State Wildlife Grant (SWG)
FINAL PERFORMANCE REPORT

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF WILDLIFE CONSERVATION
PO Box 115526
Juneau, AK 99811-5526

Alaska Department of Fish and Game
State Wildlife Grant

GRANT NUMBER: C-SWG-1-2021 (F22AP00315)

PROJECT TITLE: Baseline biodiversity heat maps and climate correlates for Alaska's Species of Greatest Conservation Need

PERIOD OF PERFORMANCE: January 1, 2022 – May 31, 2024

REPORT DUE DATE: Due to FAC September 24, 2024

PRINCIPAL INVESTIGATOR: Dr. Andy Baltensperger

COOPERATORS: Dr. Nancy Fresco, Dr. Julie Hagelin, Ms. Tracey Gotthardt.

I. SUMMARY OF WORK COMPLETED ON PROJECT TO DATE.

OBJECTIVE 1: Create 1 database that compiles range information and conservation priority rankings for 3 taxonomic groups (birds, mammals, amphibians) representing all 268 terrestrial SGCN species in Alaska.

ACCOMPLISHMENTS: Complete. We successfully developed geodatabases for each of 3 taxonomic groups (7 amphibians, 159 birds, and 45 mammals), composed of species organized by conservation priority ranking. For each species we utilized range map shapefiles at the 12-digit HUC watershed scale developed by the Alaska Gap Project (AKGAP). In addition to compiling a set of all Species of Conservation Concern (SGCN), SGCN were organized within each geodatabase into 4 priority ranking groups (i.e., high, moderately high, moderate, and low conservation priorities) based on Alaska Species Ranking System (ASRS) final rank color categories in 2020 (i.e., red [I-II], orange [III-V], yellow [VII-VIII], and blue final [VI, VIII] color categories; Gotthardt et al. 2016). It should be noted that lists of species by final rank have changed somewhat since the completion of our database (accs.uaa.alaska.edu/wildlife/alaska-species-ranking-system). We also developed a sixth geodatabase of species in decline for bird species listed as declining by the Breeding Bird Survey (BBS) or Christmas Bird Count (CBC; (Alaska Department of Fish & Game 2015). Since there are now comparable authorities to identify Alaskan mammals in decline, we included species listed as endangered, threatened, vulnerable, near threatened, or petitioned for review by the U.S. Endangered Species Act (ESA; Alaska Department of Fish & Game 2015 Appendix A). We did not develop declining databases for amphibians, as such lists have not yet been developed for Alaska. Map development was limited to those 211 species listed in the ASRS and for which Alaska Gap Analysis Project (AKGAP) range maps were available. All species lists used in geodatabase development are available on the Scenarios Network for Alaska + Arctic Planning (SNAP) Data Portal.

OBJECTIVE 2: Create 1 application to compile 21 priority multi-species richness heat maps for groups of terrestrial, vertebrate wildlife SGCN to identify hotspots of terrestrial diversity across Alaska.

ACCOMPLISHMENTS: Complete. We developed a new workflow application that creates multi-species richness heat maps. The application sums HUC occupancy across species by converting shapefiles to rasters, extracting those values to the centroids of HUC polygons, and then spatially joining the presence or absence (1/0) of each species to their occupied HUC polygons. The result is a shapefile containing all of the 12-digit HUC polygons as records and fields denoting presence or absence for each of the species in the priority group considered, as well as additional HUC identifiers and attributes. We successfully created heatmaps for the 16 priority species groups for which data were available. The remaining priority groups contained no species. Overall species richness was highest in southcentral Alaska, especially on the Kenai Peninsula, around Prince William Sound, and throughout mainland Southeast Alaska (Fig 1a). The highest overall species richness (n = 126) occurred along some coastal areas Prince William Sound, and also exceeded 80% (n > 100) in small areas near Juneau and Haines, AK. The coastal region of Norton Sound also had high numbers of SGCN (n > 100).

