Crown of the Continent
Landscape Conservation Design

Phase One Technical Report

Contents

Finn, S., N. Poremba, P. Matson, M. McFadzen, A. Douglas, M. Heller. 2021. Crown of the Continent Landscape Conservation Design Phase 1 Technical Report. Crown Managers Partnership. 24 July 2021.

Introduction

The Crown Managers Partnership (CMP) is coordinating the Crown of the Continent Landscape Conservation Design (LCD) process to help land managers collectively achieve landscape-scale ecological objectives while working within agency and organizational jurisdictions and mandates. By bringing stakeholders together, the LCD provides the opportunity for land managers to prioritize and coordinate actions on the ground.

Representing 42 stakeholder entities across 31,000 sq km (50,500 mi^2) in Montana, Alberta, and British Columbia, we are developing spatial designs for 15 priority landscape features. Spatial design integrates stakeholder and subject matter expert knowledge and objectives of resource management plans with broad data sets to generate spatial optimization models and maps.

Ultimately, the spatial designs will be supported with priority strategies that link local and agency actions and resources through a road map. The road map will describe how we can achieve expressed desired conditions, and ultimately, our vision for the Crown: *Ensuring a resilient, connected landscape that supports healthy ecosystems and human communities*.

This report summarizes the progress made by the Analysis Team on the spatial design step of the LCD Phase One. It describes a pilot effort of the spatial design process for 13 of the 15 priority ecological features (Finn et al. 2020) including the goals of optimization modeling, the data resources and scoring method used for model building, the steps for modeling each landscape feature, and conclusions and lessons learned from the process. The Phase One pilot was intended to test the process, software, data inputs, manipulations and management, and our ability to generate useful outputs. Phase One process did not generate meaningful ecological models, thus all optimization outputs (maps) displayed below include the caveat: “Draft: Please do not cite or distribute”. We feel this test of the process was successful and Phase Two objectives include co-production of relevant optimization models grounded in vetted data and expert knowledge. This report is part of the LCD project’s ongoing effort to be transparent and inclusive. Questions and comments may be directed at the lead author or by participating in the LCD Leadership Team or Technical Team.

Goals of Optimization Modeling and its Role in Conservation Design

Using ecological features selected by the Leadership Team, we initiated a process leading to sets of optimization models describing conservation opportunity in the Project Area. We used Marxan, a decision support tool designed to aid in the spatial planning of human uses and protected areas on land and at sea (Ball et al. 2009). Marxan is primarily intended to solve the 'minimum set problem', a particular class of reserve design problem. In general, our goal is to identify where we may capture a minimum representation of biodiversity for the smallest possible cost (McDonnell et al. 2002) that can serve Crown managers and decision-makers as we expand a reserve network across the ecosystem. The rationale is that cheaper or less socially disruptive reserve networks are more likely to be implemented (Game and Grantham 2008). Given reasonably comprehensive data on species, habitats and/or other relevant biodiversity features, Marxan aims to identify the reserve system (a combination of planning units) that will meet user-defined biodiversity targets for the minimum "cost" (Ball and Possingham 2000; Possingham et al. 2000).

For Phase One analyses, we advanced on that goal by understanding the source data we could access; qualitatively evaluating that data and converting it to a standard currency required by Marxan; and, generating raw outputs that serve as proof of concept – not useful spatial optimization models, which come later in the process.

Data Resources

There are two broad categories of datasets required to complete Phase One: 1. data which describe where focal features are located on the landscape, and 2. data that describe where on the landscape a focal feature may be negatively impacted.

To address the former data need, we discovered and acquired data describing confirmed observations of focal features, modeled probability of occurrence and/or estimates of spatial suitability for the focal feature, or inferential models that correlate key life history requirement(s) for the feature. These data were compiled with guidance from Montana, British Columbia, and Alberta data managers (the LCD Technical Team). We identified approximately 97 source data layers as potential descriptors of our focal ecological features. For the Phase One analysis we used 60 input data sources describing the 13 ecological features (we did not identify sufficient data for 'riparian' and 'ecological connectivity' and did not include those features in this assessment).

Throughout Phase One modeling, we incorporated only one "cost/resistance layer," which represents elements on the landscape that may negatively impact a focal feature. We did this to simplify our feature data evaluations and better understand and assess the feature data with greater clarity before incorporating more complexity in the model. The cost data layer used in Phase One models for all focal features was the Global Human Modification Index developed by Kenedy et al. (2020). This index includes both the footprint and intensity of multiple direct anthropogenic-sourced threats, such as roads, housing, extractive industries, etc. Phase Two will incorporate additional cost layers that are fine tuned to each focal feature individually.

General Data Handling and Scoring for Marxan

Having a complete understanding of the limitations of the data allows one to minimize propagation of error and more accurately assess the validity of results from the analysis. Spatial, temporal and representational consistency were considered (Alidina et al. 2008). We evaluated data in terms of the broader goals and objectives of the Design (biodiversity conservation, socio-economic benefits) and evaluated data related to its quality and extent.

We used ArcGIS desktop (v. 10.8.1) to define planning units, assemble and review data describing conservation features, and calculate how much of each feature is located within each planning unit. We selected a 2 km^2 hexagon planning unit as a trade off among processing speeds and relevance to management planning. We then displayed and evaluated source data feature-by-feature to understand what each dataset and associated metric represented and to evaluate if metrics met our objectives.

We devised a standard scoring process where a score of 10,000 indicated a planning unit was highly suitable for a given feature and a score of 0 (zero) was completely unsuitable. Analysts were given the liberty to score source data at levels between 10,000 and 0 based on their evaluations. Extensive processing notes were recorded for each input dataset and processing step (see Appendices). This produced 13 synthetic data layers (one for each ecological feature evaluated) ready for Marxan optimization runs.

We initiated modeling for each feature independently (see feature sections, page 8) to ensure input-output processing was true to expectations, to visually evaluate single feature Marxan outputs based on our knowledge of the ecosystem, and to adjust the Feature Representation Target (FRT). This parameter defines the amount of the feature to be included in potential solutions generated by Marxan. For Phase One, we consistently set FRT at 30% and 70% (i.e., two model runs) for every feature. These values, and our consistent use of them across all features is not likely to produce meaningful output ecologically; however, consistency at this testing stage allowed us to gain a deeper understanding of the relative value of the broad array of source datasets and to observe how the software interpreted that data and our scoring schema.

Based on initial assessments, analyses and evaluations we elected to run separate but parallel models for each of the three jurisdictions: British Columbia, Alberta and Montana. Source data was often restricted to one of these jurisdictions primarily because the source data was developed or contracted by state and provincial agencies or by partners whose area-of-interest is completely within one of these jurisdictions (for example, Glacier National Park is wholly within Montana). Our data syntheses and evaluations led us to expect the potential for wide variations in model outputs, so we used this Phase One approach to explore that possibility.

Modeling the 13 features for each of three jurisdictions and with FRT set at either 30% or 70% resulted in a total of 84 output models.

Initial Technical Review

Before the initial phase of data processing began, the Crown Managers Partnership (CMP) spatial definition of the Crown of the Continent Ecosystem (CoC) extent was expanded to approximately align with level 8 Hydrologic Units (HUC). This decision necessitated an expanded search with the goal of obtaining as much data the Analysis Team could find. Finding the corresponding data proved to be challenging, however, as the original raw data files either did not exist or did not expand much further beyond the CMP boundary. Still, other data was much harder to track down as certain datasets were outdated and perhaps unsupported, and could no longer be found. Other datasets had to be specially requested and approved by agency officials before download.

