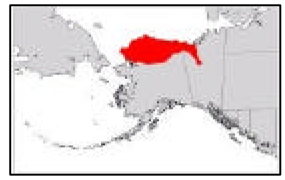
Alaska - Yukon Arctic Ecoregional Assessment
Update #10: Decision Support Tool



Introduction

The goal of the Alaska-Yukon Arctic ecoregional assessment is to integrate the best available information about the distribution of species and ecological systems of the region to identify the lands and waters most necessary to sustain the ecoregion's biodiversity. The assessment is a rigorous analysis employing thousands of pieces of detailed information. We analyzed ecological data using a decision support tool, known as SITES. We used SITES to integrate four basic approaches to conservation planning:

1) *Representation:* Ensure that a broad spectrum of environmental variation, or each major ecosystem type, is represented (e.g., vegetative, abiotic, and freshwater and marine habitat classes).
2) *Special elements*: Focus on rare or at-risk communities, rare physical habitats, concentrations of species, locations of at-risk species, and locations of highly valued species or their habitats.
3) *Focal species*: Include species that require large areas or several well-connected areas (e.g. caribou) or are sensitive to human disturbance (e.g. polar bear).
4) *Efficiency*: Seek low-cost areas of high species richness, while meeting the objectives of representation. Meet the first three objectives in the least area possible.

This update describes the decision support tool and provides the results of two different approaches to analyzing the ecological data using SITES: ***representation*** and ***relative biodiversity***. The first analysis, representation, uses SITES to integrate the four approaches listed above. The second, relative biodiversity, provides additional information for making conservation decisions by indicating relative species richness across the ecoregion.

Overview of the Decision Support Tool

The large number of conservation targets and the large size and diverse types of data sets (see Updates #2-6) describing elements of this study required the use of a systematic, flexible, and efficient site selection procedure. We used the site selection software SITES[1] to aid our analyses. SITES operates as "an analytical toolbox for designing ecoregional conservation portfolios" (Andelman et al. 1999) and results can be displayed with Geographic Information Systems. Thus, SITES results are 'solutions' to questions (asked in the form of SITES parameters) that can be displayed on a map.

[1] SITES (v1.0) was developed at the University of California, Santa Barbara, under a contract to The Nature Conservancy. For more information about SITES, go to www.conserveonline.org

SITES Parameters

Several adjustable parameters influence SITES outcomes. A brief description of some of these parameters follows:

Planning units: Distribution data for all targets (including ecological systems, special elements, and focal species) are assigned to planning units. We divided the ecoregion into approximately 10,000 hexagons for terrestrial and marine data and nested watersheds[2] for freshwater information. Each hexagon is 5,000 hectares in size. Because these two types of planning units are coincident (occur in the same space), we defined an explicit relationship between them to allow SITES to analyze them simultaneously. SITES results are expressed as configurations of planning units.

Boundary length: Boundary length defines the relationship between adjacent and coincident planning units. The value of the boundary length can be modified to favor certain relationships. For example, watersheds up/down stream of each other may be assigned low boundary lengths to favor their mutual selection, while watersheds on either side of a ridge may be assigned higher lengths since there is little ecological relationship between them. SITES calculates the perimeter of selected planning units to assess the efficiency of its solution.

Goal: Quantitative and spatial conservation goals are set for each target as the basis for selecting whether a planning unit is in or out of the solution. A goal's quantitative component defines the number of target occurrences or percent of total distribution necessary to adequately conserve the target in the ecoregion (e.g., 8 seabird colonies). A spatial component describes how target occurrences should be distributed across the ecoregion (e.g., 2 colonies in each of the 4 subregions containing colonies). Goals have a large influence on the outcome of SITES runs.

Species penalties: Species penalty is a 'cost' imposed for failing to meet target goals. These penalties determine whether or not SITES gives priority to meeting goals for some targets (species and systems) over others. Efficiency may be reduced if the species penalties are high.

Cost: The cost of conservation may be uniform for all planning units, or it may be based on a Cost Suitability Index that integrates economic, socio-political, and biological factors to identify areas of least conservation cost[3]. In this ecoregion, the decision to use equal or variable costs has a large influence on the outcome of SITES runs.

Boundary modifier: The boundary modifier influences the degree to which SITES tries to choose adjacent planning units; a larger boundary modifier will increase "clustering" and efficiency in the solution.