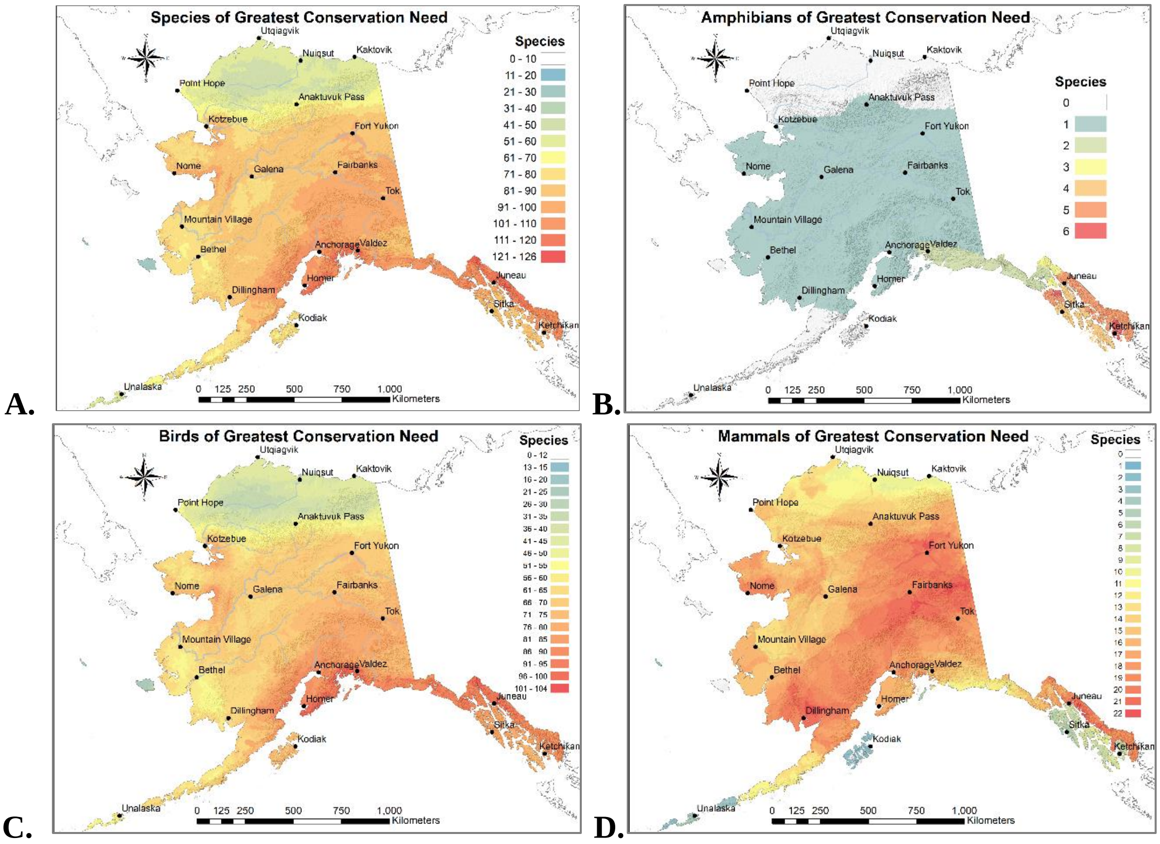
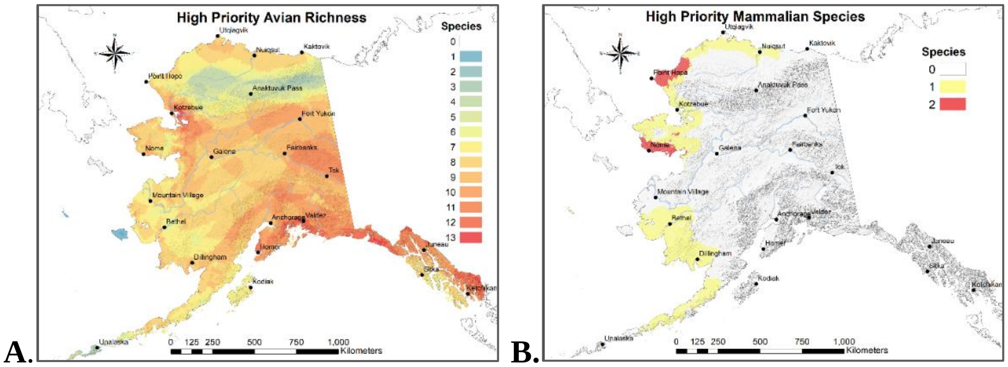


Fig 1. Species richness maps for all SGCN species (A), amphibians (B), birds (C), and mammals (D) resulting from Objectives 1 and 2.

