APPENDIX 1 – ENVIRONMENTAL PREDICTOR DATA

CONTENTS

OVERVIEW

A set of 94 potential predictor layers compiled to use in distribution modeling for the target taxa. Many of these layers derive from previous modeling work by WYNDD[1, 2], but a number were developed specifically for this project. While some layers were available directly from data providers, most required at least basic processing to ensure that the projection, extent, and cell size and alignment of all layers matched. All predictor data layers were stored in TIF format for compatibility with the *rgdal* package[3] in R[4]. Predictor rasters used the "WyLAM" projection (EPSG ID: 8155), and had a cell size of 30m.

CLIMATE

The bulk of the climate data used in modeling comprised a set of 19 climatic layers representing monthly and quarterly temperature and precipitation means, ranges, and extremes[5], downloaded from the Worldlclim website (http://www.worldclim.org/) on February 17, 2014 (Table A1-1). These original data layers were in unprojected (i.e., geographic) coordinates, as ESRI-format rasters with a 30 arc-second cell size. Visual inspection of the predictor data layers revealed that two of the Bioclim layers, bio8 and bio9, exhibited artificially abrupt spatial shifts in their values due to the change in wettest/driest quarter from one quarter to the next. These two layers were therefore not included in the initial models that evaluated the relative performance and correlation between Bioclim predictors. Two additional predictors – "Number of Frost Days" (FROSTDAYS) and "Growing Degree Days" (GROWDD) – derived from DAYMET data from 1980-1997[6-8].

Table A1-1. Climate predictor variables.

Variable	Raster Name	Units
Annual Mean Temperature	"bio1"	°C*10
Mean Diurnal Range (Mean of monthly (max temp - min temp))	"bio2"	°C*10
Isothermality (BIO2/BIO7) (* 100)	"bio3"	Dimensionless Index
Temperature Seasonality (standard deviation *100)	"bio4"	°C*100
Max Temperature of Warmest Month	"bio5"	°C*10
Min Temperature of Coldest Month	"bio6"	°C*10
Temperature Annual Range (BIO5-BIO6)	"bio7"	°C*10
Mean Temperature of Wettest Quarter	"bio8"	°C*10
Mean Temperature of Driest Quarter	"bio9"	°C*10
Mean Temperature of Warmest Quarter	"bio10"	°C*10
Mean Temperature of Coldest Quarter	"bio11"	°C*10
Annual Precipitation	"bio12"	Millimeters
Precipitation of Wettest Month	"bio13"	Millimeters
Precipitation of Driest Month	"bio14"	Millimeters
Precipitation Seasonality (Coefficient of Variation)	"bio15"	Dimensionless Index
Precipitation of Wettest Quarter	"bio16"	Millimeters
Precipitation of Driest Quarter	"bio17"	Millimeters
Precipitation of Warmest Quarter	"bio18"	Millimeters
Precipitation of Coldest Quarter	"bio19"	Millimeters
Frost Days	"frostdays"	Days

Growing Degree Days	"growdd"	Days

HYDROLOGY

Hydrology variables represented distance to nearest water feature or wetland habitat type (Table A1-2). The four layers representing distance to water features ("d2pfw," "d2psw," "d2pw," and "d2w") were created by finding the Euclidean distance to subsets of the water features (e.g., streams, ponds, lakes), contained in the National Hydrography Dataset (NHD)[9], as described in Keinath et al.[2] The Distance to Wetland Habitat layer was created by combining features from previously generated layers representing buffered hydrology and riparian ecological systems[1] with wetland features from the National Wetland Inventory (NWI)[10] layer, and then finding the minimum distance to any of the features. This layer was generated to help address shortcomings related to omission of important wetland features in each of the individual input layers.

Table A1-2. Hydrology predictor variables.

