea Ice in December

Variable Type: Continuous

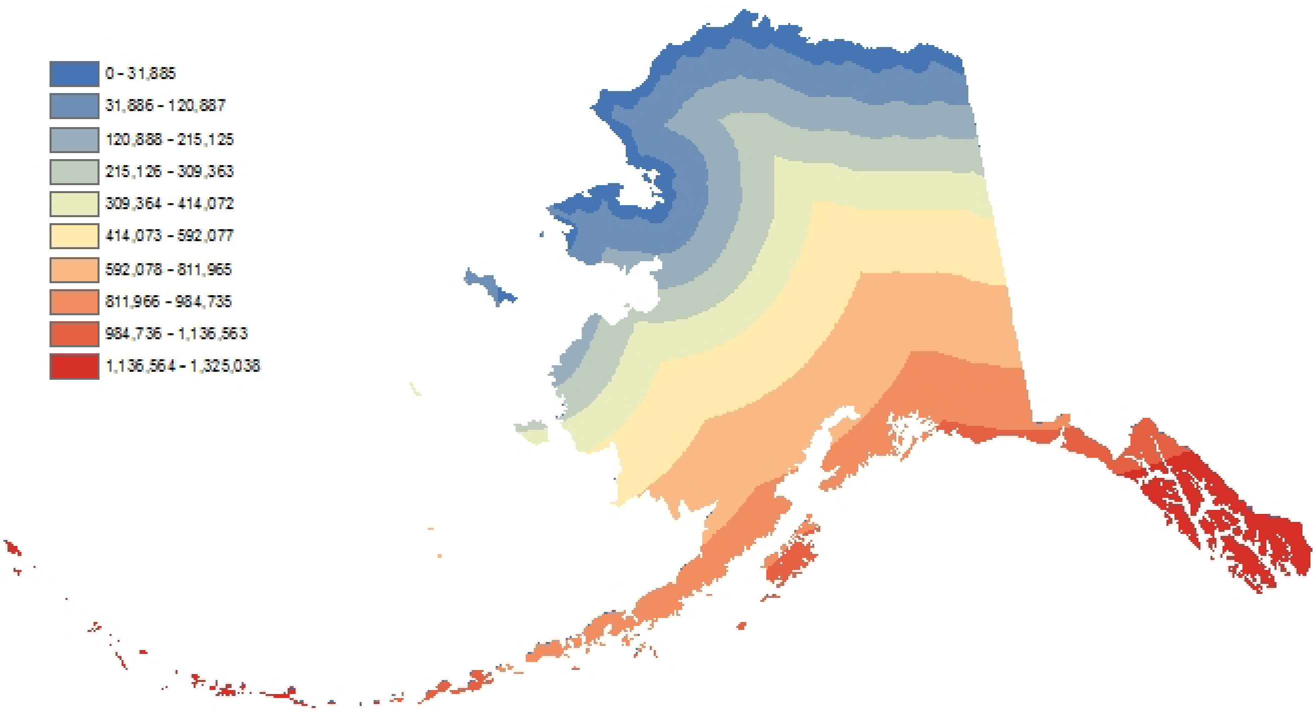
File Name: sice_dec_dist

GAP Model Type (s): Inductive

Attribute: Distance (m)

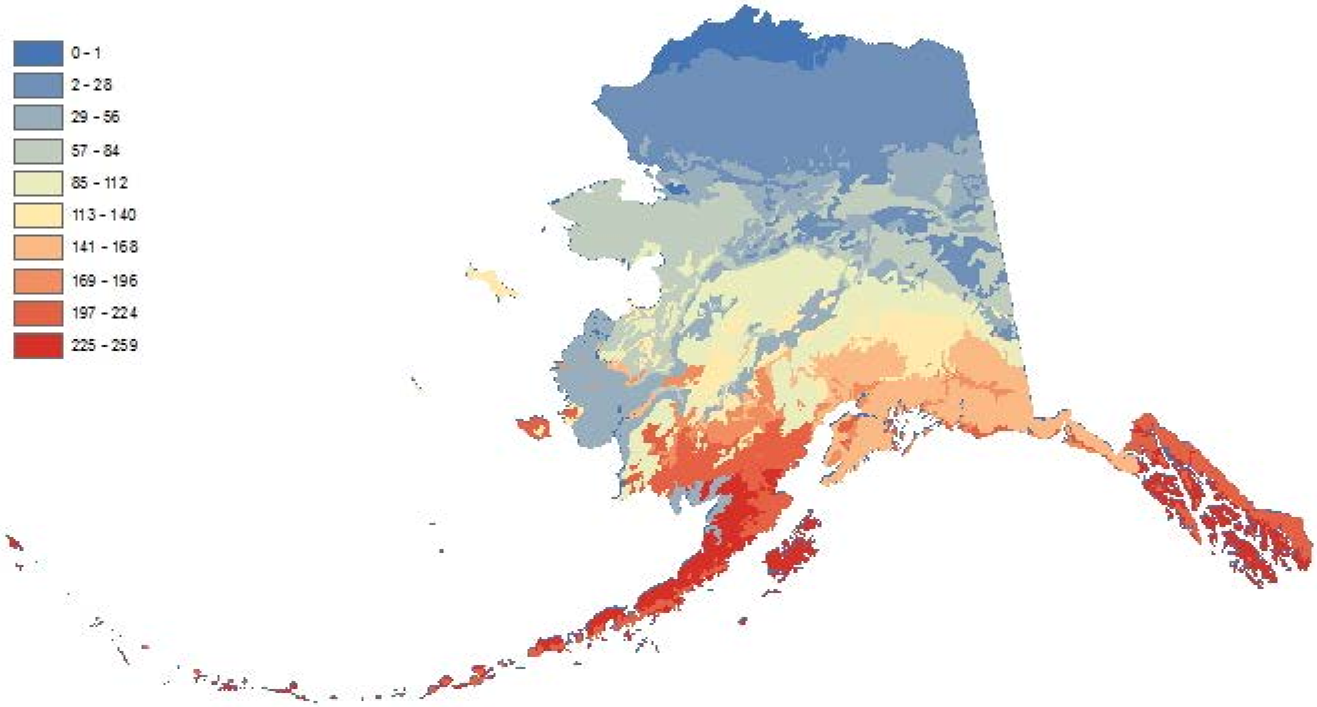
Data Source: NSIDC

Processing Notes: Arctic sea ice distribution was derived from passive-microwave remote sensing data archived by the National Snow Ice and Data Center. See: http://nsidc.org/data/nsidc-0051.html . Monthly mean coverages for December of the years 2003-2007 were combined into a composite feature. Planar distances exterior to these features were calculated using ArcGIS Spatial Analyst toolbox.



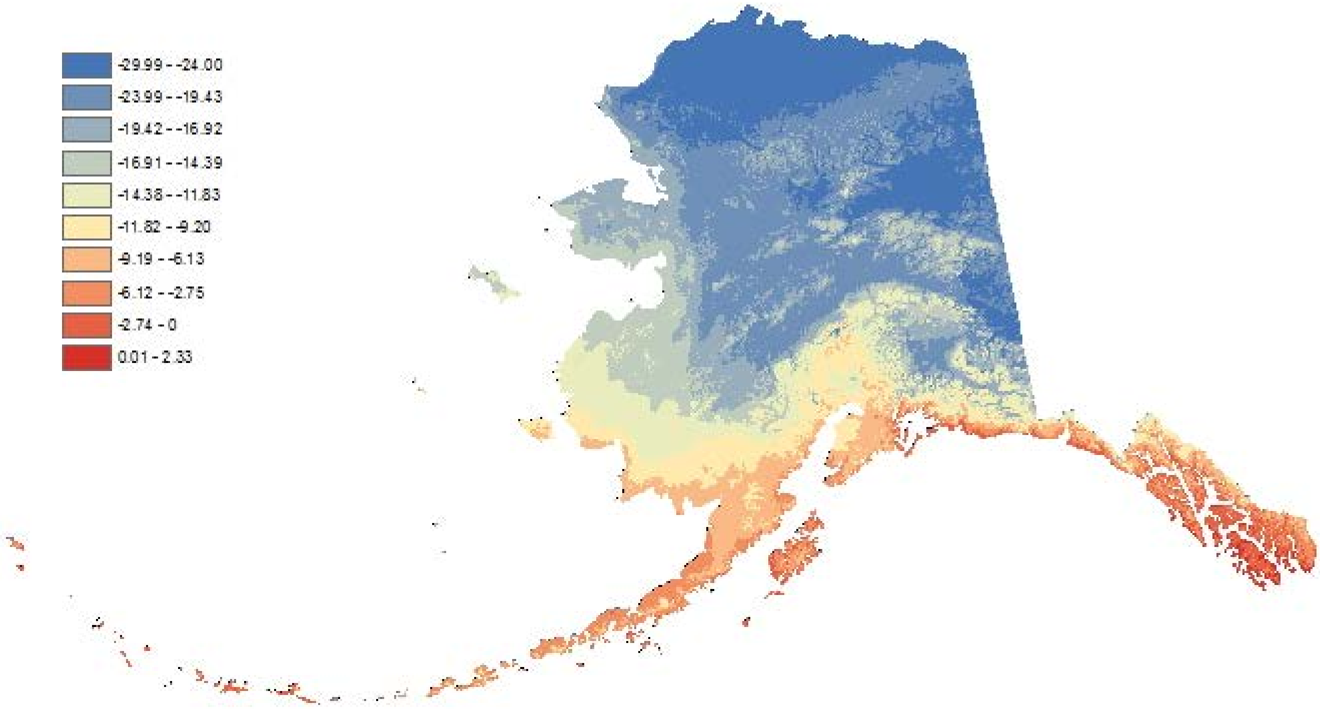
Dataset Name:	Distance to Sea Ice in June	*Variable Type:*	Continuous
File Name:	sice_jun_dist	*GAP Model Type (s):*	Inductive
Attribute:	Distance (m)	*Data Source:*	NSIDC

Processing Notes: Arctic sea ice distribution was derived from passive-microwave remote sensing data archived by the National Snow Ice and Data Center (NSIDC). See: http://nsidc.org/data/nsidc-0051.html. Monthly mean coverages for June of the years 2003-2007 were combined into a composite feature. Planar distances exterior to these features were calculated using ArcGIS Spatial Analyst toolbox.