Maps indicated that the highest amphibian species richness (n = 6) occurred in Southeast Alaska (Fig. 1b), with 60% (n = 5-6) of considered species occurred on the northern end of Sitka Island and in the region of Southeast Alaska surrounding Ketchikan. The highest richness for SGCN birds (n = 104) occurred in Southcentral Alaska (including the eastern Kenai Peninsula and Prince William Sound areas), northern Southeast Alaska, with 80% (n > 83) of considered species occurring along the Gulf of Alaska coastline and in one area of coastline in northeastern Norton Sound (Fig 1c). The highest species richness for mammals occurred along the southern Seward Peninsula and northwest Arctic coasts. Mammalian SGCN richness was highest (n = 15) across portions of eastern Interior Alaska, especially in the Upper Koyukuk River Valley, Yukon-Tanana Uplands, and in the central Alaska Range (Fig 1d).

Among the highest priority bird species, a maximum of 13 co-occurred in coastal areas near Seward and Whittier, AK, as well as in Norton and Kotzebue Sounds (Fig 2a). Other areas of high species richness among high priority bird species occurred along the Yukon and Kuskokwim Rivers of Interior Alaska. The lowest richness for high priority birds spanned the Brooks Range, where ≤ 4 species co-occurred (Fig 2a). Of the 3 high priority mammal species considered, just 2 co-occurred on the southern Seward Peninsula and northeast of Point Hope, AK (Fig 2b). We did not produce a map for high-priority amphibians since no amphibians qualified as high-priority.


High Priority Avian Richness

High Priority Mammalian Species

Fig 2. Species richness maps for high priority SGCN birds (A) and mammals (B) resulting from Objectives 1 and 2.

Five amphibian species were ranked as moderately-high priority and all of these co-occurred near Ketchikan (Fig 3a). Mainland and island Southeast Alaska included the ranges of 2-4 species, with only Wood Frogs occurring throughout mainland Alaska. Of the 23 moderately high priority bird species, a maximum of 16 species co-occurred along the Kenai Peninsula coast from Homer to Valdez, with another hotspot in the Glacier Bay region. High species richness also occurred in the Norton and Kotzebue Sound regions (Fig 3b). Thirty-three mammalian species were categorized as moderately high priority. A maximum of 16 of these co-occurred in mainland Southeast Alaska, eastern Interior Alaska, and Southwest Alaska near Dillingham. The lowest mammalian richness was found across the Alexander Archipelago and along the eastern Beaufort Sea Coast (Fig 3c)

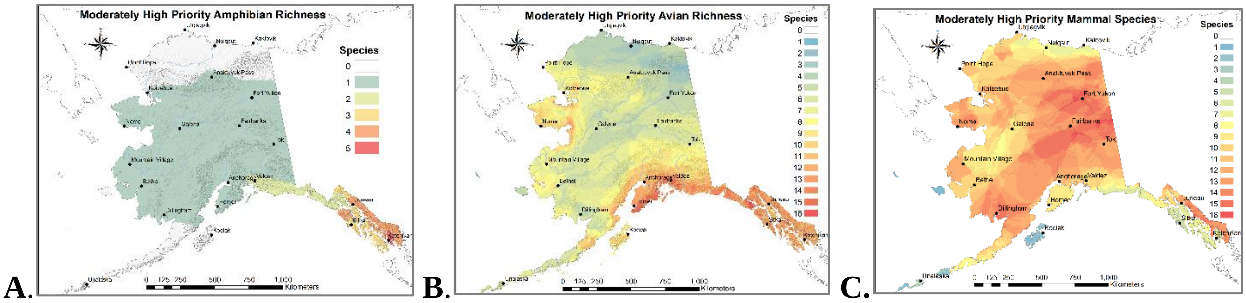


Fig 3. Species richness maps for moderately-high priority SGCN amphibians (A), birds (B), and mammals (C), resulting from Objectives 1 and 2.

Only the Roughskin Newt (*Taricha granulosa*) was categorized as a moderate priority amphibian. Its range encompasses most of Southeast Alaska (Fig 4a). Patterns for the moderate priority bird group were similar to the high priority avian SGCN and all avian SGCN richness maps, in that the highest numbers of species (n = 13) occurred on the Kenai Peninsula and in Prince William Sound, as well as along the coasts of Norton and Kotzebue Sounds (Fig 4b). Of the three moderate priority mammal species, Northern Bog Lemmings co-occurred with woodchucks in eastern Interior Alaska and with Steller's Sea Lions along the Gulf of Alaska coast (Fig 4c).