Fortunately for the Technical Team, our Leadership Team was well informed about the project and convincing them to share data was not an overwhelming issue. After working through the selection process (see Feature Selection report) and justifying our final focal species, stakeholder agencies and organizations were happy to share what information they had regarding the feature of interest. The remainder of the data was downloaded from open source data hubs, such as Montana's Natural Resource Information System (NRIS), or Canada's Open Data Portal. Unfortunately, we could not fill all the data gaps (e.g., Tribal lands) exposing a shortcoming in our approach (see Lessons Learned, below).

After sufficient data input had been gathered and began to be evaluated, additional data challenges arose. The problem was not so much that source data came in mixed data formats [rastes, vector (points, polygons)] but rather in understanding the purpose of the data and therefore our interpretation of the datasets. For example, ungulate data from Alberta consisted of non-species specific "Critical Winter Wildlife habitat zones" and were broadly scored at 10,000, while "General Use" for ungulates in Montana was assigned a score of 5,000. Our analysis team spent a substantial amount of time digging into the metadata to understand the source data we could access, and subsequently each team member had to justify their rationale for using the data. This resulted in source data scoring inconsistencies among features.

Finally, the analysis team has some last minute layers to add and differing cost layers to work with, and we realize the need to take a deeper look at the consistency of the layers and the data processing steps taken between each feature. These results are being thoroughly evaluated by the Analysis Team and shared with the Technical Team to answer doubts, share insight, and try different techniques.

Specific Process Steps for Features

Feature: Landcover

Brief Description of feature: The leadership Team identified Aquatic (lakes and large rivers), Forest, Grassland, Riparian and Shrubland landcover features as focal features for the LCD. The single source data layer used was acquired from the Commission for Environmental Cooperation (http://www.cec.org) North American Land Change Monitoring System. It is MODIS-derived landcover from 2010 at 250 m resolution. Source data has 19 landcover classes of which we extracted five:

Landcover/Priority LCD Feature	Class(es)
Forest	1, 2, 5, 6
Shrubland	8
Grassland	10
Wetland	14
Water / Aquatic	18

Figure 1: Landcover from the Commission for Environmental Cooperation North American Land Change Monitoring System.

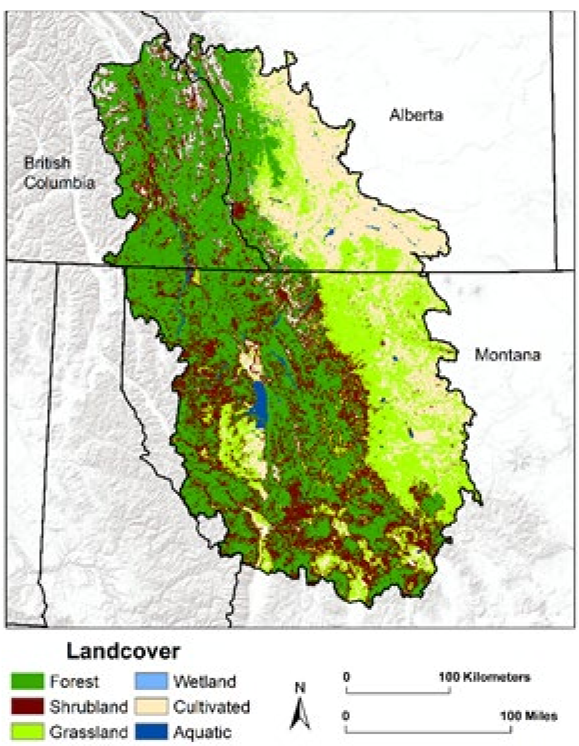


Table 1: Landcover Input Data Table

Source File	Provider	Jurisdiction	Data Type	Final File Name
Land_Cover_2010_TIFF.zip	CEC	AB, BC, MT	Modeled Raster	cec_lc_250alb

Landcover data processing: First, we reprojected the source file to the Project projection; then reclassified the input to lump the four original forested classes into a single Forest class for Phase One analysis. To prepare data for Marxan we used the 'Reclass by ASCII File' tool to extract and score individual landcover classes in separate files for each of the five focal landcover features. Each landcover feature pixel was scored 10,000 (feature present). For Phase One processing, the 5 landcover classes were optimized simultaneously using Marxan version 2.43 (2011).

Figure 2: Histogram of scoring for Landcover in the Project Area.

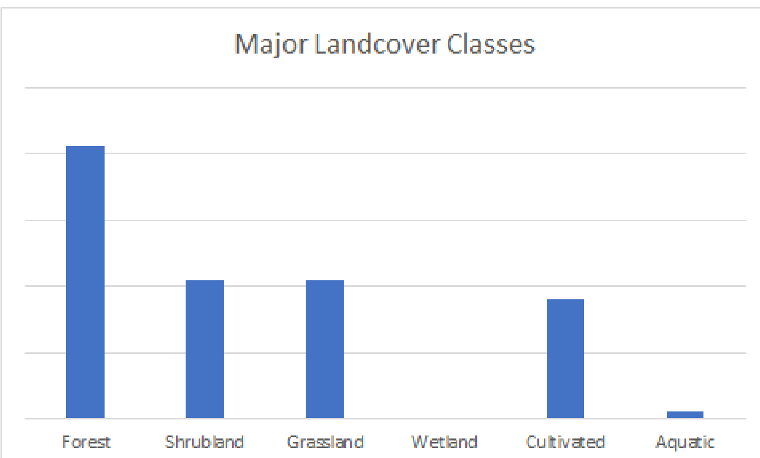
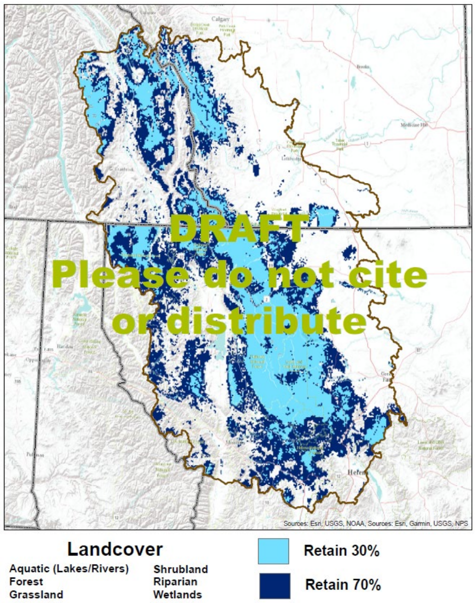


Figure 3: Marxan Optimized Output for Landcover features at the 30% and 70% FRT Levels.



Specific problems identified/encountered; potential remedies:

1. Riparian landcover not represented in 250 m CEC data: need to find alternate source data and focus a specific analysis on that feature
2. Wetland distribution poorly represented in 250 m CEC data: will use 30 m CEC layer for Phase Two. Even though some better wetland data exist for portions of the project area, the consistency and resolution of the 30 m CEC data should provide the best, most consistent outputs.

Feature: Elk (*Cervus canadensis*)

Brief Description of feature: The largest wild ungulate in the Crown of the Continent Ecosystem (CCE), elk are typically short distance migrants that spend summers in subalpine and alpine basins and move to lower elevation floodplains and open forests in winter. We used 16 source data layers, sourced from 6 data providers, to estimate elk distribution and space-use across the CCE (Table 2). Various source data describe general range, winter range, calving areas, mineral licks, and response to human disturbance (Boyce MS, Ciuti S 2020).