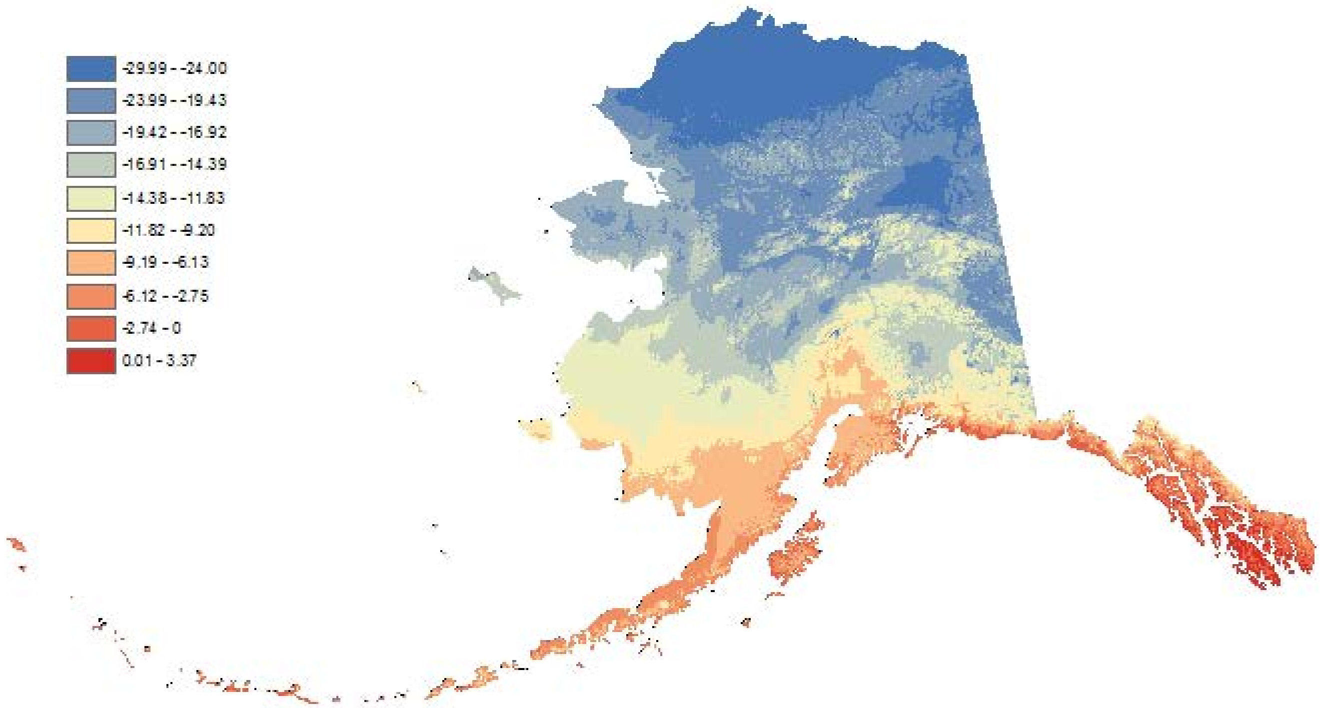
Dataset Name:	Soils	*Variable Type:*	Categorical
File Name:	soils	*GAP Model Type (s):*	Inductive
Attribute:	Class	*Data Source:*	NRCS STATSGO

Processing Notes: Soil types were derived from 2011 STATSGO soil survey data developed by the U.S. Department of Agriculture, Natural Resource Conservation Service. Data were originally mapped to a scale of 1:2,500,000. These data were rasterized and each unique MUSYM (e.g. soil mapping unit) value was designated an arbitrary class value.



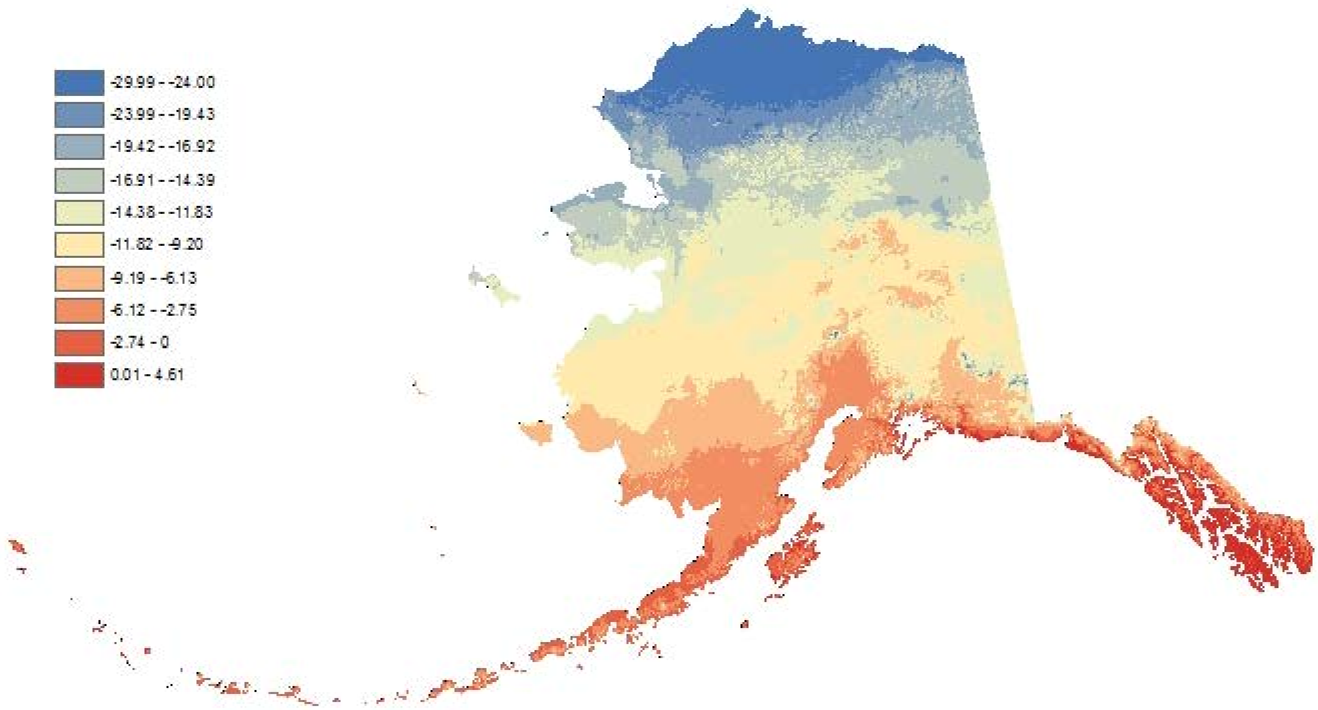
Dataset Name:	Average Temperature in January	*Variable Type:*	Continuous
File Name:	tmean01	*GAP Model Type (s):*	Inductive
Attribute:	Temperature (Celsius)	*Data Source:*	PRISM

Processing Notes: Mean historical temperature for January was derived from the 2010 PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which is a modeled climatological dataset summarized at monthly intervals across the period 1981-2010. See: http://www.prism.oregonstate.edu/. Data were resampled (not downscaled) from grids with 800m cell and projected from a geographic coordinate system of NAD83.