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[2] See *Update #4: Freshwater Ecosystem Model* for a discussion about nested watersheds.

[3] See *Update #9: Cost Suitability Index* for a discussion of the 'costs' of conservation and how they were incorporated into a Cost Suitability Index.

Optimizing the Solution

SITES uses an algorithm called "simulated annealing with iterative improvement" as a heuristic method for efficiently selecting regionally representative sets of areas for biodiversity conservation (Pressey et al. 1996; Csuti et al. 1997; Possingham et al. 1999). It is not guaranteed to find a solution, which is prohibitive in computer time for large, complex data sets such as ours. Rather, the algorithm attempts to minimize 'costs' while maximizing attainment of conservation goals in a compact footprint. To do this, SITES attempts to minimize total cost by selecting the fewest planning units and smallest overall area needed to meet as many target goals as possible, including stratification goals (see below), and by selecting planning units that are clustered together rather than dispersed. SITES accomplishes this task by calculating the "objective function:"

Objective Function = *Cost* + *Species penalty* + *Boundary length*

To minimize the objective function, SITES selects different planning units and re-evaluates the function through multiple iterations. For example, we tasked SITES with 5 million iterations in a single run to find one minimum function solution, and we repeated this 10 times to produce a single summed solution.

Alternative scenarios can be evaluated by varying the three components of the objective function or by modifying other controls, such as the boundary modifier or goals. In addition, planning units can be "locked" in or out of the solution to analyze how well goals are met. The power of SITES lies in its flexibility to create many alternatives depending on inputs. Like other models, it is best used to inform, analyze, and refine questions, rather than to provide a single solution.

Stratification

To account for adequate representation of variation across the ecoregion and to maintain adequate separation distances between target occurrences in case of stochastic events such as disease or catastrophic disturbance, the ecoregion was stratified into 31 subregions, including 8 freshwater, 11 terrestrial, and 12 marine subregions. The 8 freshwater subregions, called Ecological Drainage Units, are broad-scale hydrologic units in the ecoregion.[4] Delineation of 11 terrestrial subregions was the result of merging the Unified Ecoregions of Alaska (Nowacki et al. 2001) with the ecological drainage units[5] (see Figure 1). The 12 marine subregions were differentiated primarily by variations in bathymetry, ocean currents, sea ice, and salinity.

Goals for targets are set for the entire ecoregion (an overall goal) as well as for subregions in which the target occurs. For example, a goal for a fish species may be set for ecological drainage units where the fish occurs while goals for caribou herds were set for the terrestrial subregions in which they occur. Because goals were set for multiple life stages for some species (e.g. caribou calving areas, insect relief areas), the SITES algorithm had to simultaneously account for 350 ecoregion-wide goals and 1,224 subregional goals for the Alaska-Yukon Arctic ecoregion.