Variable	Raster Name	Units
Distance to Permanent Flowing Water	"d2pfw"	Meters
Distance to Permanent Standing Water	"d2psw"	Meters
Distance to Permanent Water	"d2pw"	Meters
Distance to Any Water	"d2w"	Meters
Distance to Wetland Habitat	"d2wethab"	Meters

LAND USE AND LAND COVER

Land use/land cover (LULC) predictor variables represented a variety of factors identified as potentially important for the modeling taxa (Table A1-3). Some of these variable layers were already available as raster data; others were created based one or more input data sources. With the exception of the Biome predictor, all other layers were generated for previous projects, and additional details regarding their creation can be found in the associated reports[1, 2]. The Biome predictor was generated by grouping Level IV Ecoregions[11] into a set of categories representing broad-scale biomes (Table A1-4). The resulting layer was then converted to a raster in a consistent format with the other predictors.

Table A1-3. Land use/land cover predictor variable

Variable	**Raster Name**	**Units**
Bare Ground Index	"bare"	Percent
Biome	"biome"	Categorical
Conifer Index	"confr"	Percent
Cottonwood Index	"pode"	Percent
Deciduous Forest Index	"decid"	Percent
Forest Canopy Cover	"FORESTCC"	Percent
Herbaceous Cover Index	"herb"	Percent
Landscape Contagion Index	"contag"	Percent

Mean Forest Cover	"forest"	Percent
Pinyon-Juniper Index	"pj"	Percent
Ponderosa Pine Index	"pipo"	Percent
Sagebrush Index	"sage"	Percent
Shrub Index	"shrub"	Percent

Table A1-4. Reclassification schema for generating a Biome predictor from Level IV Ecoregion data.

Level IV Ecoregion Name	Biome	Raster Code
Absaroka Volcanic Subalpine Zone	Montane/Subalpine	3
Absaroka-Gallatin Volcanic Mountains	Montane/Subalpine	3
Alpine Zone	Alpine	0
Bighorn Basin	Basin	1
Bighorn Salt Desert Shrub Basin	Basin	1
Black Hills Core Highlands	Montane/Subalpine	3
Black Hills Foothills	Foothills	2
Black Hills Plateau	Montane/Subalpine	3
Casper Arch	Plains	4
Crystalline Mid-Elevation Forests	Montane/Subalpine	3
Crystalline Subalpine Forests	Montane/Subalpine	3
Dry Mid-elevation Sedimentary Mountains	Montane/Subalpine	3
Flat to Rolling Plains	Plains	4
Foothill Shrublands	Foothills	2
Foothill Shrublands and Low Mountains	Foothills	2
Granitic Subalpine Zone	Montane/Subalpine	3
High Elevation Valleys	Montane/Subalpine	3
Laramie Basin	Basin	1
Mesic Dissected Plains	Plains	4
Mid-elevation Sedimentary Mountains	Montane/Subalpine	3
Mid-Elevation Uinta Mountains	Montane/Subalpine	3
Moderate Relief Plains	Plains	4
Montana Central Grasslands	Plains	4
Partly Forested Mountains	Montane/Subalpine	3
Pine Bluffs and Hills	Plains	4
Pine Scoria Hills	Plains	4
Platte River Valley and Terraces	Plains	4
Powder River Basin	Plains	4
Pryor-Bighorn Foothills	Foothills	2
Rolling Sagebrush Steppe	Basin	1
Sagebrush Steppe	Plains	4
Salt Desert Shrub Basins	Basin	1
Sandy and Silty Tablelands	Plains	4

Sedimentary Subalpine Zone	Montane/Subalpine	3
Semiarid Pierre Shale Plains	Plains	4
Sub-Irrigated High Valleys	Basin	1
Yellowstone Plateau	Montane/Subalpine	3

Soils and Substrate

Soil characteristics are extremely important in shaping distributions for many plant and animal species, but can be difficult to represent with data of sufficient spatial resolution to be useful[12]. STATSGO data was used in conjunction with the National Resource Conservation Service's (NRCS) Soil Data Viewer[13] to generate raster layers that mapped important chemistry, texture, and moisture characteristics[2] (Table A1-5). Two versions of each of these layers was generated; the first created a layer based on the surface layer of soil ("_surf" suffix), and the second used all components in the top 200 cm of the soil (no suffix). A bedrock calcium layer was also generated by assigning an ordinal score to each bedrock geology[14] unit that indicated its Calcium content (Table A1-6). This layer was important for modeling species that are considered caliciphiles.