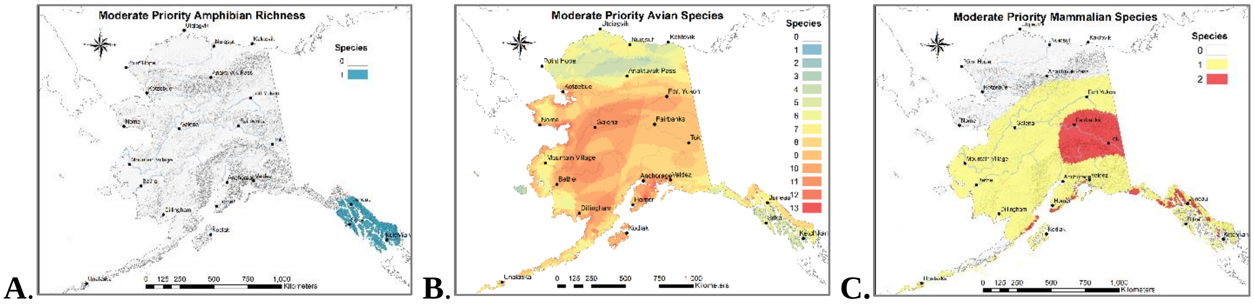


Fig 4. Species richness maps for moderate priority SGCN amphibians (A), birds (B), and mammals (C), resulting from Objectives 1 and 2.

Fourteen bird species were categorized as low priority species and a maximum of 13 species co-occurred in Southeast Alaska near Juneau, with high numbers also co-occurring west of Cook Inlet (Fig 5a). Of the 2 low priority mammal species for which we had data, Northern Red-backed Voles (*Mictomys borealis*) and Red Squirrels (*Tamiasciurus hudsonicus*) co-occurred across mainland Alaska south of the Brooks Range and mainland Southeast Alaska (Fig 5b). No amphibian species were categorized as low priority.

Among 41 species of declining birds, maximum species richness (n=38) occurred in mainland Southeast Alaska with richness exceeding 30 species in several areas of eastern Interior and Southcentral Alaska (Fig 5a). Species richness of declining birds decreased towards the north and west coasts of Alaska. Of the 4 declining mammal species, areas near Nome, Point Hope, and on the Alaska Peninsula contained a maximum of 2 species (Fig 5b). No amphibian species were deemed to be in decline.

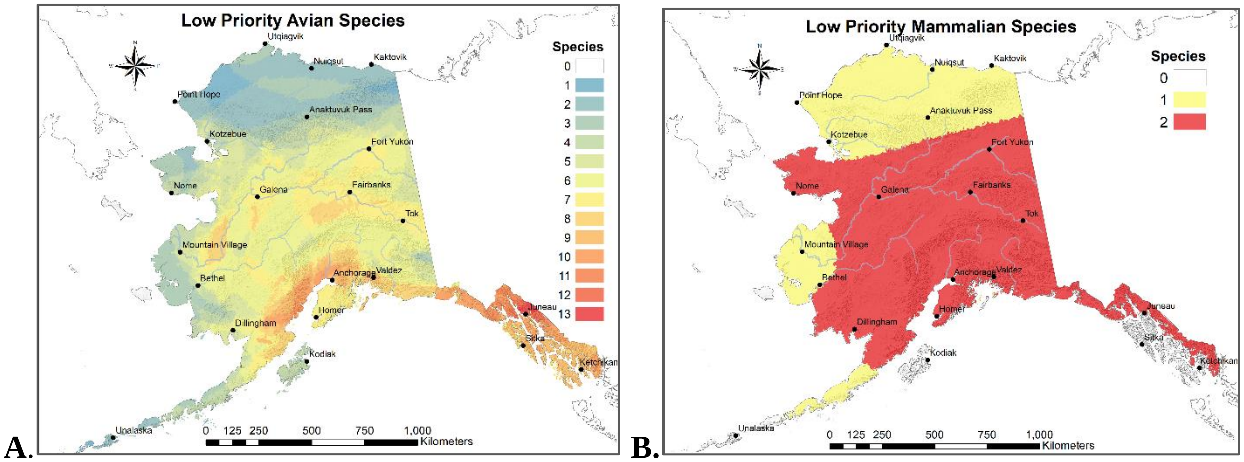


Fig 5. Species richness maps for low priority SGCN birds (A) and mammals (B) resulting from Objectives 1 and 2.