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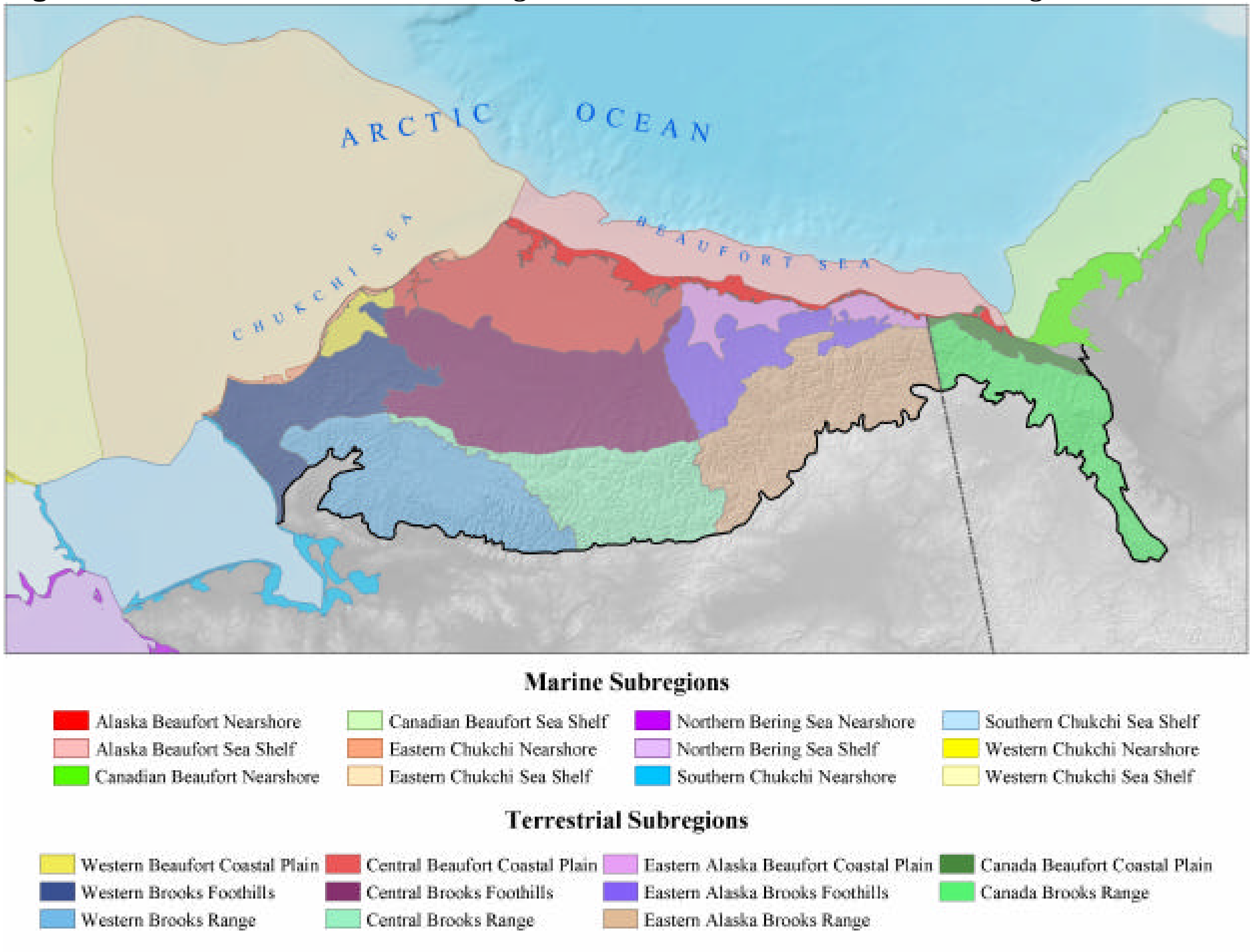
[4] See *Update #4: Freshwater Ecosystem Model* for a map of the ecological drainage units.

[5] The Unified Ecoregions of Alaska were labeled "subregions" in previous updates for analyses across broad environmental gradients. The terrestrial subregions shown in this update were used to set conservation goals, thus ensuring adequate representation of targets and habitats across the ecoregion.

Figure 1. Terrestrial and Marine Subregions of the Alaska-Yukon Arctic Ecoregion



Analyses: Representation and Relative Biodiversity

Representation and relative biodiversity are two approaches to analyzing ecological data in SITES. Representation analysis offers insights to the question: What is the minimum area—and where is it—that we must manage for conservation if we wish to conserve a viable representation of the ecoregion's biodiversity? Relative biodiversity analysis helps us understand the relative contribution of each planning unit to the total area available for the conservation of each conservation target. Both approaches are relevant to decisions about conservation and should be considered together, along with irreplaceability analysis and identification of critical habitat for vulnerable species, to arrive at robust and realistic conservation decisions.

The representation and relative biodiversity results presented below are meant to illustrate the two analyses, not provide a definitive conservation design. The best conservation decisions will be made using these tools and data collaboratively with stakeholders and decision makers in the Alaska-Yukon Arctic.