Figure 4: Elk input source data (Montana)

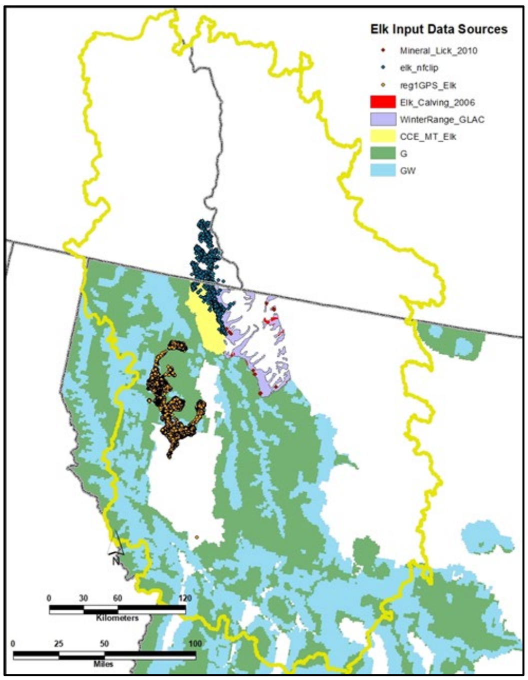


Figure 5: Elk input source data (British Columbia)

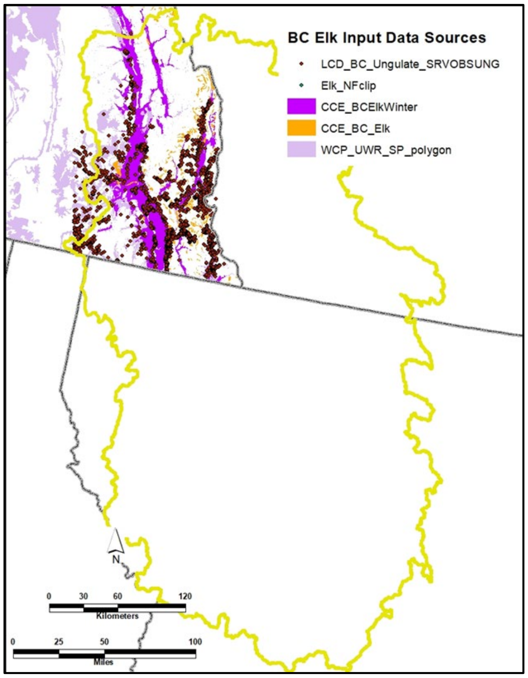


Figure 6: Elk input source data (Alberta)

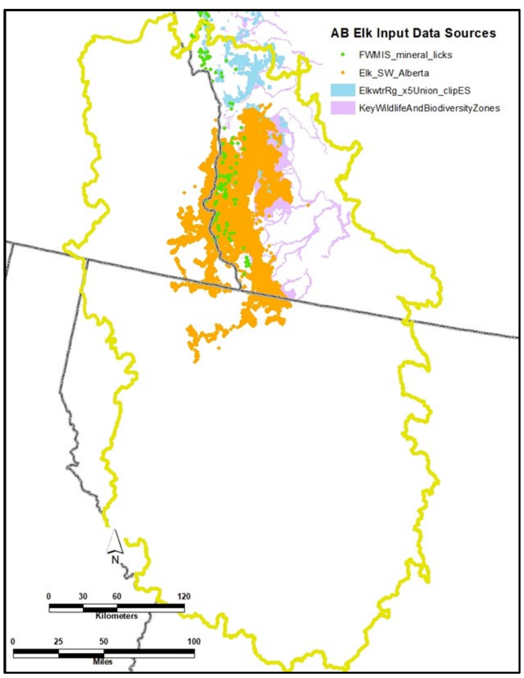


Figure 7: Elk input source data (Montana, British Columbia, Alberta)

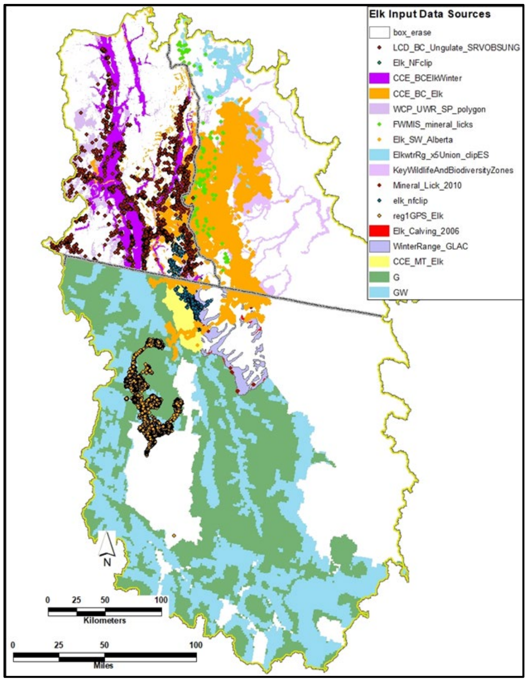


Table 2: Elk Input Data Table

Source File	Provider	Jurisdiction	Data Type	Final File Name
Elk_Distribution_in_Montana.shp	MT FWP	MT	Polygon	LCD_MT_Elk_Distribution.shp
CCE_MT_Elk	CMP	MT	Polygon	LCD_CCE_MT_Elk_.shp
WinterRange_GLAC	GNP	MT	Polygon	LCD_ WinterRange_GLAC.shp
Elk_Calving_2006	GNP	MT	Polygon	LCD_ Elk_Calving_2006.shp
Reg1GPS_Elk	MT FWP	MT	GPS point	LCD_ MT_ElkGPSReg1_350buf.shp
Elk_NFclip.shp	CMP	MT/BC	Point	LCD_ CCE_Elk_NFclipMT_350buf.shp
Mineral_Lick2010	GNP	MT	Point	LCD_ Mineral_Lick2010_350buf.shp

AB_KeyWildBiodZone.shp	Alberta Environment and Parks	AB	Polygon	LCD_AB_KeyWildBiodZone.shp
FWMMIS_mineral_licks.shp	Alberta Environment and Parks	AB	Point	LCD_ FWMMIS_mineral_licks_AEA__350buf clip.shp
Elk_SW_Alberta.shp	CA.gov	AB	Polygon	LCD_ Elk_SW_Alberta_AEA_diss_buf350.shp
Canada_AL263_AEA.shp	CA.gov	AB	GPS point	LCD_Canada_AL263_AEA_AB
WCP_UWR_SR_poly.shp	CA.gov	BC	Polygon	LCD_BC_ElkWinterRange.shp
CCE_BCElkWinter.shp	CMP	BC	Point	LCD_ CCE_BCElkWinter.shp
CCE_BC_Elk.shp	CMP	BC	Point	LCD_ CCE_BC_Elk.shp
Elk_NFclip.shp	CMP	BC/MT	Polygon	LCD_ CCE_Elk_NFclipBC_350buf.shp
Canada_AL263_AEA.shp	CA.gov	BC	GPS point	LCD_Canada_AL263_AEA_BC_buff350.shp

Elk data processing: Each layer was converted to an Albers Equal Area projection and scored based on priority usage. Known locations based on empirical data were given scores of 10,000, while areas of general use were scored 5,000. Layers were updated (ArcMap tools - analysis, overlay tab) with one another to remove duplicate or redundant features, and then rasterized for input to Marxan.