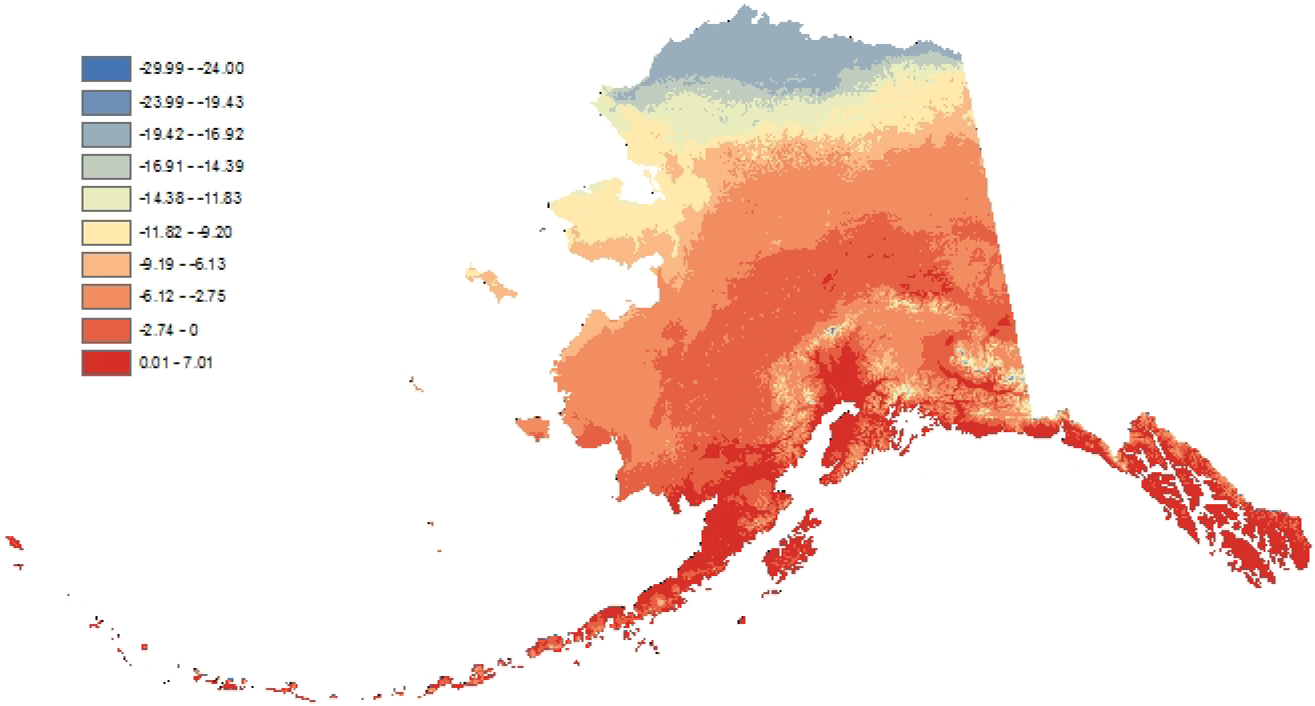
Dataset Name:	Average Temperature in February	*Variable Type:*	Continuous
File Name:	tmean02	*GAP Model Type (s):*	Inductive
Attribute:	Temperature (Celsius)	*Data Source:*	PRISM

Processing Notes: Mean historical temperature for February was derived from the 2010 PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which is a modeled climatological dataset summarized at monthly intervals across the period 1981-2010. See: http://www.prism.oregonstate.edu/. Data were resampled (not downscaled) from grids with 800m cell and projected from a geographic coordinate system of NAD83.



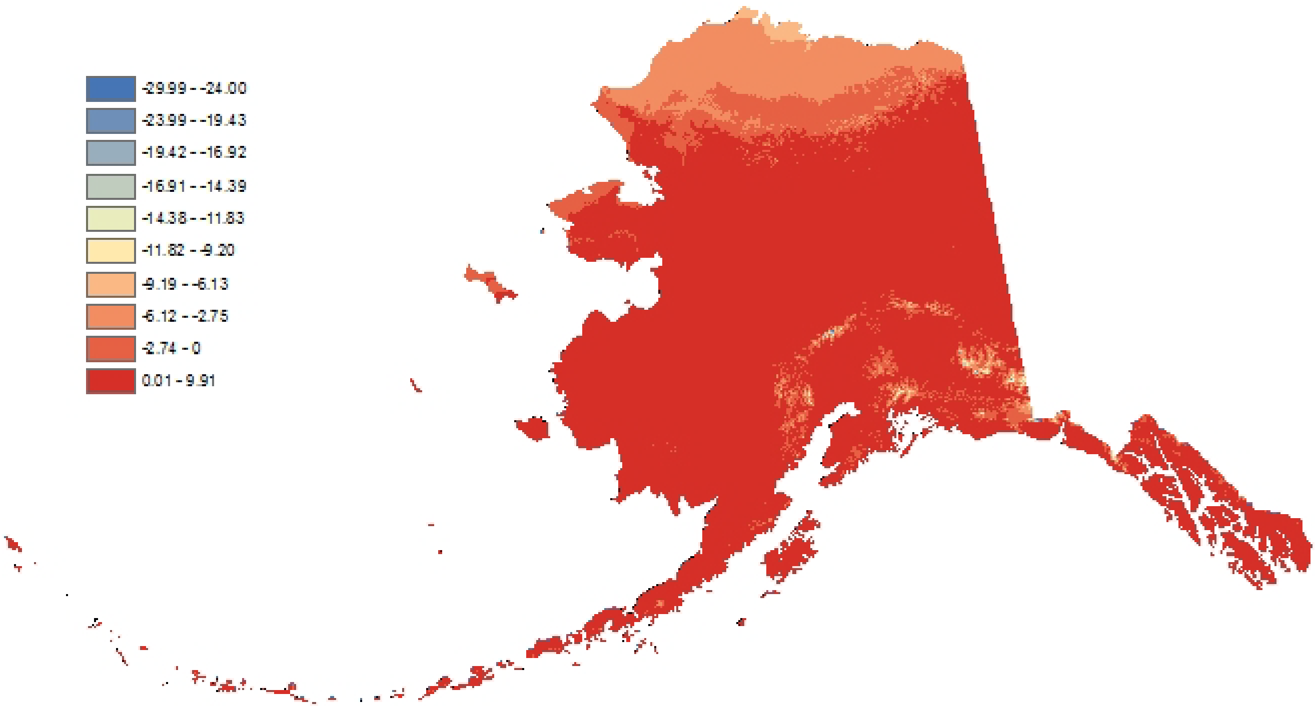
Dataset Name:	Average Temperature in March	*Variable Type:*	Continuous
File Name:	tmean03	*GAP Model Type (s):*	Inductive
Attribute:	Temperature (Celsius)	*Data Source:*	PRISM

Processing Notes: Mean historical temperature for March was derived from the 2010 PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which is a modeled climatological dataset summarized at monthly intervals across the period 1981-2010. See: http://www.prism.oregonstate.edu/. Data were resampled (not downscaled) from grids with 800m cell and projected from a geographic coordinate system of NAD83.



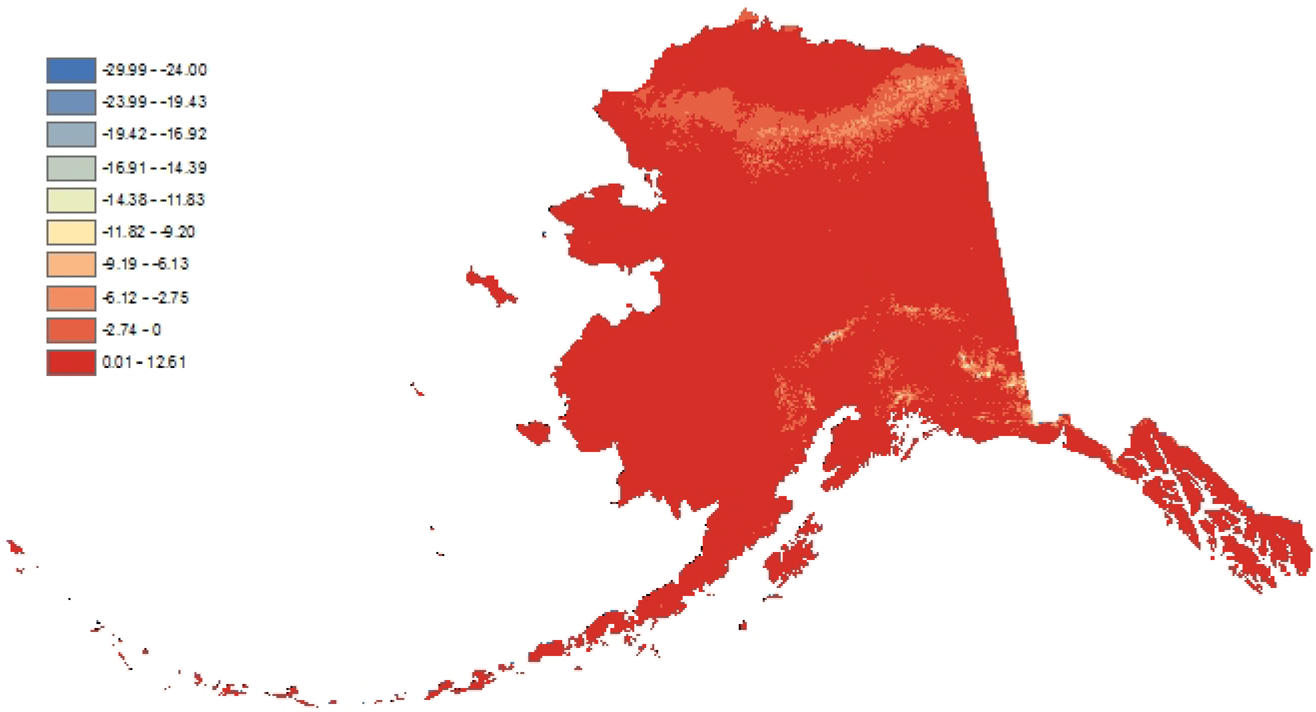
Dataset Name:	Average Temperature in April	*Variable Type:*	Continuous
File Name:	tmean04	*GAP Model Type (s):*	Inductive
Attribute:	Temperature (Celsius)	*Data Source:*	PRISM

Processing Notes: Mean historical temperature for April was derived from the 2010 PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which is a modeled climatological dataset summarized at monthly intervals across the period 1981-2010. See: http://www.prism.oregonstate.edu/. Data were resampled (not downscaled) from grids with 800m cell and projected from a geographic coordinate system of NAD83.