Table A1-5. Soil predictor variables used in modeling. The "_X" suffix indicates that two versions of the variable were generated – one using the surface soil layer, and one using the components in the top 200 cm of soil.

Variable	Raster Name	Units
Available Water Content	"awc_X"	centimeters of water per centimeter of soil for each soil layer
Bedrock Geology Calcium Content	"geol_calc"	Ordinal scale ranging from "none" (0) to "high" (4)
Calcium Carbonate (soil)	"caco3_X"	Percent of carbonates, by weight, in the fraction of the soil less than 2 millimeters in size
Cation-exchange capacity	"cec_X	Milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value
Depth to Shallowest Restrictive Layer	"d2srl"	Centimeters
Depth to water table	"dep2watr"	Centimeters
Electrical Conductivity	"EC_X"	Millimhos per centimeter at 25 degrees C
Erosion Factor, K, Whole Soil,	"kfactor_X"	Index ranging from 0.02 to 0.69, with higher values indicating higher susceptibility to erosion
Flooding Frequency Class	"flood_freq"	Ordinal
Hydric Rating	"hyd_rating"	Ordinal
Organic matter	"orgmat_X"	Percentage, by weight, of organic material less than 2 millimeters in diameter
Percent clay	"pclay_X"	Percent
Percent gypsum	"gypsum_X"	Percent

Variable	Raster Name	Units
Percent sand	"psand_X"	Percent
Percent silt	"psilt_X"	Percent
pH	"soilph_X"	pH when mixed with an equal amount of water
Range production (difference between favorable and unfavorable year values)	"rangepdif"	Pounds per acre of air-dry vegetation
Range production (Favorable Year)	"rangepfav"	Pounds per acre of air-dry vegetation
Range production (Normal Year)	"rangepnorm"	Pounds per acre of air-dry vegetation
Range production (Unfavorable Year)	"rangepunf"	Pounds per acre of air-dry vegetation
Saturated Hydraulic Conductivity (KSAT)	"ksat_X"	micrometers per second
Sodium adsorption ratio	"sar_X"	Ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration

Table A1-6. Lookup table used to reclassify Bedrock Geology layer into the ordinal, "Bedrock Geology Calcium Content" layer. Bedrock Geology units not appearing in the list below received a "geol_calc" score of "0."

Description	Code	"geol_calc" score
Ankareh Formation-Red and maroon shale and purple limestone. Thaynes Limestone-Gray limestone and limy siltstone. Woodside Shale-Red siltstone and shale. Dinwoody Formation-thrust belt-Gray to olive-drab dolomitic siltstone	@ad	2
Chugwater Formation-Red siltstone and shale. Alcova Limestone Member in upper middle part in north Wyoming. Thin gypsum partings near base in north and northeast Wyoming. Chugwater Group or Formation-Red shale and siltstone containing thin gypsum partings	@c	2
Chugwater Formation-Red siltstone and shale. Alcova Limestone Member in upper middle part in north Wyoming. Thin gypsum partings near base in north and northeast Wyoming. Dinwoody Formation-northern Yellowstone area-Olive-drab dolomitic siltstone and gree	@cd	2
Chugwater Formation-Red siltstone and shale. Alcova Limestone Member in upper middle part in north Wyoming. Thin gypsum partings near base in north and northeast Wyoming. Goose Egg Formation-Red sandstone and siltstone, white gypsum, halite, and purple to	@Pcg	2
Red sandstone and siltstone, white gypsum, halite, and purple to white dolomite and limestone	@Pg	2
Jelm Formation-Red sandstone. Chugwater Group or Formation-south Wyoming-Red shale and siltstone containing thin gypsum partings near base. Group includes Popo Agie Formation (red shale and red, yellow, and purple siltstone; lenses of lime-pellet conglome	@Pjs	1
Red shale, red siltstone, and white gypsum beds; gypsum beds especially abundant near base	@Ps	1
Gallatin Limestone-north Wyoming-Blue-gray and yellow mottled hard dense limestone. Gros Ventre Formation-north Wyoming-Soft green micaceous shale (Upper and Middle Cambrian Park Shale Member), underlain by blue-gray and yellow mottled hard dense limeston	_r	3