Figure 8: Histogram of scoring for Elk by jurisdiction.

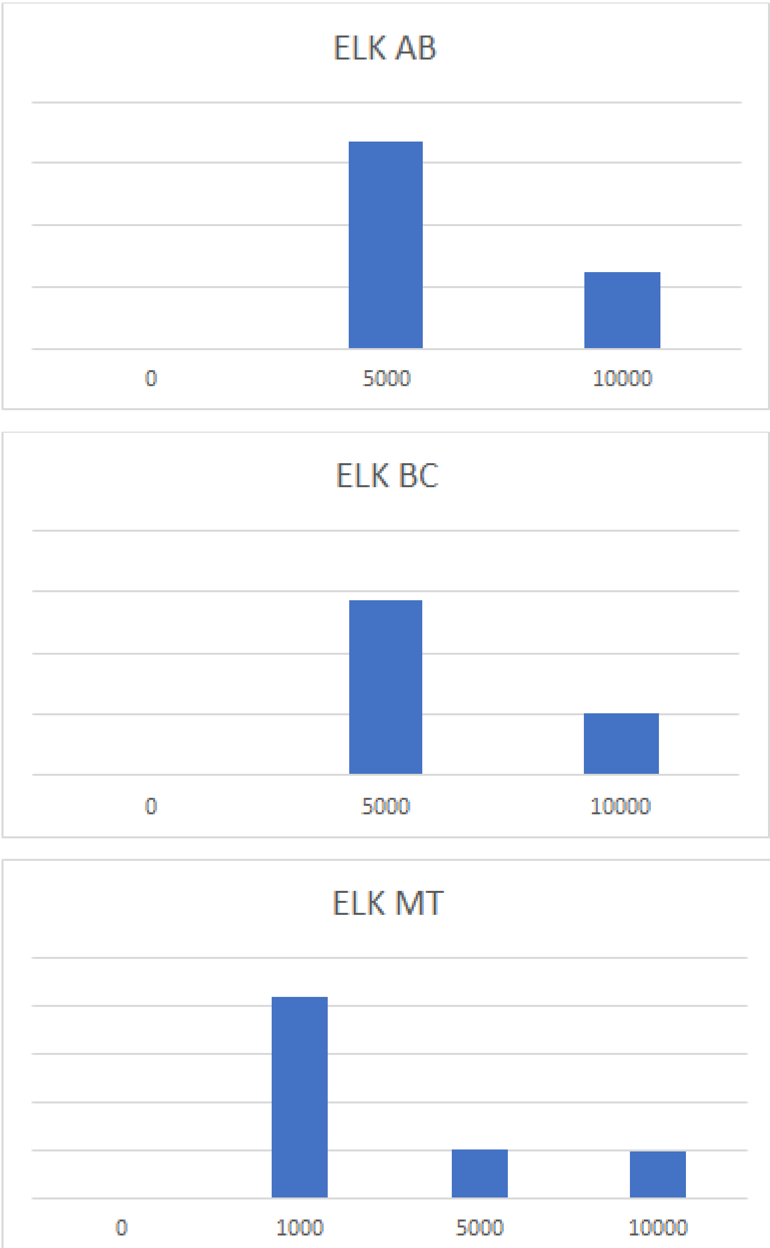
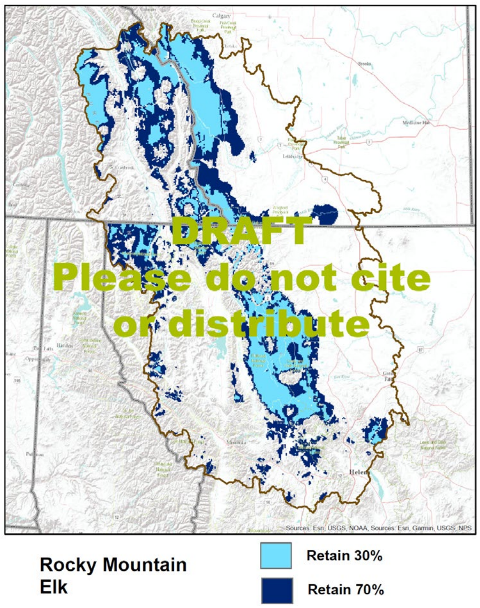


Figure 9: Marxan Optimized Output for Elk feature at the 30% and 70% FRT Levels.



Specific problems identified/encountered; potential remedies:

1. Did not have representation for Flathead and Blackfeet Reservations.
2. Montana Elk Step 11: Zonal Statistics as a Table & Export Table

Use Zonal Statistics as a Table to generate output data specifically linked to the “pulayer” file (in this case pulayer_MT_2km_hex.shp):

I originally had issues using the PUID as the Zone Field! Only shows FID and I cannot select PUID (although it is in the attribute table). Zone field work around: Open attribute table: Table Options/Add Field name it PUID (I named mine PUID3 because there already was a PUID field) Type = Short Integer (I had to create type=text because short integer was too short, allowing only 4 digits…); To populate the PUID field with consecutive numbers, right-click the PUID field name and select Field Calculator. Double click FID in ‘Fields’ box, click the + and then type “<space> 1” so the expression in the “PUID =” box says [FID] + 1. Click OK.

3. Last minute datasets still need incorporated (SRVOBSONG – BC, Personal Observations on Hwy 206– PLM, MT)

Feature: Mule Deer (*Odocoileus hemionus*)

Brief Description of feature: One of two *Odocoileus* cervids in North America, the mule deer is virtually ubiquitous across the Rocky Mountains including the CCE. Similar to elk, mule deer typically migrate short distances seasonally to take advantage of peak forage. Large but loosely concentrated winter herds disperse upslope in spring when does bear young and spend the summer in small family groups. We used 11 data layers, sourced from 5 data providers, to estimate mule deer distribution and space-use across the CCE (Table 3). Various source data describe general range, winter range, calving areas and mineral licks.

Figure 9: Mule Deer input source data (Montana)

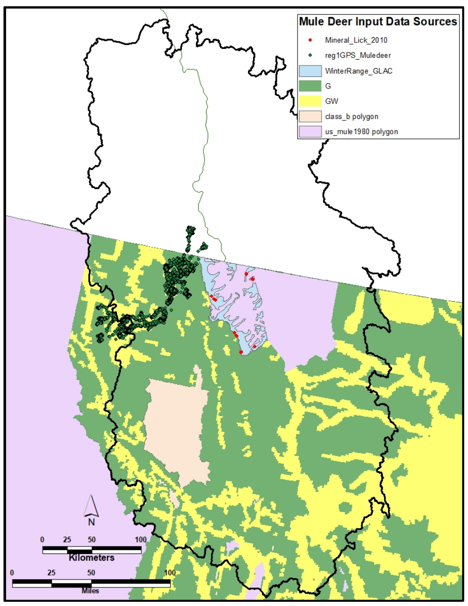


Figure 10: Mule Deer input source data (Alberta)