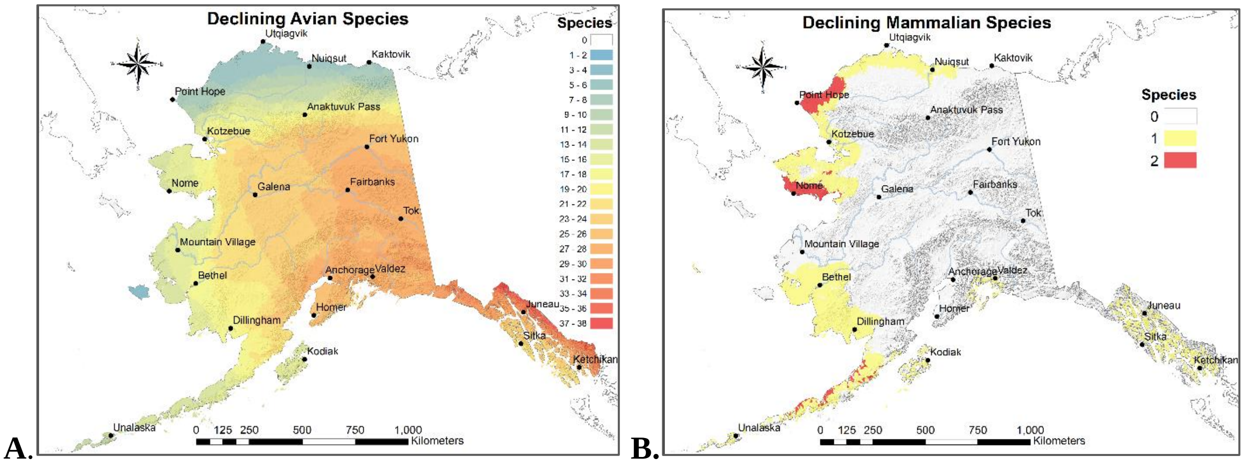


Fig 6. Species richness maps for declining SGCN birds (A) and mammals (B) resulting from Objectives 1 and 2.

Objective 3: Conduct 1 investigation that relates species richness hotspots from 21 multi-species maps with ≥ 12 environmental, topographic, and/or habitat predictors across Alaska.

Accomplishments: Complete. We delineated species richness hotspots by highlighting all HUCs containing more than 60% of considered amphibian species or 80% of the maximum number of co-occurring bird or mammal species. We related 24 environmental predictors (described in Table 1, below) to the species richness maps for all SGCN species and the high priority groups for amphibians, birds, and mammals, and extracted environmental attributes to the centroids of each 12-digit HUC. We used a randomForest analysis in R 4.1.1 to correlate environmental factors with the presence of high numbers of species for all SGCN species, Mammals, Birds, Amphibians. Species richness was insufficient for analyzing high priority mammals and amphibians. We also ranked the importance of environmental factors in predicting species richness hotspots and used partial dependence plots to visualize non-linear responses of important predictors.

We collected geospatial environmental data layers hypothesized to be important correlates of species richness for all taxa and priority groups. This list includes topographic, habitat, and climatic predictors downloaded from the SNAP data portal, and other in-situ geographic predictors (Table 1). We ran Spearman correlation dendrograms on the full SGCN dataset to quantify the correlative relationships among 24 predictors. Using a threshold of $\rho^2 = 0.7$, we identified 14 of the predictors as uncorrelated. We ran randomForests models using both the reduced (14) and full (24) predictor sets and found that the reduced set produced poorer performing models (i.e. higher mean square error) and so opted to use the more accurate models, which also allowed us to evaluate the full range of predictors, not only those that were uncorrelated.

Table 1. Environmental predictors that were related to 16 priority species maps, their abbreviations in models, their resolution, units, timeframe, and climate projection scenarios.