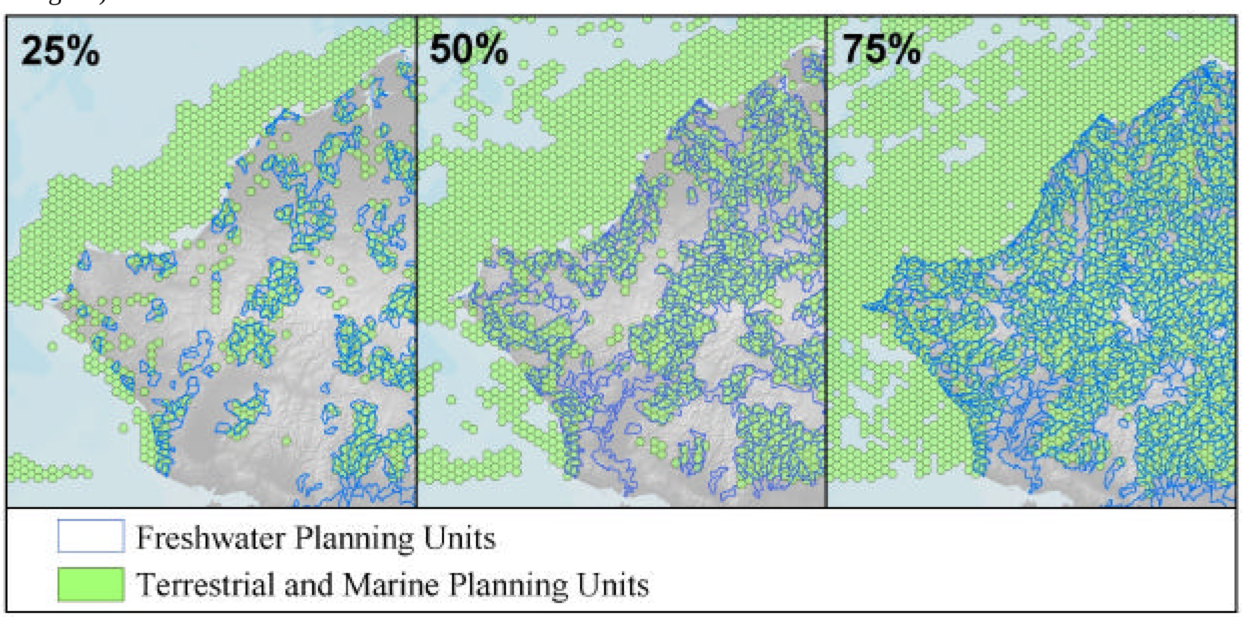
Representation Analysis

Representation analysis is designed to select the most efficient combination of planning units that will integrate the four planning approaches mentioned earlier: representation of environmental variation, focus on special elements, conservation of habitat for focal species, and efficiency in footprint and cost. The analysis requires setting multiple parameters, each of which affects the outcome.

The two parameters that influence the outcome most are goals and costs. Establishing conservation goals is a process rooted in the most difficult—and most important—scientific questions in biodiversity conservation (i.e., How much area, habitat, populations, etc. are enough to ensure the long-term viability of native species and ecosystems?). As some have pointed out (e.g. Noss and Cooperrider 1994, Soule and Sanjayan 1998), these questions cannot be answered by theory alone, but require an empirical approach, target-by-target, and a commitment to monitoring and continual re-evaluation over the long-term. Appropriate guidelines for setting costs and quantitative and spatial goals are sparse in intact ecoregions like the Alaska-Yukon Arctic. Although more work needs to be done on these topics, we can move forward with analyses using best available information as placeholders.

Figure 2 represents three examples of representation analyses where all parameters are held constant except for the quantitative goal. Here, SITES was run using goals of 25, 50, and 75 percent of the total distribution of each conservation target. The three images represent the best solutions of 10 runs of 5 million iterations each. In these examples, goals were met for most targets. For instance, in the 50% run, all targets met the assigned overall ecoregional goal of 50%, but subregional distribution goals for 10 of the 200 ecosystem targets were not met; capturing them would have increased the 'cost' of the solution beyond an acceptable objective function value. Although SITES identified these three solutions as the most optimal for the given parameters, these combinations of planning units may not contain the best examples of habitat. Results such as these require expert review and are simply the starting point for collaboratively building realistic and robust conservation designs.

Figure 2. Example of 3 SITES analyses with variable representation goals
(goals = 25%, 50%, or 75%; boundary modifier = 0.01; costs based on Cost Suitability Index; all species penalties = 1.0; boundary length = actual length between planning units and explicit relationship between watersheds and hexagons)