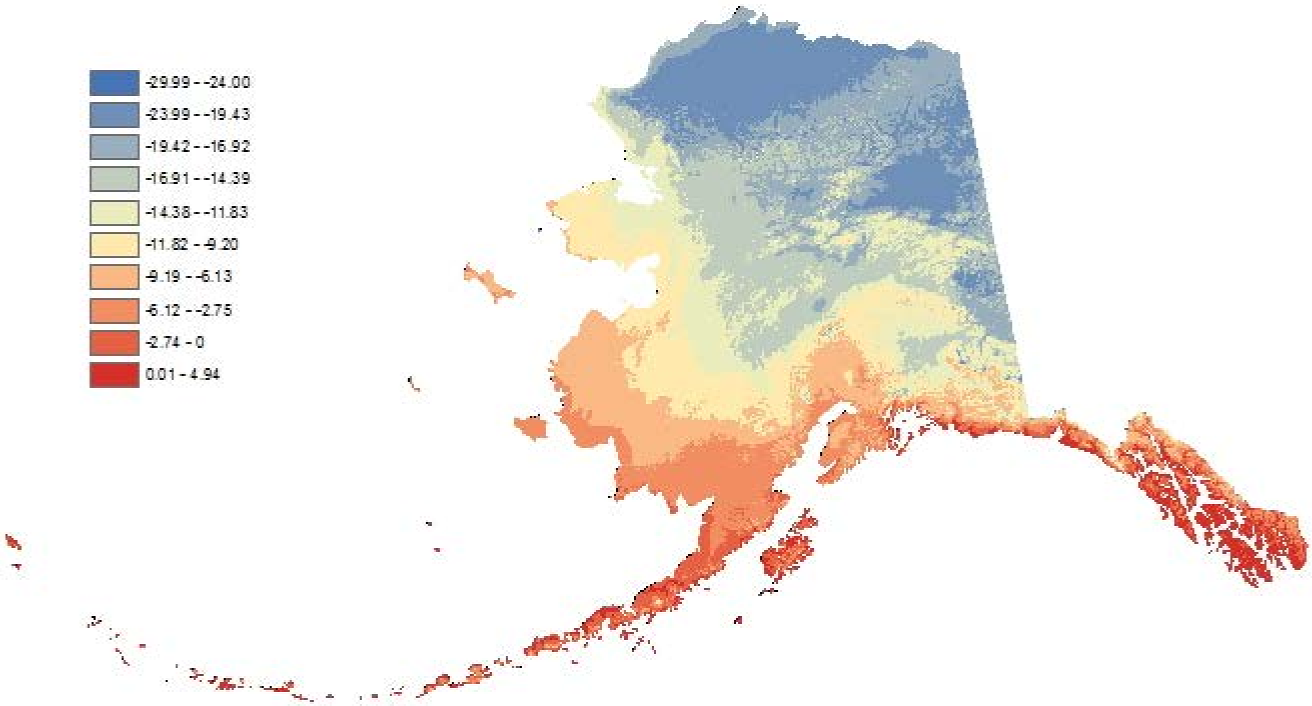
Dataset Name:	Average Temperature in May	*Variable Type:*	Continuous
File Name:	tmean05	*GAP Model Type (s):*	Inductive
Attribute:	Temperature (Celsius)	*Data Source:*	PRISM

Processing Notes: Mean historical temperature for May was derived from the 2010 PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which is a modeled climatological dataset summarized at monthly intervals across the period 1981-2010. See: http://www.prism.oregonstate.edu/. Data were resampled (not downscaled) from grids with 800m cell and projected from a geographic coordinate system of NAD83.



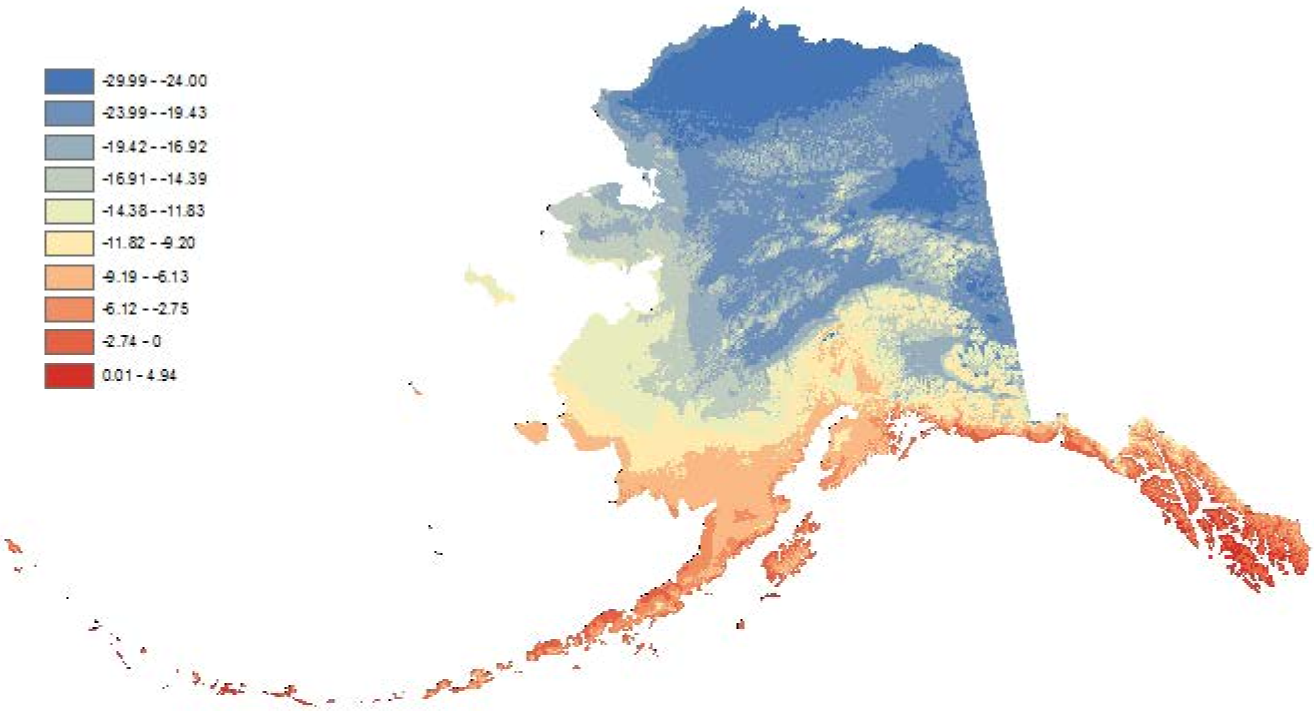
Dataset Name:	Average Temperature in September	*Variable Type:*	Continuous
File Name:	tmean09	*GAP Model Type (s):*	Inductive
Attribute:	Temperature (Celsius)	*Data Source:*	PRISM

Processing Notes: Mean historical temperature for September was derived from the 2010 PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which is a modeled climatological dataset summarized at monthly intervals across the period 1981-2010. See: http://www.prism.oregonstate.edu/. Data were resampled (not downscaled) from grids with 800m cell and projected from a geographic coordinate system of NAD83.



Dataset Name:	Average Temperature in November	*Variable Type:*	Continuous
File Name:	tmean11	*GAP Model Type (s):*	Inductive
Attribute:	Temperature (Celsius)	*Data Source:*	PRISM

Processing Notes: Mean historical temperature for November was derived from the 2010 PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which is a modeled climatological dataset summarized at monthly intervals across the period 1981-2010. See: http://www.prism.oregonstate.edu/. Data were resampled (not downscaled) from grids with 800m cell and projected from a geographic coordinate system of NAD83.