Description	Code	"geol_calc" score
Three Forks Formation-northern Yellowstone area-Pink, yellow, and green dolomitic siltstone and shale; north Wyoming-Yellow and greenish-gray shale and dolomitic siltstone. Jefferson Formation-northern Yellowstone area-Massive siliceous dolomite; north Wy	DO	2
Gypsum Spring Formation-Interbedded red shale, dolomite, and gypsum. In north Wyoming wedges out south in T. 39 N. Nugget Sandstone-north Wyoming-Gray to dull-red crossbedded quartz sandstone. Chugwater Formation-Red siltstone and shale. Alcova Limestone	J@	2
Gypsum Spring Formation-Interbedded red shale, dolomite, and gypsum. In north Wyoming wedges out south in T. 39 N. Nugget Sandstone-north Wyoming-Gray to dull-red crossbedded quartz sandstone	J@gc	2
Thrust belt-Buff to pink crossbedded well-sized and well-sorted quartz sandstone and quartzite; locally has oil and copper-silver-zinc mineralization; north Wyoming-Gray to dull-red, crossbedded quartz sandstone	J@gn	1
Nugget Sandstone-thrust belt-Buff to pink crossbedded well-sized and well-sorted quartz sandstone and quartzite; locally has oil and copper-silver-zinc mineralization; north Wyoming-Gray to dull-red, crossbedded quartz sandstone. Ankareh Formation-Red and	J@n	1
Sundance Formation-Greenish-gray glauconitic sandstone and shale, underlain by red and gray nonglauconitic sandstone and shale. Gypsum Spring Formation-Interbedded red shale, dolomite, and gypsum. In north Wyoming wedges out south in T. 39 N.	Js	1
Stump Formation-Glauconitic siltstone, sandstone, and limestone. Preuss Sandstone or Redbeds-Purple, maroon, and reddish-gray sandy siltstone and claystone; contains salt and gypsum in thick beds in some subsurface sections. Twin Creek Limestone-Greenish-	Jsg	2
Cloverly Formation-north and south Wyoming-Rusty sandstone at top, underlain by brightly variegated bentonitic claystone; chert-pebble conglomerate locally at base. Morrison Formation-north Wyoming-Dully variegated claystone, nodular limestone, and gray s	Jst	1
Black shale, fine-grained brown sandstone, thin limestone, and bentonite beds	Kbl	2
Gannett Group-Red sandy mudstone, sandstone, and chert-pebble conglomerate; thin limestone and dark-gray shale in upper part, more conglomeratic in lower part. Includes Smoot Formation (red mudstone and siltstone), Draney Limestone, Bechler Conglomerate,	Kft	2
Greenhorn Formation-Light-colored limestone, marl, and limy sandstone interbedded with gray concretionary shale. Belle Fourche Shale-Black soft bentonitic concretionary shale	Kg	2
Greenhorn Formation-Light-colored limestone, marl, and limy sandstone interbedded with gray concretionary shale. Belle Fourche Shale-Black soft bentonitic concretionary shale. Mowry Shale (age 94 to 98 Ma)-Silvery-gray hard siliceous shale containing abun	Kgb	2
Cloverly Formation-north and south Wyoming-Rusty sandstone at top, underlain by brightly variegated bentonitic claystone; chert-pebble conglomerate locally at base; northeast Wyoming-Rusty to light-gray sandstone containing lenticular chert-pebble conglom	Ki	1
Cloverly Formation-north and south Wyoming-Rusty sandstone at top, underlain by brightly variegated bentonitic claystone; chert-pebble conglomerate locally at base. Morrison Formation-north Wyoming-Dully variegated claystone, nodular limestone, and gray s	KJ	2
Kootenai Formation-Rusty thin-bedded sandstone, grayish-red soft claystone, white limestone, and chert-pebble conglomerate. Morrison Formation-northern Yellowstone area-Variegated silty claystone and fine-grained sandstone. Ellis Group-Swift Formation-Cal	KJg	2
Cloverly Formation-north and south Wyoming-Rusty sandstone at top, underlain by brightly variegated bentonitic claystone; chert-pebble conglomerate locally at base. Morrison Formation-north Wyoming-Dully variegated claystone, nodular limestone, and gray s	KJk	1
Light-colored limestone and gray to yellow speckled limy shale (age about 83 Ma)	Kmv	2