Predictors	Resolution	Units	Timeframe	Projection Scenario
Permafrost upper depth (pfrsttp)	1 km	m	2023	5ModelAvg_rcp8.5
Permafrost lower depth (pfrstbs)	1 km	m	2023	5ModelAvg_rcp8.5
Distance to mean March sea ice (seaice3)	1/4 degree	m	2022	Euclidian Distance to nearest concentration >0%
Distance to mean September sea ice (seaice9)	1/4 degree	m	2021	Euclidian Distance to nearest concentration >0%
Flammability (flmblty)	1 km	%	2023	5 Model average; RCP8.5_FMO
Snow Day Fraction January (snowdy1)	771 m	%	2020-2029	CCSM4 8.5
Snow Day Fraction July (snowdy7)	771 m	%	2020-2029	CCSM4 8.5
Mean Spring precipitation (prcpMAM)	771 m	mm	mean 2010-2019	AR5 rcp8.5 5-model average
Mean Summer precipitation (prcpJJA)	771 m	mm	mean 2010-2019	AR5 rcp8.5 5-model average
Mean Fall precipitation (prcpSON)	771 m	mm	mean 2010-2019	AR5 rcp8.5 5-model average
Mean Winter precipitation (prcpDJF)	771 m	mm	mean 2010-2019	AR5 rcp8.5 5-model average
Mean Spring temperature (tempMAM)	771 m	degrees	mean 2010-2019	AR5 rcp8.5 5-model average
Mean Summer temperature (tempJJA)	771 m	degrees	mean 2010-2019	AR5 rcp8.5 5-model average
Mean Fall temperature (tempSON)	771 m	degrees	mean 2010-2019	AR5 rcp8.5 5-model average
Mean Winter temperature (tempDJF)	771 m	degrees	mean 2010-2019	AR5 rcp8.5 5-model average
Date of Freeze (dof)	771 m	days	2020-2029	AR5 rcp8.5 5-model average
Date of Thaw (dot)	771 m	days	2020-2029	AR5 rcp8.5 5-model average
Length of Growing Season (logs)	771 m	days	2020-2029	AR5 rcp8.5 5-model average
Distance to treeline (treelin)	771 m	m	2015	Euclidian Distance to AR5/CMIP5
Distance to coast (coast)	771 m	km		Euclidian Distance to 1:63k Coastline
Elevation (dem)	300 m	m		
Latitude (coords.x2)	6 decimals	degrees		
Longitude (coords.x1)	6 decimals	degrees		

RandomForests models were accurate in predicting species richness based on underlying environmental conditions for All SGCN Species, and for each taxonomic class of SGCN species (Table 2). Models for All SGCN species, SGCN Amphibians, and SGCN Birds were highly accurate ($r^2 > 90.0\%$), and able to predict well to the patchy distributions of high numbers of species. The SGCN Mammal model was somewhat less accurate indicating a more even distribution of species across the state, which was not as useful in discerning important environmental predictors for mammalian richness.

Table 2. The number of species used in each randomForests model and the performance metrics used to evaluate them. n = maximum number of species considered, MSE = Mean Square Error, r^2 = % variance explained.

Model	n	MSE	r^2
All SGCN Species	212	32.16	91.39%
SGCN Amphibians	7	0.004	94.54%
SGCN Birds	160	14.12	94.75%
SGCN Mammals	45	65.35	65.95%

Among these top five model predictors, only March Sea Ice Proximity and Longitude were correlated with each other beyond $\rho^2 = 0.7$ (Fig. 7). RandomForests ranked the relative importance of environmental predictors in the models for each taxonomic group, with the same predictors repeatedly appearing among the most important (e.g., Latitude, Longitude, Treeline Proximity, Coast Proximity; Fig. 8). In the All SGCN model, March Sea Ice was the 4th most important predictor, whereas Mean Summer Precipitation was among the top 5 predictors in the other 3 models (Fig. 8). Partial dependence plots show the non-linear, predicted responses of the top model predictors across their range of values, while controlling for other predictors in the model (Fig. 9). Good predictors of all SGCN species richness were environments of intermediate latitudes, greater longitudes, close proximities to latitudinal treeline and the coast, and intermediate proximity to the sea ice extent in spring (Fig. 9).