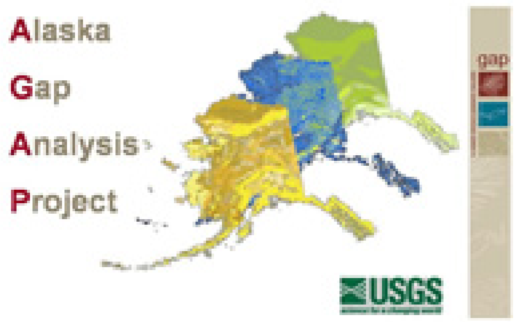


Dataset Name:	Average Temperature in December	*Variable Type:*	Continuous
File Name:	tmean12	*GAP Model Type (s):*	Inductive
Attribute:	Temperature (Celsius)	*Data Source:*	PRISM

Processing Notes: Mean historical temperature for December was derived from the 2010 PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which is a modeled climatological dataset summarized at monthly intervals across the period 1981-2010. See: http://www.prism.oregonstate.edu/. Data were resampled (not downscaled) from grids with 800m cell and projected from a geographic coordinate system of NAD83.

Alaska
Gap
Analysis
Project

ALASKA GAP ANALYSIS PROJECT



External Review Process

Background

The Alaska Gap Analysis Project is predicting habitat for 347 vertebrate species and subspecies that reside, breed, or use habitat in the state of Alaska for a substantial portion of the their life history. The gap analysis approach uses the predicted distributions of animal species habitat to evaluate their conservation status relative to existing land management (Scott et al. 1993). However, the maps of species distributions may also be used to answer a wide variety of management, planning and research questions relating to individual species or groups of species. In addition to the maps, great utility may be found in the literature and occurrence data that is assembled to produce the species distribution models.

The premise of our endeavor is that we are modeling to identify areas of the landscape that contain physical and biotic features that likely will or do support occurrence of specific animal taxa. That modeling is based on a set of associations (wildlife habitat relationships or environmental and climatic) developed for each taxa relative to a set of landscape features that are compiled at the statewide scale. Namely, we are modeling potentiality for occurrence of suitable habitat features or environmental niches for each animal taxon; we are not preparing predictions of absolute occurrence of any individual taxa on any given day.

The list of species to model was determined by identifying decision rules for taxon inclusion. In preparation for modeling, we compiled over 1.6 million occurrence records from 650 unique data sources, developed watershed-scale range maps for each target species, and populated a habitat-associations database that cross-walks species habitat descriptions from the literature and expert input to ecological systems. A species' distribution, at 60 meter resolution, was created using a model to predict areas suitable for occupation within its range. We used a combination of deductive and inductive modeling techniques to produce our final models. Deductive models were derived using a suite of spatial variables including habitat types, elevation, hydrological characteristics, and distance to/from forest edge. Inductive models were derived using known points of occurrence and their intersection with a suite of environmental parameters. Final distribution maps are intersections of these two independently derived models, delimited by range limits of the target species, and evaluated for classification success. To create the most accurate models possible we are engaging taxa experts to provide a review of the watershed derived range maps and species distribution models.

Objectives

An important factor for model implementation is understanding the objectives of the modeling effort and the assumptions of the models. The objective of the species distribution models are to:

1. Provide maps that predict the distribution of terrestrial vertebrate species throughout their range in Alaska to support analysis of conservation status; and
2. Develop a database of geographic ranges, wildlife habitat relationships, and predicted distribution of each vertebrate species for the long-term utility of GAP and its cooperators (Csuti and Crist 2000).

Along with these objectives are several assumptions associated with GAP vertebrate habitat models (Csuti and Crist 1998):

1. Species are assumed to occur within a distribution model representing potential habitat but are not predicted to occur at any particular point within that model.
2. Species are assumed to be present within their predicted distribution model, but no assumptions are made about the abundance of the species within their distribution.
3. Species are assumed to be present during some portion of their life history, but not necessarily during the entire year. This is especially the case for breeding birds, who are only present in Alaska during the pre-breeding, breeding, and post-breeding season (spring through early fall). Therefore, for many avian taxa, we only produced distribution models for the breeding season.

We encountered many challenges while creating both range and distribution maps. Thus, we are soliciting external review from knowledgeable individuals on the modeled terrestrial vertebrates across the state. The purpose of the model review is both to inform the process with which models are developed and potentially revised, and to provide user’s confidence that species models are accurate and useable within the scale and context they are intended. This document describes the expert review process within AKGAP.

Review Approach

The AKGAP habitat models have three model components that we would like reviewed. These are:

1. Range extent (Range)
2. Wildlife habitat relationships (Report)
3. Distribution models (3 model types = 1 deductive, 1 inductive, 1 combined)

Range Extent

Review of individual species range maps is to ensure that the range extent accurately depicts the known range of the species. The review should include an evaluation of: 1) extent, and 2) seasonal coding (this section is most relevant to migratory taxa, e.g., permanent resident, summer breeder).

Some considerations include:

1. Does the range extent, as depicted by hydrologic units, reflect the known range of species?
2. Are the hydrologic units correctly coded?

Wildlife Habitat Relationships

Review of this section will either substantiate or refute the habitat relationships used to produce the deductive models. This process should include: 1) review of each relationship used in the model, 2) concurrence with the relationships; and 3) review of references to ensure that important citations are not missed.

Questions to focus on this part of the review include:

1. Are the habitat relationships (within the limits of available information) correctly identified?
2. Are there additional relationships not identified, which should be included? Knowledge regarding the limitations of the habitat relationships is also requested.

Distribution Models

Review of predicted distribution maps is a subjective review based on expert knowledge. The review of this tier should focus on the following questions:

1. Does the depiction look plausible?
2. Does the depiction identify too much habitat?
3. Does the depiction not identify enough habitat?
4. Does the predicted distribution appear to be spatially correct?

Rules for model modification

Modifications must be identified based on a reference with associated source code or documented as personal communication (Table D-1).

Table D-1. Categories of reference information.

Category	Description
1	Information is based on substantive direct investigation and published (printed or electronic) in an outlet subject to peer evaluation.
2	Information is based on direct investigation or general review and is available in any of a variety of general publications that are serial or ad hoc documents of a technical nature subject to uncertain degree of professional review.
3	Information is derived directly or indirectly from individuals with demonstrated limited or broad expert credence; formats include but are not limited to word-of-mouth accounts, field journals, specimen record tags or forms, labeled photographs, etc.
4*	Information is inferred from associations applicable to similar taxa.

* Though not a preferred reference, because of taxonomy changes this option may be applicable.

Literature Cited

Csuti, B. and P. Crist. 1998. Methods for Assessing Accuracy of Animal Distribution Maps, Gap Analysis Program, University of Idaho, Moscow, Idaho. http://www.gap.uidaho.edu/ Date Accessed: 02 July 2003.

Material for Expert Reviewers

Expert Review packet: All documents and materials for the AKGAP expert review are accessible via the internet at: http://sealab.uas.alaska.edu/page.php?npID=13.

Reviewer Items

- **External Review and Process** – this document**.**
- **External Review Form** - questionnaire we are asking each reviewer to fill out. One questionnaire per species.
    - For reviewers that want to submit reviews as hard copies, please print and fill in the External Review Form and mail all hard copy documents to:
      Tracey Gotthardt
      Attn: AKGAP Expert Review
      707 A Street, Suite 103
      Anchorage, AK 99501

      Or email to: tagotthardt@uaa.alaska.edu

- **Landfire Overview** – Document describing the LANDFIRE Ecological Systems, including a map, map legend and searchable table.
- **Ancillary Data documentation** – overview of development of several ancillary data layers used for modeling.
- **Table of Accuracy Statistics for Models**

Documents to be reviewed: Pdfs or jpegs of these documents can be obtained from the website http://sealab.uas.alaska.edu/page.php?npID=13. Search for your species under the headings **Mammals, Birds**, or **Amphibians**. Species are arranged in phylogenetic order. Documents to be reviewed include:

- Seasonal Range by HUC (jpg)
- Predicted Distribution Model – deductive, inductive, combination (jpg)
- Wildlife Habitat Relationships report (pdf)

Additional information:

- **Ancillary Data** – maps depicting each of the ancillary data layers used to develop distribution models.

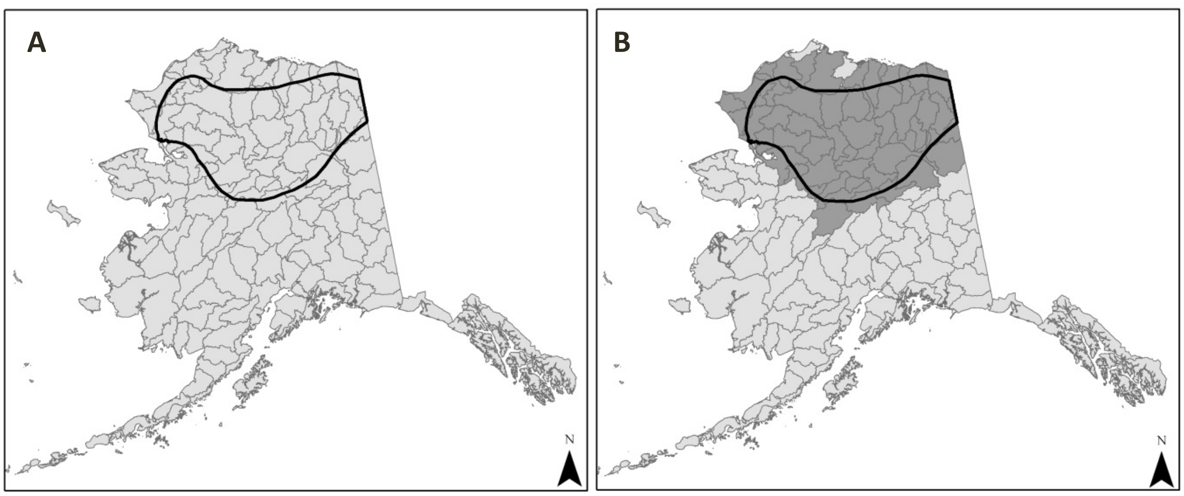
Modeling Methods

Range Mapping

We define range 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 (Aycrigg and Beauvais 2007).