Description	Code	"geol_calc" score
Niobrara Formation-(age about 83 Ma)-Light-colored limestone and gray to yellow speckled limy shale. Carlile Shale-Dark-gray sandy shale; Sage Breaks Member at top; Turner Sandy Member in middle	Kn	3
Niobrara Formation-(age about 83 Ma)-Light-colored limestone and gray to yellow speckled limy shale. Frontier Formation-north and south Wyoming-Gray sandstone and sandy shale. Mowry Shale-(age 94-98 Ma)-Silvery-gray hard siliceous shale containing abundan	Kns	3
Steele Shale (age about 78 to 82 Ma)-Gray soft marine shale containing numerous bentonite beds and thin lenticular sandstone. Niobrara Formation (age about 83 Ma)-Light-colored limestone and gray to yellow speckled limy shale	Ksb	2
Sage Junction Formation-Gray and tan siltstone and sandstone. Quealy Formation-Variegated mudstone and tan sandstone. Cokeville Formation-Tan sandstone, claystone, limestone, bentonite, and coal. Thomas Fork Formation-Variegated mudstone and gray sandston	Kso	1
Madison Limestone or Group-Group includes Mission Canyon Limestone (blue-gray massive limestone and dolomite), underlain by Lodgepole Limestone (gray cherty limestone and dolomite). Darby Formation-Yellow and greenish-gray shale and dolomitic siltstone un	Kws	4
Pahasapa Limestone-Gray massive dolomitic limestone. Englewood Limestone-Pink slabby dolomitic limestone	MD	4
Blue-gray massive cherty limestone and dolomite. Locally includes unnamed dolomite and sandstone of Devonian and Cambrian (?) age	MDe	4
Madison Limestone or Group-Group includes Mission Canyon Limestone (blue-gray massive limestone and dolomite), underlain by Lodgepole Limestone (gray cherty limestone and dolomite). Darby Formation-Yellow and greenish-gray shale and dolomitic siltstone un	MDg	4
Madison Limestone or Group-Group includes Mission Canyon Limestone (blue-gray massive limestone and dolomite), underlain by Lodgepole Limestone (gray cherty limestone and dolomite)	MDO	4
Madison Limestone or Group-Group includes Mission Canyon Limestone (blue-gray massive limestone and dolomite), underlain by Lodgepole Limestone (gray cherty limestone and dolomite). Bighorn Dolomite-thrust belt and north Wyoming-Gray massive cliff-forming	Mm	4
North Wyoming-shown in small areas of complex structure-east flank of Absaroka Range-Dinwoody Formation, Phosphoria Formation and related rocks, Tensleep Sandstone, and Amsden Formation (Lower Triassic through Upper Mississippian); east flank of Bighorn M	MO	4
Bighorn Dolomite-northern Yellowstone area-Light-gray massive siliceous dolomite; thrust belt and north Wyoming-Gray massive cliff-forming siliceous dolomite and locally dolomitic limestone. Gallatin Group-Snowy Range Formation-Medium-gray limestone and u	MzPz	4
Northern Yellowstone area-Light-gray massive siliceous dolomite; thrust belt and north Wyoming-Gray massive cliff-forming siliceous dolomite and locally dolomitic limestone	O_	4
Gray, tan, and red thick-bedded sandstone underlain by interbedded sandstone and pink and gray limestone. May include some Devonian (?) sandstone along east flank of Laramie Mountains	Ob	4
Casper Formation-Gray, tan, and red thick-bedded sandstone underlain by interbedded sandstone and pink and gray limestone. May include some Devonian (?) sandstone along east flank of Laramie Mountains. Fountain Formation-Arkose and red sandstone	P&c	2
Red and white sandstone underlain by gray dolomite and limestone, red shale, and red and gray sandstone. Lowermost unit may be Late Mississippian in age	P&cf	2
Buff and red limy sandstone; some thin limestone beds, solution breccias, and gypsum	P&h	2