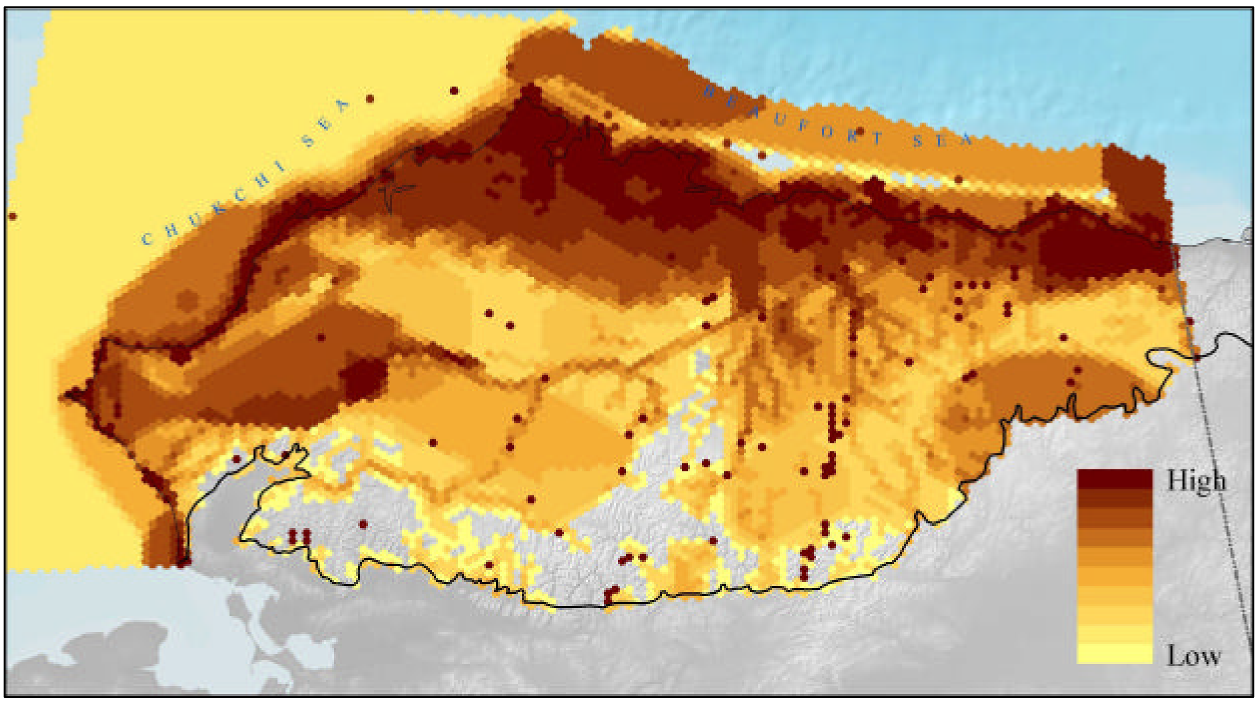


Relative Biodiversity

Relative biodiversity is an index that indicates the relative contribution of each planning unit to the total distribution of each conservation target. When relative biodiversity indices (RBI) for all targets are combined, the result approximates species richness, as species that are coincidentally distributed in a planning unit are added up. The relative biodiversity index may also be thought of as a surrogate for irreplaceability, since the index highlights planning units that carry a disproportionate share of the distribution of a target; such planning units are likely to be in any SITES solution in order to meet a target's goal and thus may be considered irreplaceable. RBIs, therefore, combine perspectives on richness (overlapping ranges) and irreplaceability (higher-density distributions).

Figure 3 depicts the result of combining relative biodiversity indices for each of the four major taxonomic groups of fine filter targets – birds, marine mammals, terrestrial mammals, and vascular plants. The RBIs for each group were normalized and then summed. In Figure 3, the darker colors represent areas of high overlap of target species distribution (approximating species richness) as well as areas that contribute heavily to the overall distribution of targets. Areas on the map that are not colored (gray areas) are not devoid of species; we were simply unable to find or incorporate spatial data for fine filter targets in these areas into the assessment. It is important to remember that the RBI does not reflect the condition of the landscape (e.g., ownership, extent of development) within a planning unit.

Figure 3. Relative Biodiversity Index for All Fine Filter Conservation Targets



The representation and relative biodiversity analyses are complementary approaches to identifying a network of lands and waters that might sustain the ecoregion's biodiversity in the long-term. While representation analyses emphasize inclusion of a portion of all biodiversity across a stratified environmental gradient, the RBI draws attention to specific areas that contribute disproportionately to a robust conservation network design. Together, they provide a scientific starting point for making wise decisions about the ecological future of the Alaska-Yukon Arctic.