The first map product developed for each target taxon was a range map, using 8-digit hydrologic units (Hydrologic units) as map units, following methods employed by other recent regional GAP range mapping efforts (Boykin et al. 2007). 8-digit HUCs (HUC8s) were used to identify species ranges. The intent of the HUC8 was to constrain the habitat model. In some cases the HUC-depicted range can extend well beyond the known range of the species.

We acquired initial polygon range maps for individual taxa from NatureServe (http://www.natureserve.org/getData/animalData.jsp) and from the Alaska Natural Heritage Program. We then tessellated each polygon range map into its constituent HUC8s (Figure 1).



FigureD.1. Area outlined in black indicates the original (polygon) range map for the Alaska Marmot overlaid on 8-digit HUCs (A). Dark gray area indicates all HUC8s that intersected or were included within the original polygon range map (B), and is considered the

We then assigned initial values for two attributes to each HUC8:

Season: Possible values were Summer, Spring/Fall, Winter, Yearround. Especially for migratory taxa, the value of the Season attribute was assigned with the specific modeling season (equate Breeding with Summer), and modeling season date, in mind.

Seasons were defined as follows: Winter (December - February); Fall/Spring (March - May and August - November); Summer (June or July); Yearround (all months).

Occurrence: Possible values were Known, Suspected, Historical, or Accidental. "Known" equated to the presence of documented occurrences of the target taxon, or confident expert prediction of occurrence, within a given HUC8. Less confident conclusions were grounds for selecting the "Suspected" modifier. "Historical" indicated the last known record of occurrence for a given HUC8 predated 1910. "Accidental" was only selected when infrequent or irregular records were available for a given HUC8.

Distribution Models

A species' distribution, at 60 meter resolution, was created using a model to predict areas suitable for occupation within its range. We used a combination of **deductive** and **inductive** modeling techniques to produce our final models.

Deductive Models

Deductive distribution modeling followed the traditional, land cover-based procedures of previous Gap Analyses. Deductive models were derived using a suite of spatial variables including habitat types, elevation, hydrological characteristics, and distance to/from forest edge. This process can be described as designating land cover types from a given classification system as either suitable or unsuitable for occupation by a given taxa (Beauvais et al. 2013).

We used the LANDFIRE Existing Vegetation Type (EVT) map as our statewide land cover map. The EVT layer represents the species composition currently present at a given site. Vegetation map units are primarily derived from NatureServe's Ecological Systems classification, which is a nationally consistent set of mid-scale ecological units. Additional units are derived from NLCD, National Vegetation Classification Standard (NVCS) Alliances, and LANDFIRE specific types.

We developed a database of wildlife habitat relationships to help delineate habitats that were considered suitable for occupation by a given taxa. Habitat descriptions were extracted from the NatureServe Explorer database, the Alaska Natural Heritage Programs (AKNHP) Biotics database, and through exhaustive literature review. The descriptive habitat associations from the literature were then cross-walked to Ecological Systems and other associated ancillary variables by AKGAP species modeling team, with substantial assistance from vegetation ecologists at AKNHP (Figures 2 and 3).

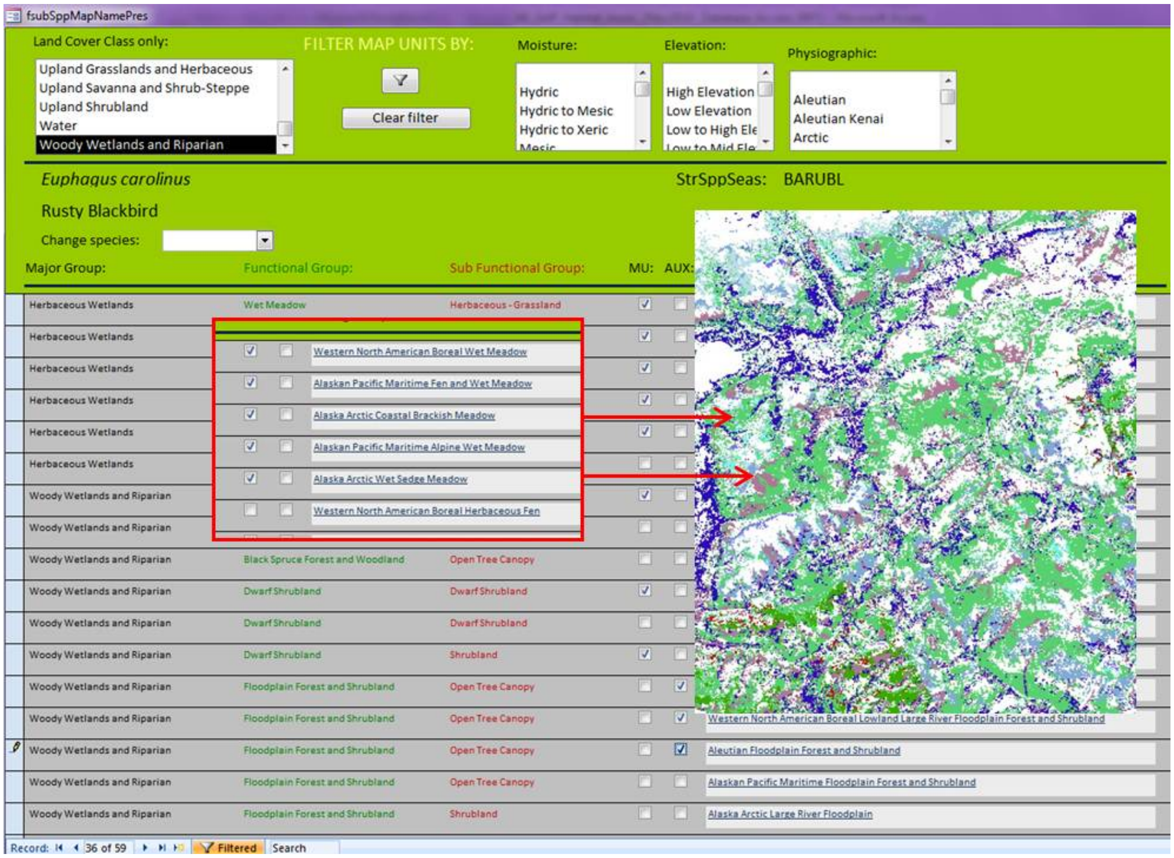


Figure D.2. Example of the habitat associations crosswalk to ecological systems. There were 142 ecological systems defined for Alaska. Map inset is of habitat types selected for.

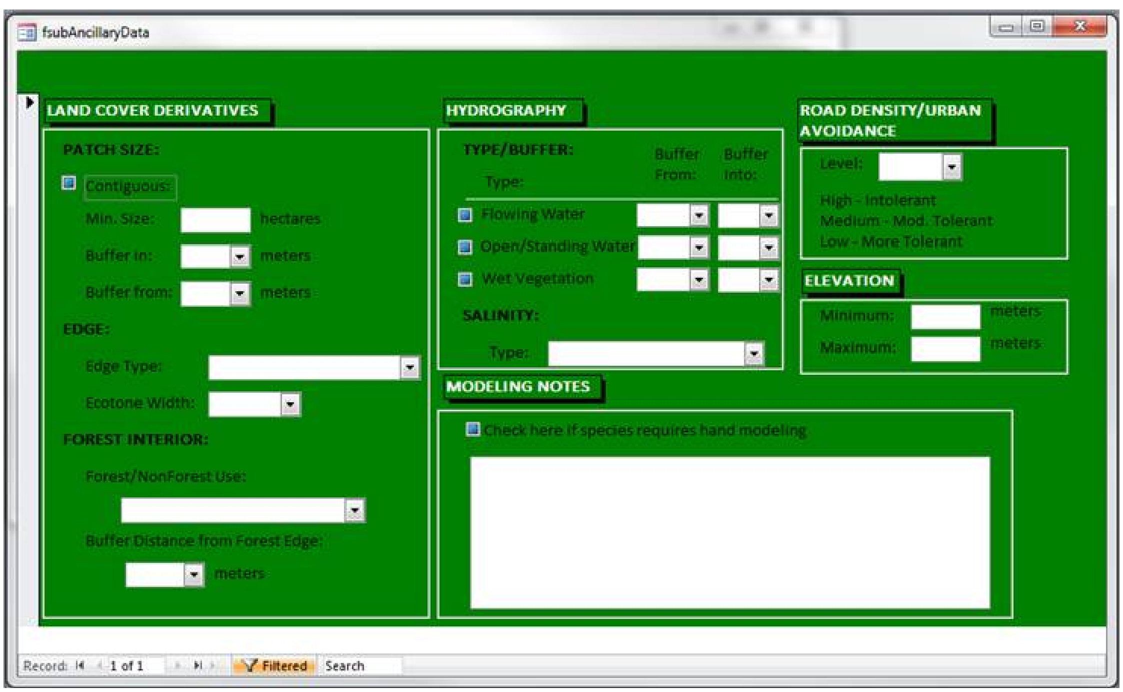


Figure D.3. Additional ancillary data selections for further model refinement.