Description	Code	"geol_calc" score
Wells Formation-Gray limestone interbedded with yellow limy sandstone. Amsden Formation-thrust belt-Red and gray cherty limestone and shale, sandstone, and conglomerate. Casper Formation-Gray, tan, and red thick-bedded sandstone underlain by interbedded s	P&m	3
Phosphoria Formation and related rocks-thrust belt-Upper part is dark- to light-gray chert and shale with black shale and phosphorite at top; lower part is black shale, phosphorite, and cherty dolomite; northern Yellowstone area-Brown sandstone and dolomi	P&M	3
Forelle Limestone-Thin-bedded limestone; locally is a member of the Goose Egg Formation. Satanka Shale-Red shale	P&Ma	2
Minnekahta Limestone-Gray slabby hard limestone. Locally is a member of the Goose Egg Formation. Opeche Shale-Red soft sandy shale. Locally is a member of the Goose Egg Formation	Pfs	2
Tensleep Sandstone-north Wyoming-White to gray sandstone containing thin limestone and dolomite beds. Permian fossils have been found in the topmost beds of the Tensleep at some localities in Washakie Range, Owl Creek Mountains, and southern Bighorn Mount	PM	2
Thrust belt-Upper part is dark- to light-gray chert and shale with black shale and phosphorite at top; lower part is black shale, phosphorite, and cherty dolomite; north Wyoming-Brown sandstone and dolomite, cherty phosphatic and glauconitic dolomite, pho	Pmo	1
Madison Limestone or Group. Darby Formation-on west flank of Washakie Range-Yellow and greenish-gray shale and dolomitic siltstone underlain by fetid brown dolomite and limestone. Bighorn Dolomite-thrust belt and north Wyoming-Gray massive cliff-forming s	Pp	3
Lacustrine white marl, claystone, sandstone, conglomerate, and tuff; generally radioactive (Pleistocene or Pliocene)	Qt	2
Northwest Wyoming (Jackson Hole) (Pleistocene or Pliocene)-Paleozoic clasts, chiefly of Madison Limestone, in a lithified carbonate matrix; central (Medicine Bow Mountains) and east Wyoming (east of Laramie Mountains) (Pleistocene to Miocene)-Giant granit	QTb	2
Brightly variegated bentonitic claystone and tuffaceous sandstone, grading laterally into greenish-gray sandstone and claystone. In and east of Jackson Hole contains gold-bearing lenticular quartzite conglomerate (formation age 49 Ma)	Sl	3
Sepulcher Formation-Andesitic and dacitic volcaniclastic rocks. Lamar River Formation-Andesitic lava and volcaniclastic rocks. Cathedral Cliffs Formation-Light-colored andesitic volcaniclastic rocks	Tai	1
Greenish-gray, olive-drab, and white tuffaceous sandstone and claystone; lenticular marlstone and conglomerate	Taw	1
Clasts of red quartzite, gray chert, and limestone in a gray to white tuffaceous sandstone matrix	Tbf	1
Upper 5,000 ft chiefly red conglomerate and red claystone; underlain by white tuff, limestone, claystone, and basal gray conglomerate	Tcc	2
Green River Formation-thrust belt-Buff laminated marlstone and limestone, brown oil shale, and siltstone. Includes Angelo and Fossil Butte Members; southwest Wyoming-Oil shale, light-colored tuffaceous marlstone, and sandstone. Wasatch Formation-thrust be	Tglu	2
Oil shale and marlstone	Tgrw	2
Green, brown, and gray tuffaceous sandstone, shale, and marlstone; contains evaporites in subsurface sections (age about 49 Ma)	Tgt	2
Wilkins Peak Member (age about 49 Ma)-Green, brown, and gray tuffaceous sandstone, shale, and marlstone; contains evaporites in subsurface sections. Tipton Shale Member or Tongue-Oil shale and marlstone	Tgw	2
Abundant gray limestone and dolomite clasts and sparse rhyolite and quartzite clasts in a talc and clay matrix	Tha	2
Red to variegated claystone, sandstone, and algal-ball (?) limestone; some beds of large Paleozoic boulders and detachment masses of Paleozoic and Mesozoic rocks	Tii	2