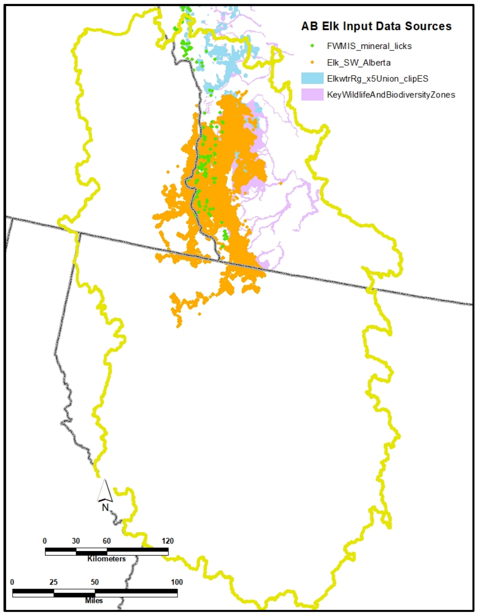


Figure 11: Mule Deer input source data (British Columbia)

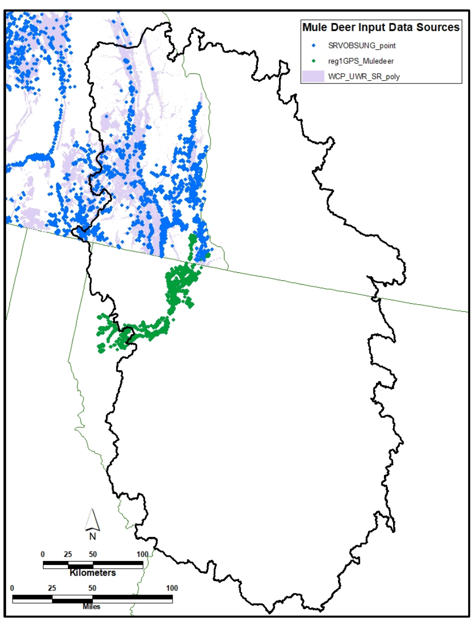


Figure 12: Mule Deer input source data (Montana, Alberta, British Columbia)

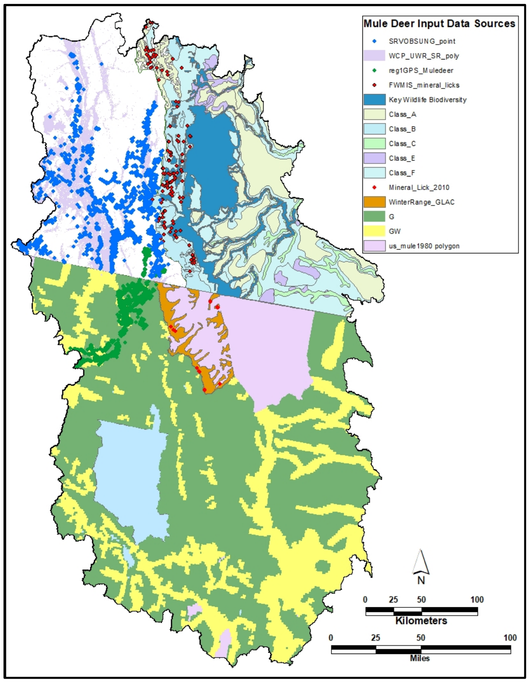


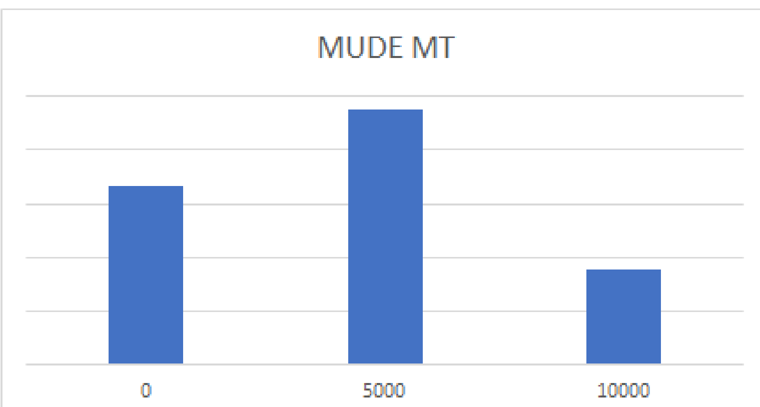
Table 3: Mule Deer Input Data Table

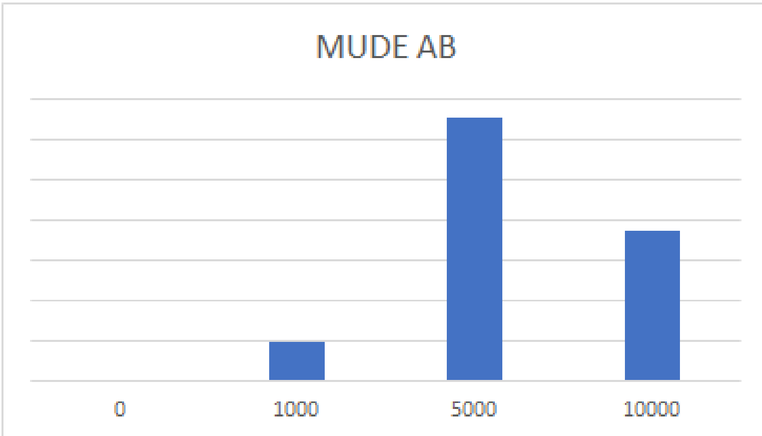
Source File	Provider	Jurisdiction	Data Type	Final File Name
MuleDeer_Distribution_in_Montana.shp	MT FWP	MT	Polygon	LCD_MT_MuleDeer_Distribution.shp
WinterRange_GLAC.shp	GNP	MT	Polygon	LCD_ WinterRange_GLAC.shp
us_mule1980_polygon.shp	Alberta Environment and Parks	MT	Polygon	LCD_ muledeer1980.shp
Reg1GPS_MuleDeer.shp	MT FWP	MT/BC	Point	LCD_ MT_MuleDeerGPSReg1_350buf.shp
Mineral_Lick2010.shp	GNP	MT	Point	LCD_ Mineral_Lick2010_350buf.shp
AB_KeyWildBiodZone.shp	Alberta Environment and Parks	AB	Polygon	LCD_AB_KeyWildBiodZone_AEA.shp

Class_A-F.shp	Alberta Environment and Parks	AB	Polygon	LCD_ AB_ClassA_F.shp
FWMMIS_mineral_licks.shp	Alberta Environment and Parks	AB	Point	LCD_ FWMMIS_mineral_licks _350buf.shp
WCP_UWR_SR_poly.shp	CA.gov	BC	Polygon	LCD_BC_MuleDeerWinter Range.shp
LCD_BCclip.shp	CMP	BC	Polygon	LCD_BCclip_AEA.shp
SRV_OBSUNG.shp	CA.gov	BC	Point	N/A. Was not used during the initial run. Needs incorporated into the second iteration.

Mule Deer data processing: Each layer was converted to an Albers Equal Area projection and scored based on priority usage. Layers were updated (ArcMap tools - analysis, overlay tab) with one another to remove duplicate or redundant features, and rasterized for input to Marxan.

Figure 13: Histogram of scoring for Mule Deer by jurisdiction.