Models were developed to incorporate habitat utilization across the taxon's entire range in Alaska. We found that many wide ranging taxa utilized habitat differently across their range or elevational limitations were different due to latitudinal differences over the study area. In an attempt to capture regional variation in habitat utilization, Ecological Systems were filtered and then selected by physiographic region (including: Aleutian, Artic, Boreal, Sub-boreal, North American Pacific Maritime and Temperate Pacific) and elevation (high, medium, low).

Deductive models were then derived using a combination of the Ecological Systems that best described land cover types suitable for occupation by each target taxon, plus any additional categorical variables (e.g. distance to edge, elevation) selected by the species modeling team. The HUC8 range maps were then used to delineate the final modeled extent.

Inductive Models

Inductive models were derived using known points of occurrence and their intersection with a suite of environmental parameters. Inductive modeling included data processing and filtering, ancillary data layer development or refinement, and the application of the Maximum Entropy algorithm (MaxEnt version 3.3.1) to produce models.

Occurrence Data Collection and Processing

Occurrence data were acquired from over 650 unique data sources, resulting in a dataset of approximately 1.6 million records for 430 species. Records were summarized in a common format and attributed with 30 common fields. Positional accuracy (if not provided) was estimated based on the record's mapping protocol using standards established by the Natural Heritage Network (http://www.natureserve.org/prodServices/standardsMethods.jsp). All records were stored in a geodatabase that was queried as needed for analysis and modeling.

For migratory species, all occurrences outside the designated modeling season were removed from the dataset. For avian species, the primary season of interest was the breeding season, in which case, all non-breeding season occurrences were eliminated. Breeding season was broadly defined as such: for breeding waterfowl, May through August, for all other breeding birds, June, July and August. We then eliminated duplicate records. Next, we eliminated remaining records with mapping precisions >2000 m. Finally, we eliminated any remaining records of observation made before 1990. We selected 1990 as an arbitrary cutoff for two reasons: 1) 87% of the occurrence data were collected between 1990 and 2010, and 2) we felt that over the past 20 years, environmental conditions have remained reasonably stable across the study area.

Preliminary models were run using all occurrence data that met the above criteria. These preliminary datasets were then reviewed to identify species with highly autocorrelated data, which can sometime bias environmental niche models (Jimenez-Valverde and Lobo 2006, Johnson and Gillingham 2008). We thinned dense clusters of occurrences resulting from oversampling by applying a stratified sampling method using 12-digit HUCs to spatially separate occurrences. At least two, and up to ten occurrences were randomly selected from each HUC to be included in the modeling procedure. The number of occurrences used depended on the number of overall occurrence data points available for, and the results of further iterations of modeling.

After initial review, preliminary models for species that had poor model results were re-run using alternative data selection procedures. The first alternative data selection method removed or reduced the year restriction and included data from years prior to 1990, as long as they met the other filtering restrictions. This method was only used if the prior models for the species did not meet internal review criteria. The initial filtering restrictions resulted in several species that simply lacked adequate occurrence data to run a model. For these species, we reduced both the accuracy and date restrictions, in an attempt to produce a large enough sample to run a model, cognizant of the fact that by reducing accuracy restrictions we were potentially reducing the accuracy of the modeled output . Taxa with <10 final modeling records were excluded from the inductive modeling process. The distributions of such taxa were modeled entirely through the deductive process.

Environmental Data Collection and Processing

We selected 20 environmental predictor variables to use in all of our inductive distribution modeling. Environmental predictor variables were comprised of climatic data, elevation, geology, soils, and distance to specific landscape features (e.g. distance to coast). Environmental predictor layers were projected in the Alaska Albers Equal Conical projection and resampled to 60 m cell size, such that there projection, extent, cell size and alignment were consistent. These processes were performed in ArcGis 10.0.

Refer to the report titled "Ancillary Data Documentation" under the **Reviewer Items** tab at: http://sealab.uas.alaska.edu/page.php?npID=17 for more detailed description in individual predictive layers and their development, their range of parameters, and usage in modeling species predicted distributions.

Model Generation and Validation

For each target taxon, we used the MaxEnt algorithm, version 3.3.1 (http://www.cs.princeton.edu/~schapire/MaxEnt/), to produce our inductive species distribution models. All models were produced using the same 20 environmental variables. Thirty percent of the occurrence data were held back to test the model. We used area under the curve (AUC) statistics derived from receiver operating characteristics analyses, which is automatically calculated by MaxEnt, to estimate performance. Models with an AUC of .75 and higher were considered acceptable, while models with AUCs lower than .75 were rejected.

Model Display

Model outputs include an ASCII file which was converted to a continuous raster grid for import into ArcGIS. Each cell in the raster contains a probability value that represents the probability of occurrence for that particular species, ranging from 0.0 to 1.0. For these models, a binary threshold was applied that divided the continuous output into two categories: predicted absence (0) and predicted presence (1).

We overlaid the occurrence data used to produce the model with the modeled output to determine the raster value for each cell. We then calculated the mean raster cell value (and sd), and applied this as our threshold. The final modeled output was then clipped to the species known and suspected range within the state – thus, limiting predictions to areas of the state that are believed to be part of the species range.

Final Distribution Models

Final distribution models are intersections of the independently derived deductive and inductive models, delimited by range limits of the target species, and evaluated for classification success (Figure 4).

For those resident taxa for which only a deductive distribution model was generated (because they had <10 post-filtering occurrence records), the final deductive distribution model was designated as the final project distribution model. The mapped expression of that model within the boundaries of each taxon's final range was used as the final distribution map.

For those taxa for which we produced both a deductive and in inductive model, we intersected the maps of both models and clipped the result to the taxon's final range boundaries. We then visually inspected the clipped result to assess whether it predicted presence throughout most of the taxon's range (in which case the intersection map was accepted as the taxon's final distribution map) or left large portions of the taxon's range with no predicted presence (in which case the intersection map was rejected, and the mapped expression of the taxon's final deductive model was chosen as its final distribution map).