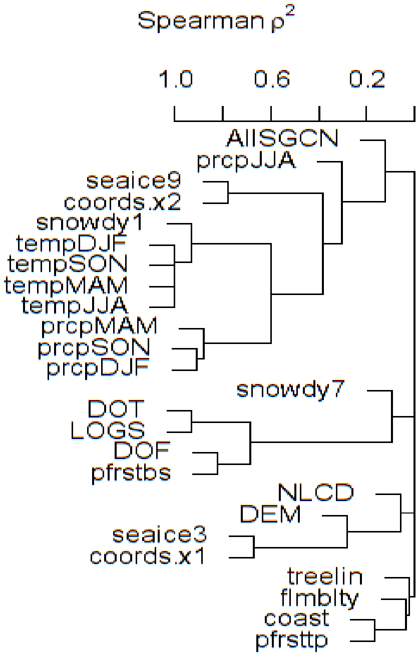


Fig 7. Spearman correlation matrix illustrating degrees of correlation between 24 environmental predictors and overall species richness for All SGCN Species. This figure indicates the correlative relationships among model predictors (Fig. 7). Only March Sea Ice (seaice3) vs. Longitude (coords.x1) and September Sea Ice (seaice9) vs. Latitude (coords.x2) had Spearman correlations (ρ^2) greater than our threshold of 0.7, supporting the independence of most predictors and some small redundancies among the models' top predictors.

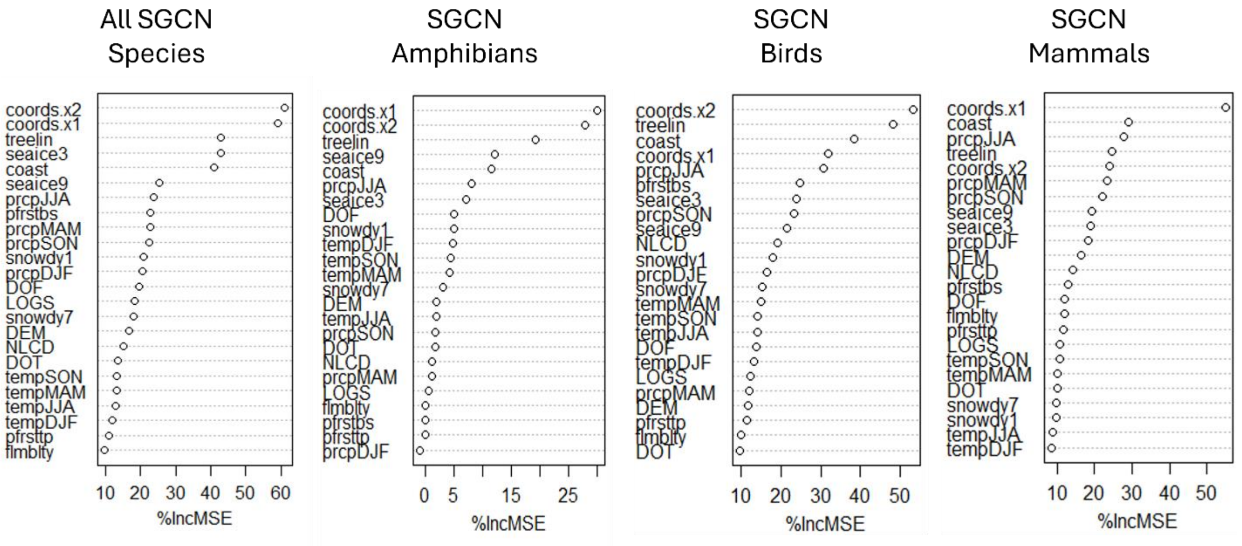


Fig 8. Relative predictor importance rankings (based on mean square error; MSE) for each of the 24 environmental predictors included in 4 species richness category models. See Table 1 for predictor abbreviation definitions. Latitude (coords.x2), Longitude (coords.x1), Proximities to Treeline (treelin) and the Coast were among the top predictors in all models. Distance to Sea Ice in March (seaice3) and in September (seaice9) were also important predictors in the All SGCN and SGCN Amphibian models, respectively, whereas summer precipitation (prcpJJA) was also important in the SGCN Bird and SGCN Mammals models.