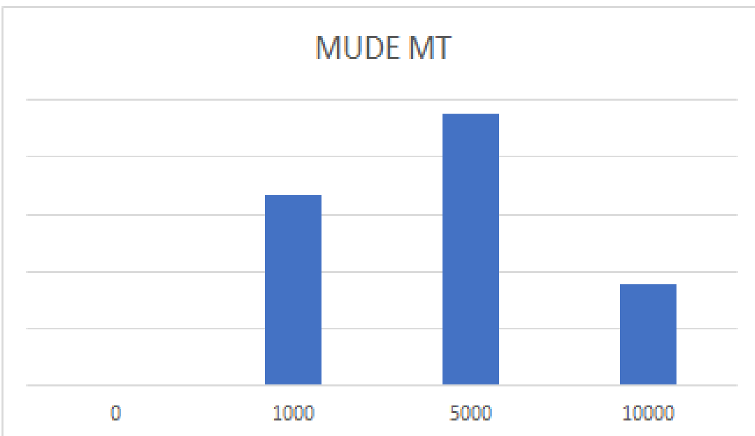
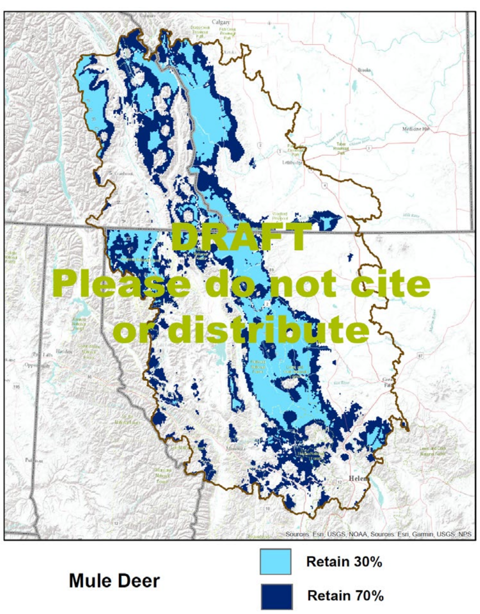


Figure 14: Marxan Optimized Output for Mule Deer feature at the 30% and 70% FRT Levels.



Specific problems identified/encountered; potential remedies:

1. Last minute datasets need incorporated (SRVOBSONG – BC)
2. Need to fill in data gaps for Native American reservations in Montana. This gap was initially filled with coarse resolution data from 1980.

Feature: Bull Trout (*Salvelinus confluentus*)

Brief Description of feature: The bull trout (*Salvelinus confluentus*), a salmonid native to northwest North America thrives in the highest, coldest headwater streams. Bull trout is the provincial fish of Alberta. In the US the species is listed as threatened under the Endangered Species Act. Seven data layers, consisting of modeled and observed data, including point observation data, habitat suitability modeling, and critical habitat data, acquired from four sources were used for this analysis (Table 4).

Figure 15: Map of summary of input data for Bull Trout

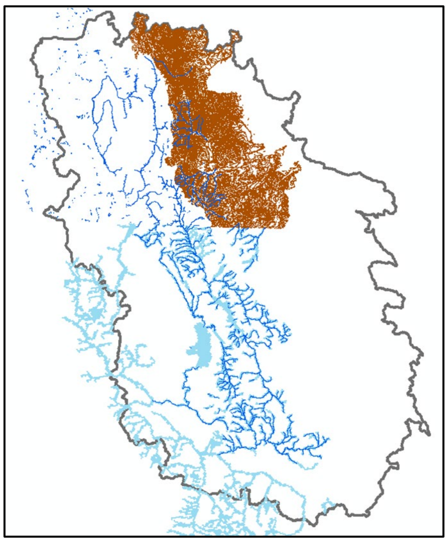


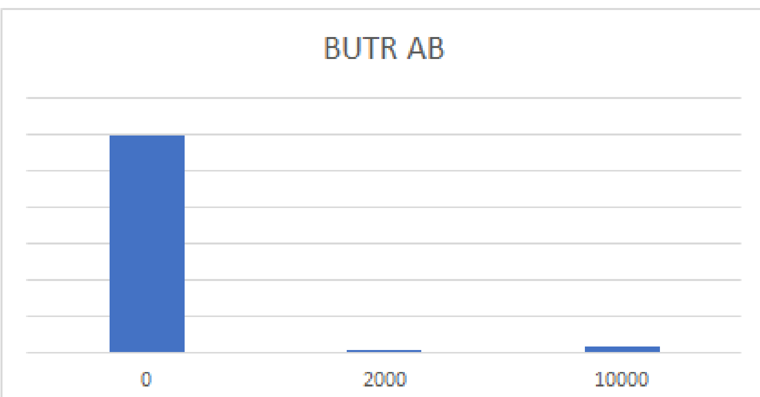
Table 4: Bull Trout Input Data Table

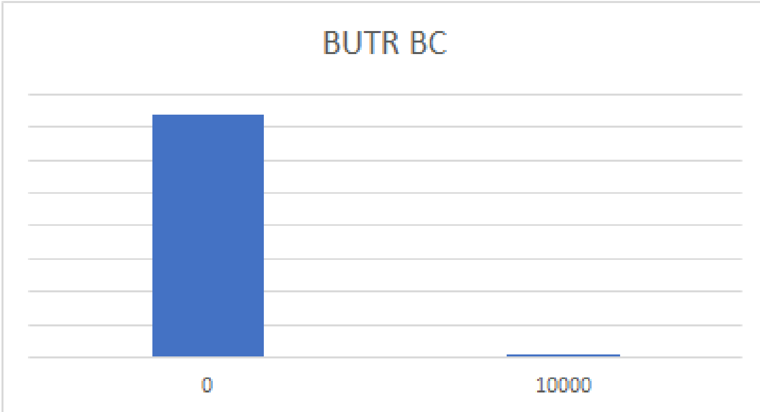
Source File	Provider	Jurisdiction	Data Type	Final File Name
CCE_BT_StreamsFinal	USGS/Phil Matson	CCE-wide	Critical habitat - polylines	AB_BT_merge4
BLTR_Habitat	Gov't of AB	AB	Range map - polygon	BLTR_Habitat
CriticalHab_BT	Gov't of Canada (Species at Risk)	AB	Critical Habitat - polygon	Obs_Hab_BT_no_overlap
FWMIS_BT_FishSurvey	FWMIS database	AB	Observation points	Obs_Hab_BT_overlap

FISS_BC_BT	Gov't of BC	BC	Observation points	FISS_streams_BT
WHSE_BASEMAPPING_FWA_STREAM_NETWORKS_SP	Gov't of BC	BC	Streams network - polylines	WHSE_BASEMAPPING_FWA_STREAM_NETWORKS_SP
MTNHP_Predicted_Habitat_Suitability_Models_20201002	Montana Natural Heritage Program	MT	Habitat suitability	MTNHP_HabSuitBT

Bull Trout data processing: Point observation data was converted to polyline stream data by exporting where observation data overlapped with stream data. Each data layer was assigned a score where the highest score (10,000) indicates high likelihood of bull trout presence. Critical habitat, highly suitable habitat, and direct observations were scored at 10,000; general habitat layers were scored at 2,000. Polygons were converted to polylines, and the layers were merged and rasterized.

Figure 16: Histogram of scoring for Bull Trout by jurisdiction.