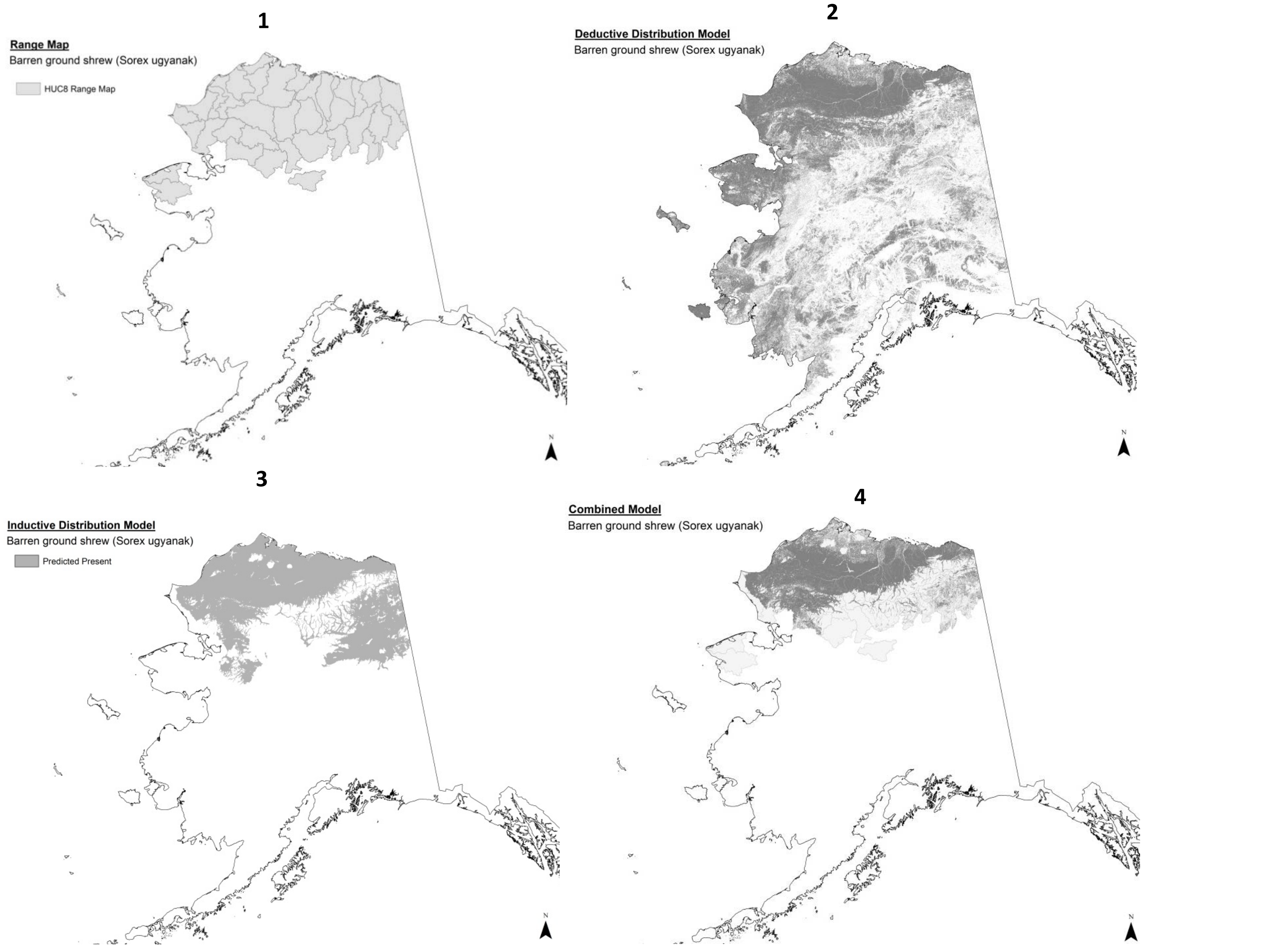


Figure D.4. Examples of intersecting an inductive distribution model with a deductive distribution model, within range boundaries, to form a final model of predicted distribution for a given taxon. Map series is for Barren ground shrew (*Sorex uganak*): 1 is the HU

Literature Cited

Aycrigg, J. and G.P. Beauvais. 2007. Novel approaches to mapping vertebrate occurrence for the Northwest Gap Analysis Project. Gap Analysis Bulletin 15:27-33.

Boykin, K. G., B. C. Thompson, R. A. Deitner, D. Schrupp, D. Bradford, L. O'Brien, C. Drost, S. Propeck-Gray, W. Rieth, K. Thomas, W. Kepner, J. Lowry, C. Cross, B. Jones, T. Hamer, C. Mettenbrink, K.J. Oakes, J. Prior-Magee, K. Schulz, J. J. Wynne, C. King, J. Puttere, S. Schrader, and Z. Schwenke. 2007. Predicted animal habitat distributions and species richness. Chapter 3 in J.S. Prior-Magee t al. (eds). Southwest Regional Gap Analysis Final Report. U.S. Geological Survey, Gap Analysis Program. Moscow, Idaho.

Beauvais, G., M. Anderson and D. Keinath. 2012. Modeling range, distribution, and habitat importance for terrestrial vertebrates in the Northwest ReGAP region. Wyoming Natural Diversity Database, University of Wyoming, Laramie, Wyoming.

Jimenez-Valverde, A. and J. M. Lobo. 2006. The ghost of unbalanced species distribution data in geographical model predictions. Diversity and Distributions 12:521-524.

Johnson, C. J. and M. P. Gillingham. 2008. Sensitivity of species-distribution models to error, bias, and model design: an application to resource selection functions for woodland caribou. Ecological Modeling 213:143-155.

ALASKA GAP ANALYSIS PROJECT

External Review Form

Reviewer Name and Affiliation:

Species under review:

Describe your geographic region of expertise for the given species (statewide, regional, local):

What is your level of knowledge regarding the given species:

Expert (e.g. have conducted multi-field studies for the taxon)
Somewhat Familiar (e.g. familiar with primary and gray literature for the taxon)
General (e.g. field-guide level knowledge of the taxon)

RANGE MAPS

Range Extent – do you agree that the range extent, as depicted by hydrologic units, accurately reflects the known range of the species?

No Opinion	5	4	3	2	1
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Range Coding – based on your knowledge of the species, do you agree with the seasonal range coding?

No Opinion	5	4	3	2	1
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

What changes would you recommend to represent the species range more accurately?

If you would like to modify the range of the species, please print out the range map and make needed corrections. Then return the map to Tracey Gotthardt or Miles Spathelf.

HABITAT DESCRIPTION

Do you feel that the habitat description adequately characterizes the species habitat?

Yes No

What changes might you recommend to improve this habitat description?

Do you approve of the Ecological Systems selections?

Yes No

What changes would you recommend for the Ecological Systems selections?

Are there any attributes that should not be used to model this species or are there other attributes that should be included with the model?

DISTRIBUTION MODELS

Do you agree that the DEDUCTIVE model output accurately reflects the taxon's distribution?

No Opinion	5	4	3	2	1
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Do you agree that the INDUCTIVE model output accurately reflects the taxon's distribution?

No Opinion	5	4	3	2	1
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Do you agree that the COMBINED model output accurately reflects the taxon's distribution?

No Opinion	5	4	3	2	1
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Of the three modeled outputs presented for your review, which model type most accurately represents the statewide distribution of the taxon?

Deductive Inductive Combined

How might AKGAP be able to better represent the species distribution more accurately?

What additional variables or attributes might help refine the model (e.g. elevational limitations)?

References

Your comments are critical to help us create the most useful models. Please describe in detail your views of the above models. Feel free to call or email Tracey Gotthardt regarding model specifics or the process in general.

Appendix E: List of Expert Reviewers

Affiliation	Name	Taxa reviewed	Range	Model
ABR	John Shook	Peregrine Falcon (plus 3 subspecies)	Yes	Yes
ADF&G	Jason Schamber	Black Scoter	Yes	Yes
ADF&G	Julie Hagelin	Ancient Murrelet, Cassin's Auklet, Parakeet Auklet, Least Auklet, Crested Auklet, Horned Puffin, Tufted Puffin	Yes	Yes
ADF&G	Karen Blejwas	Silver-haired bat, California myotis, keen's myotis, little brown myotis	Yes	Yes
ADF&G	Thomas Paragi	Ruffed Grouse, Spruce Grouse, Sharp-tailed Grouse, wolf, American marten, black bear, caribou, moose	Yes	Yes
ADF&G	Travis Booms	Osprey, Bald Eagle, Northern Harrier, Sharp-shinned Hawk, Northern Goshawk, Swainson's Hawk, Red-tailed Hawk, Rough-legged Hawk, Golden Eagle, American Kestrel, Merlin, Gyrfalcon, Snowy Owl, Gray-headed Chickadee	Yes	Yes
UAA	Audrey Taylor	Black Turnstone, Surfbird, Semipalmated Sandpiper, Western sandpiper, Dunlin, Red-necked Phalarope, Red Phalarope	Yes	Yes
UAF	Andy Baltensperger	Cinereus shrew, American pygmy shrew, dusky shrew, tundra shrew, barren ground shrew, Alaska tiny shrew, American marten, northern red-backed vole, nearctic collared lemming, root vole, long-tailed vole, singing vole	Yes	Yes
UAF	Link Olsen	small mammals, general overview	Yes	Yes
USFS	Gwen Baluss	Common Merganser, Merlin, Greater Yellowlegs, Vaux's Swift, Brown Creeper, American Pipit, Orange-crowned Warbler, Pine Grosbeak	Yes	Yes
USFS	Mary Ann Benoit, Jessica Ilse	Trumpeter Swan, Bald Eagle, Northern Goshawk, Western Screech Owl, Great Horned Owl, Snowy Owl, Northern Pygmy Owl, Barred Owl, Great Grey Owl, Short-eared Owl, Boreal Owl, Northern Saw-whet Owl	Yes	Yes
USFWS	Christopher Harwood	Whimbrel, Hudsonian Godwit	Yes	Yes
USFWS	Ellen Lance	Kittlitz's Murrelet	Yes	Yes
USFWS	Judy Jacobs	Steller's Eider, brown bear	Yes	Yes
USFWS	Jim MacCraken	Pacific walrus	Yes	Yes
USFWS	Marilyn Myers	Kittlitz's Murrelet	Yes	Yes
USFWS	Robert Platte	Greater White-fronted Goose, Tule White-fronted Goose, Emperor Goose, Snow Goose, Brant, Cackling Cackling Goose, Steller's Eider, Spectacled Eider, Yellow-billed Loon	Yes	Yes

Affiliation	Name	Taxa reviewed	Range	Model
USFWS	Steve Lewis	Willow Ptarmigan, White-tailed Ptarmigan, Sooty Grouse, Bald Eagle	Yes	Yes
USFWS	Steve Matsuoka	Smith's Longspur, McKay's Bunting	Yes	Yes
USGS	Brad Griffith	Cinereus shrew, American pygmy shrew, meadow jumping mouse, northern red-backed vole, root vole, meadow vole, yellow cheeked vole, northern bog lemming, caribou	Yes	Yes
USGS	Gretchen Roffler	Dalls sheep	Yes	Yes