Limitations of the Decision Support Tool

SITES provides a systematic, flexible, and efficient tool for comprehensively analyzing complex data to support sound, science-based conservation decisions. It is an ideal tool for collaboration among stakeholders, since inputs and parameters are easily adjusted for comparison of outputs. As with any tool, there are limitations to the use of SITES. The most basic limitation is, of course, related to inputs. It is critical to have the best available comprehensive spatial data on the ecoregion's ecological features. We have amassed dozens of datasets from various sources to support our analyses, but additional collaboration with and review by experts in the region could yet improve quality and quantity of the data.

To use SITES effectively, it is important to understand the influence and interactions among its parameters, since changes in the values of the parameters can dramatically affect the results. For example, a small increase in the boundary modifier can greatly increase how strenuously SITES attempts to select adjacent planning units, possibly affecting the objective function and making the result less efficient or more costly. The three components of the objective function must be balanced to prevent one from controlling how SITES selects planning units.

Technical limitations to the effective use of SITES are few; understanding the software program and conservation design theory, and being familiar with the strengths and weaknesses of input data present greater challenges. As a decision-support tool, the appropriate application of SITES is to inform decision-making, rather than to provide a single, unassailable answer to questions of conservation.

Conclusions and Next Steps

SITES is a powerful tool for comprehensively analyzing spatial ecological data to identify lands and waters most necessary to sustain the ecoregion's biodiversity. It can support various planning approaches, including representation and relative biodiversity analyses, generating science-based "working answers" to the questions about conservation design. The tool will be most effective if stakeholders collaborate to produce visions of the future. Together, we have the opportunity in the Alaska-Yukon Arctic to "do things right the first time"—intentionally working to conserve biodiversity as we explore other uses of the land.

This update is meant to introduce the decision support tool by presenting the results of several approaches to analyzing ecological information. Other analyses are possible and desirable for informing conservation decisions in the Alaska-Yukon Arctic. Suggestions for further analyses include:

- *Additional representation analyses*: The representation analysis should be repeated using variable goal levels, goal levels appropriate for each target, and with and without conservation costs. Varying these parameters will indicate the sensitivity of the analysis to the input data and parameter values.

- *Forecast scenarios*: SITES can be used to examine "what if" scenarios for future or potential changes due to human activities. For example, climate change models could be incorporated to influence how SITES selects planning units.[6] We could also examine effects of changes in land management on conservation design. For instance, would a new road cause SITES to shift its optimal design? What might be some consequences of removing existing protection from the area around Teshekpuk Lake?
- *Seasonal designs*: Because the Alaska-Yukon Arctic ecoregion undergoes extreme seasonal fluctuations, "seasonal conservation designs" might be useful for identifying seasonally important areas.
- *Target-by-target analysis*: It could be useful to examine results from individual species or species groups to assess how their habitat needs are represented individually in comparison to comprehensive results.
- *Irreplaceability*: An irreplaceability analysis could help assess the potential consequences of development on mitigation opportunities. Would there be other acceptable places to conserve certain species, or are there places on the landscape that contain the only known occurrences of certain species, thus are "irreplaceable?"

The above list suggests several analyses that can be performed by The Nature Conservancy and its partners to help us identify the lands and waters most necessary to sustain the ecoregion's biodiversity. The combination of ecoregional data, advanced conservation design tools (e.g., SITES), scientific expertise, and perspectives of local residents, land managers, and other stakeholders provides a potent opportunity to make sound decisions about the balance between conservation and resource development. As the development footprint in the Alaska-Yukon Arctic ecoregion expands, it is incumbent on all stakeholders to use the best information and tools available to meet our responsibility to pass along the biodiversity values we enjoy today to future generations.

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[6] See Update #7: Environmental Change Model

Contacts

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Previous Updates on the Alaska-Yukon Arctic Ecoregional Assessment

Update #1: Project Description
Update #2: Predictive Terrestrial Ecosystem Model
Update #3: Gap Analysis of Terrestrial Ecosystems
Update #4: Freshwater Ecosystem Model
Update #5: Conservation Targets
Update #6: Coastal Ecosystem Model
Update #7: Environmental Change Model
Update #8: Assessment Limitations and Data Gaps
Update #9: Cost Suitability Index

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The Nature Conservancy

The Nature Conservancy is an international non-profit conservation organization that seeks to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. Ecoregional assessments employ a science-based approach to evaluate the biodiversity significance of landscapes. For the Alaska-Yukon Arctic, our goal is to gather sufficient information to identify areas of biological significance, evaluate current and potential stresses to biodiversity, and develop appropriate and constructive conservation strategies to ameliorate threats in special areas.