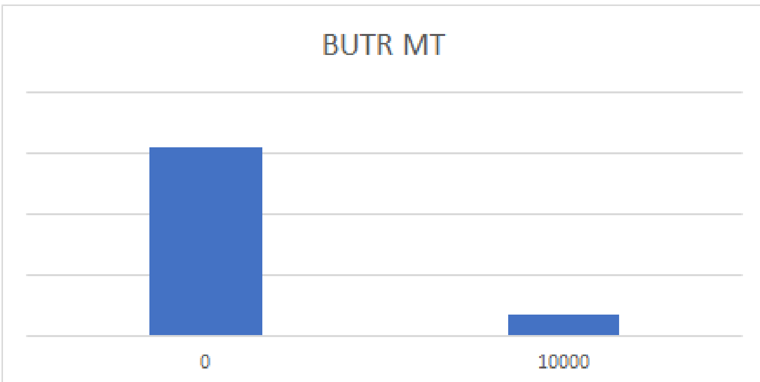
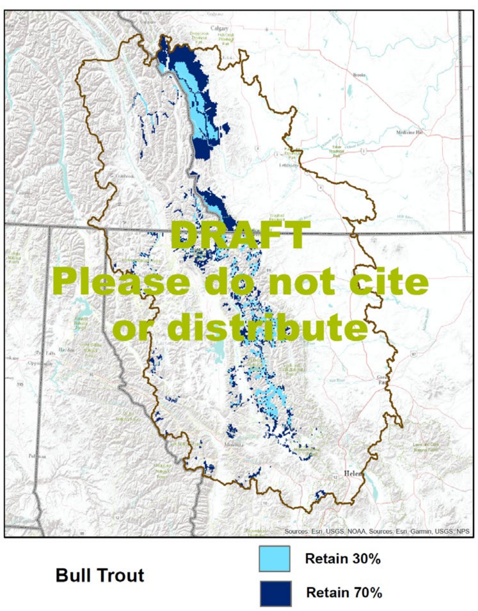


Figure 17: Marxan Output map for Bull Trout feature at the 30% and 70% FRT Levels.



Specific problems identified/encountered; potential remedies:

1. Because the potential habitat layer for Alberta contained a greater number of streams and stream orders, the Marxan output is heavily weighted towards Alberta. A potential solution is to use *select by location* where the target layer is an Alberta National Hydrology dataset, and the source layer is the bull trout habitat data.
2. The stream reaches for BC are tiny after exporting where point observations overlap with streams data. The solution to this is to dissolve the stream layer on stream order.

Feature: Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*)

Brief Description of feature: The westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) is a freshwater fish in the salmon family first described in the journals of Wiliam Clark. Westslope cutthroat populations exhibit three life history strategies: adfluvial (lake-tributary), fluvial (large river-tributary) or resident (tributary). Cutthroat trout is the state fish of Montana; however the westslope subspecies is a species of concern in Montana and Alberta. Six data layers from four sources were used in this analysis (Table 5) The data includes modeled and observed data, including point observation data and critical habitat data.

Figure 18: Map of summary of input data for Westslope Cutthroat Trout.

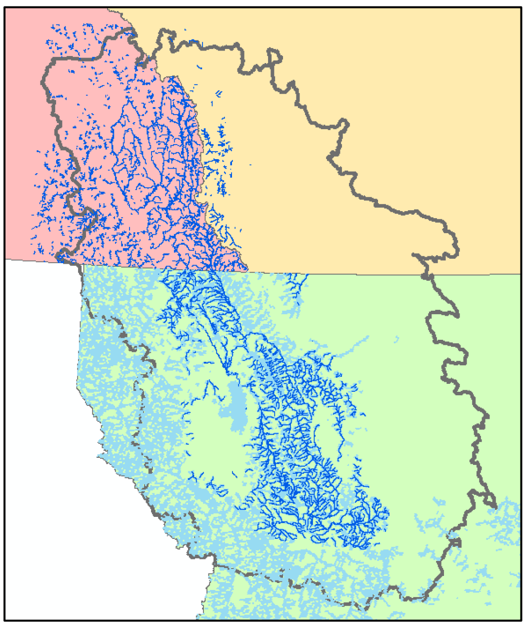


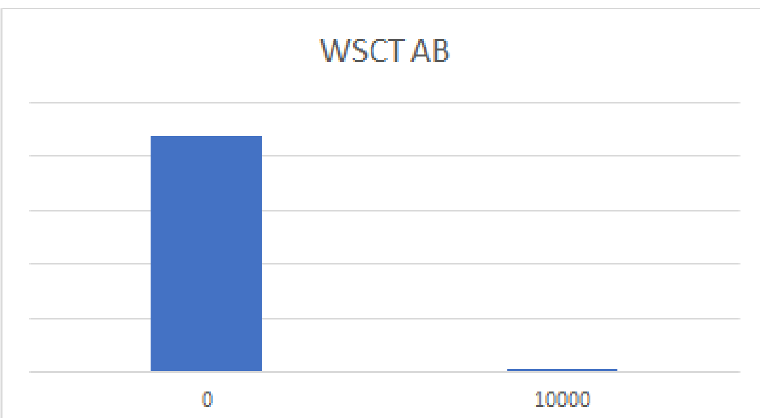
Table 5: Westslope Cutthroat Trout Input Data Table:

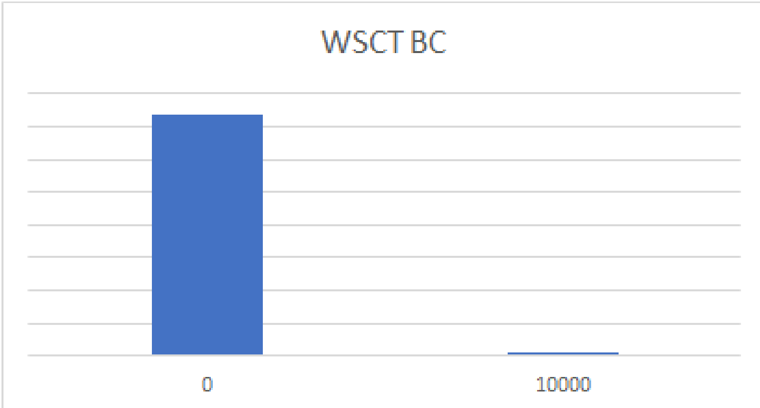
Source File	Provider	Jurisdiction	Data Type	Final File Name
CCE_WCT_StreamsFinal	USGS/Phil Matson	CCE-wide	Critical habitat - polylines	CCE_WCT_StreamsFinal
WSCT_CriticalHab	Gov't of Canada	AB	Critical habitat - polygon	WS_Hab_line
FWMIS_FishSurvey_WSCT	FWMIS database	AB	Observation points	FWMIS_WS_stream

FISS_BC_WSCT	Gov't of BC	BC	Observation points	FISS_WS_stream
WHSE_BASEMAPPING_FWA_STREAM_NETWORKS_SP	Gov't of BC	BC	Streams network - polylines	WHSE_BASEMAPPING_FWA_STREAM_NETWORKS_SP
Streams_CCE	Crown Managers Partnership	CCE	Stream network - polylines	Streams_CCE

Westslope Cutthroat Trout data processing: Point observation data was converted to polyline stream data by extracting where observation data overlapped with stream network data. Each data layer was assigned the highest score (10,000), which indicates high likelihood of westslope cutthroat presence. Because the layers used were critical habitat and direct observation data, they were all given the highest possible score. Polygons were converted to polylines, and the layers were merged and rasterized.

Fig 19: Histogram of scoring for Westslope Cutthroat Trout by jurisdiction.