Description	Code	"geol_calc" score
Northwest Wyoming (Bighorn Mountains)-Gray soft poorly bedded to massive sandstone; central Wyoming-Tuffaceous sandstone, siltstone, and white marl	Tm	1
White, gray, and green limy tuff, siltstone, sandstone, and conglomerate	Tsi	1
White lacustrine clay, tuff, and limestone. In thrust belt includes conglomerate (formation age about 9 Ma)	Tta	1
New Fork Tongue-Dull-red and green mudstone, brown sandstone, and thin limestone beds, merging southward in T. 23 N. with other units. Fontenelle Tongue or Member-Oil shale, marlstone, limestone, and siltstone; occurs along Green and New Fork Rivers and o	Twdr	2
Wind River Formation-central Wyoming-Variegated claystone and sandstone; lenticular conglomerate. Age of tuff at top 49 Ma. Indian Meadows Formation-Red to variegated claystone, sandstone, and algal ball (?) limestone; some beds of large Paleozoic boulder	Twi	1

TOPOGRAPHY

Terrain generally influences distribution in an indirect manner. For example, slope, aspect, topographic position, and ruggedness all measure various facets of topography that can influence available site moisture at a fine scale. While there are a large number of potential predictor data layers that can be generated from a single, raster elevation dataset[15-18], a smaller set was identified that describes the most important characteristics of terrain and that have proven useful in previous modeling efforts (Table A1-7)[2, 19].

Table A1-7. Terrain predictor layers.

Variable	Raster Name	Units
A^1 (Transformed Aspect -- Southeast/Northwest Gradient)	"aprime135"	Index ranging from 0 (Northwest) to 2 (Southeast)
A^1 (Transformed Aspect -- North/South Gradient)	"aprime180"	Index ranging from 0 (South) to 2 (North)
A^1 (Transformed Aspect -- Southwest/Northeast Gradient)	"aprime45"	Index ranging from 0 (Southwest) to 2 (Northeast)
A^1 (Transformed Aspect -- West/East Gradient)	"aprime90"	Index ranging from 0 (West) to 2 (East)
Compound Topographic Index	"cti"	Ratio of the upstream catchment area to slope for each cell
Distance to Cliffs	"d2cliffs40"	Meters
Distance to Rock Outcrop	"d2outcrop"	Meters
Elevation	"elev"	Meters above sea level
Heat Load Index	"hli"	Scaled index where low to high values represent low to high heat loading
Degree Slope	"slope"	Degrees

Variable	Raster Name	Units
Topographic Position Index, using a 11-cell focal window	"tpi_11"	Unitless index where values above zero indicate hills or ridgetops, values below zero indicate valleys or depressions, and values near zero indicate flat or midslope areas
Topographic Position Index, using a 21-cell focal window	"tpi_21"	”
Topographic Position Index, using a 3-cell focal window	"tpi_3"	”
Topographic Position Index, using a 31-cell focal window	"tpi_31"	”
Topographic Position Index, using a 5-cell focal window	"tpi_5"	”
Vector Ruggedness Measure, based on a 11-cell focal window	"vrm11"	Unitless Index, where higher values indicate more rugged terrain
Vector Ruggedness Measure, based on a 21-cell focal window	"vrm21"	”
Vector Ruggedness Measure, based on a 3-cell focal window	"vrm3"	”
Vector Ruggedness Measure, based on a 31-cell focal window	"vrm31"	”
Vector Ruggedness Measure, based on a 5-cell focal window	"vrm5"	”