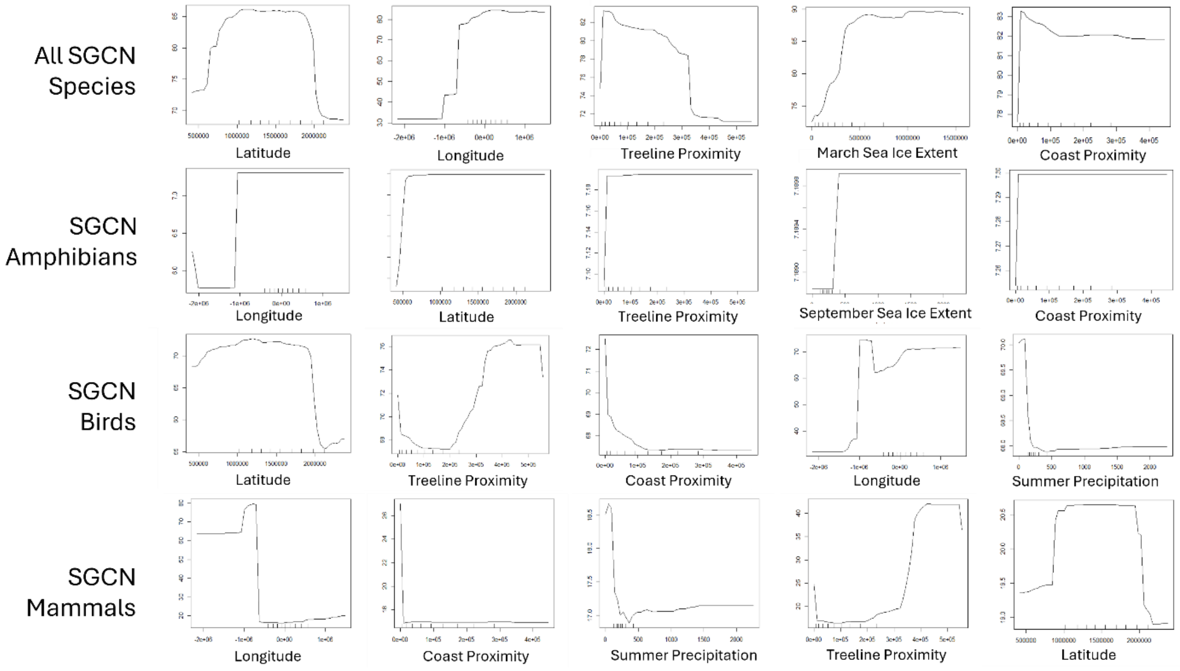


Fig 9. Partial dependence plots show the non-linear response of the top five predictors across their range of values in each model, while simultaneously controlling for other predictors in the model. Larger index values on the y-axis indicate stronger positive correlations with the predictor for the range of values indicated on the x-axis.

II. SIGNIFICANT DEVELOPMENT REPORTS AND/OR AMENDMENTS.

During the reporting period of 01/01/2024 – 05/31/2024, the grant period of performance was extended to 05/31/2024 to map terrestrial species richness in Alaska. One cooperator, Heather McFarlane, ended participation with this project, because she accepted a new position. Dr. Nancy Fresco was added, so that all objectives could be completed on schedule.

III. PUBLICATIONS

Under guidance from Dr. Fresco, SNAP personnel have quality-checked and archived shapefile datasets (with metadata) for 16 species richness map products. These datasets are publicly-available on the SNAP data portal.

IV. REVIEW OF PRIOR RESEARCH AND STUDIES IN PROGRESS ON THE PROBLEM OR NEED

Heat maps (of any taxonomic group) for Alaska are rare in the literature (e.g., small mammals; (Baltensperger 2015), and Alaska's 2015 State Wildlife Action Plan (SWAP) lacked any comprehensive effort to map and identify geographic biodiversity hotspots for terrestrial bird and mammal SGCN statewide (ADFG 2015 Appendix B). Our project combined two existing information sources to create statewide multi-species heat maps. First, we used species-specific range maps created previously by the AKGAP program (Gotthardt et al. 2014). Second, species were grouped by four conservation priority levels using the existing Alaska Species Ranking System (ASRS; Gotthardt et al. 2016; Droghini et al. 2022) which quantifies status, threats, and vulnerabilities of individual species in the state.

The heatmaps generated from this project will now provide valuable and spatially explicit information to inform conservation and management within the 2025 SWAP revision. Our work also provides an initial analysis that identified several environmental factors (i.e., latitude longitude, proximities to treeline, coast, and sea ice) as important predictors of terrestrial species richness in Alaska. We recommend further research on species occurrence, community richness, genetic patterns (e.g. genoscapes, isolated island endemics) and environmental drivers of diversity across Alaska's landscape. Combined, these data will inform efforts to better manage Alaska's biodiversity, reverse species decline, and open opportunities that leverage natural climate solutions.

This project was completed on May 31, 2024.

Prepared by: PI Dr. Andy Baltensperger
Date: 9/17/24

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