References

1. Beauvais, G. P., Andersen, M. D., and Keinath, D. A. (2012) Range, distribution, and habitat of terrestrial vertebrates in the 5-state Northwest ReGAP region. Report prepared for the USDI Geological Survey - Gap Analysis Program (Moscow, Idaho), University of Wyoming, Laramie, Wyoming.
2. Keinath, D., Andersen, M., and Beauvais, G. (2010) Range and modeled distribution of Wyoming's species of greatest conservation need, *Report prepared by the Wyoming Natural Diversity Database, Laramie Wyoming for the Wyoming Game and Fish Department, Cheyenne, Wyoming and the US Geological Survey, Fort Collins, Colorado*.
3. Bivand, R., Keitt, T., and Rowlingson, B. (2013) rgdal: Bindings for the Geospatial Data Abstraction Library, pp R package version 0.8-14.
4. R Core Team. (2013) R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing. Available at: http://www.R-project.org, Vienna, Austria.
5. Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., and Jarvis, A. (2005) Very high resolution interpolated climate surfaces for global land areas, *International journal of climatology 25*, 1965-1978.
6. Thornton, P. E., Running, S. W., and White, M. A. (1997) Generating surfaces of daily meteorological variables over large regions of complex terrain, *Journal of Hydrology 190*, 214-251.
7. Thornton, P. E., and Running, S. W. (1999) An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation, *Agricultural and Forest Meteorology 93*, 211-228.
8. Thornton, P. E., Hasenauer, H., and White, M. A. (2000) Simultaneous estimation of daily solar radiation and humidity from observed temperature and precipitation: an application over complex terrain in Austria, *Agricultural and forest meteorology 104*, 255-271.
9. Simley, J. D., and Carswell Jr., W. J. (2009) The National Map--Hydrography: U.S. Geological Survey Fact Sheet 2009-3054, 4p.
10. Service, U. S. F. a. W. (2013) National Wetlands Inventory., (Service, U. S. F. a. W., Ed.), Washington, D.C.
11. Chapman, S., Bryce, S., Omernik, J., Despain, D., ZumBerge, J., and Conrad, M. (2004) Ecoregions of Wyoming (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, *US Geological Survey (map scale 1: 1,400,000)*.
12. Franklin, J., and Miller, J. A. (2009) *Mapping species distributions: spatial inference and prediction*, Vol. 338, Cambridge University Press Cambridge.
13. United States Department of Agriculture -- Natural Resources Conservation Service. (2011) Soil Data Viewer 6.0 User Guide, United States Department of Agriculture -- Natural Resources Conservation Service,, Available online at http://soils.usda.gov/sdv/.
14. Love, J. D., and Christiansen, A. C. (1985) Geologic map of Wyoming, pp scale 1:500,000, 503 sheets, color, U.S. Geological Survey.

15. Moore, I. D., Grayson, R. B., and Ladson, A. R. (1991) Digital terrain modelling: a review of hydrological, geomorphological, and biological applications, *Hydrological Processes 5*, 3-30.
16. Gessler, P. E., Moore, I. D., McKenzie, N. J., and Ryan, P. J. (1995) Soil-landscape modelling and spatial prediction of soil attributes, *International Journal of Geographical Information Systems 9*, 421-432.
17. Evans, I. S., and Chorley, R. (1972) Spatial analysis in geomorphology, *General geomorphometry, derivatives of altitude, and descriptive statistics: Harper & Row, New York*, 17-90.
18. Gallant, J. C., and Wilson, J. P. (1996) TAPES-G: a grid-based terrain analysis program for the environmental sciences, *Computers & Geosciences 22*, 713-722.
19. Griscom, H., Keinath, D., and Andersen, M. (2010) Pocket Gopher Surveys in Southwestern Wyoming.