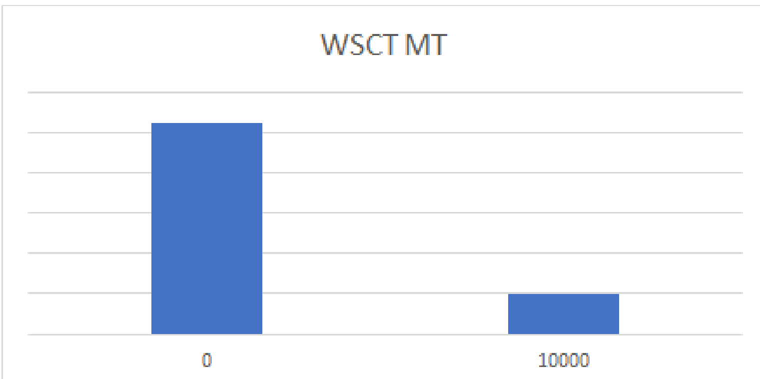
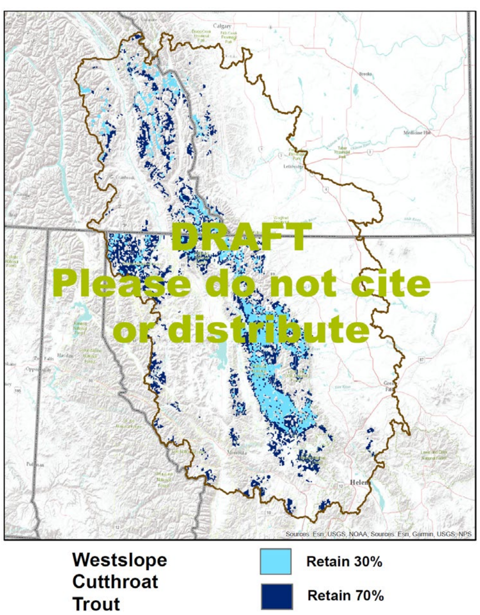


Figure 20: Marxan Output map for Westslope Cutthroat Trout feature at the 30% and 70% FRT Levels.



Specific problems identified/encountered; potential remedies:

1. There are obvious data gaps for Confederated Salish and Kootenai Tribes' and Blackfeet Nation lands. When compiling a group of subject matter experts during Phase Two, we will inquire about whether data is available for these areas.
2. Given the input data, it appears that there is significantly less westslope cutthroat trout habitat in Alberta compared to the rest of the Crown. The input data appears to have hard, illogical breaks when crossing over borders into Alberta. Subject matter experts will need to be consulted on the validity and holisticness of the Alberta datasets used.
3. The stream reaches for BC are tiny after extracting where point observations overlap with streams data. A potential solution is to dissolve the stream layer on stream order.

Feature: Whitebark Pine (*Pinus albicaulis*)

Brief Description of feature: A native to high elevation sites in western Canada and US, the whitebark pine (*Pinus albicaulis*) is often the highest elevation pine encountered. Individuals may grow to 100 feet but are often found as krummholz due to exposure. The pine seeds are an important food source for a diverse set of birds and mammals. We used four data layers, each from a unique source for modeling (Table 6). The data consists of modeled and observed data, including point observation data, predicted range, and potential range models.

Figure 21: Map of summary of input data for Whitebark Pine. Some data sets are omitted from the figure due to data sharing agreements.

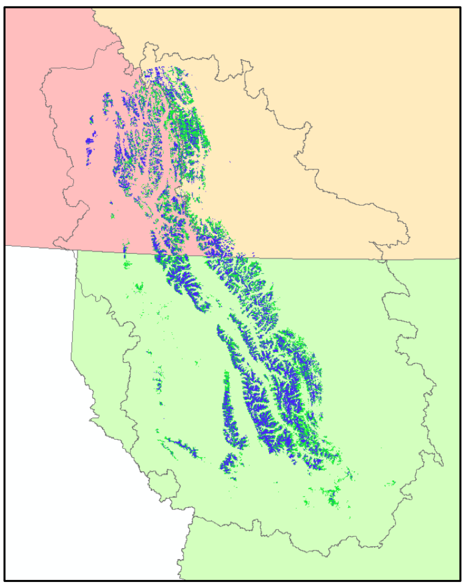


Table 6: Whitebark Pine Input Data Table (pull from here)

Source File	Provider	Jurisdiction	Data Type	Final File Name
CCE_WBP_Potential_Range_filt1	Crown Managers Partnership Hi5 Group	CCE-wide	Potential range (where WBP *could be*) - polygon	CCE_WBP_Potential_Range_filt1
CCE_WBP_PredictedRange_filt1	Crown Managers Partnership Hi5 Group	CCE-wide	Predicted Range (where WBP *is*) - polygon	CCE_WBP_PredictedRange_filt1
AB_WB_Jodie	GOA	AB	Probability of presence - polygon	AB_WB_Jodie

WhitebarkPine_WHSE_TERRESTRIAL_ECOLOGY_BIOT_OCCR_NON_SENS_AREA_SVW	The Nature Conservancy of Canada	BC	Known locations - polygons	WhitebarkPine_WHSE_TERRESTRIAL_ECOLOGY_BIOT_OCCR_NON_SENS_AREA_SVW

Whitebark Pine data processing: Polygon data was rasterized, and each data layer was assigned a score where the highest score (10,000) indicates high likelihood of whitebark pine presence. Predicted range, known locations, and high probability areas were assigned a score of 10,000, and potential range was assigned a score of 5,000. The layers were merged for input into Marxan.

Figure 22: Histogram of scoring for Whitebark Pine by jurisdiction.

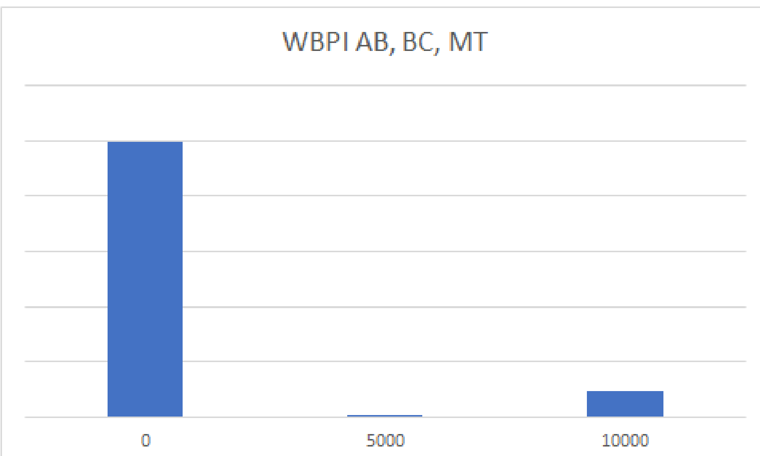
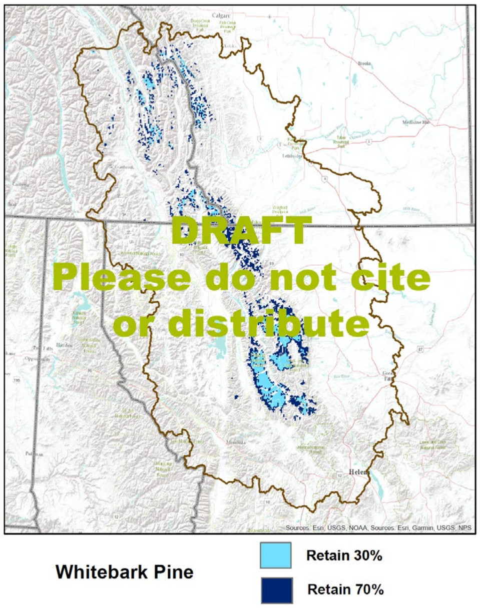


Figure 23: Marxan Output map for Whitebark Pine feature at the 30% and 70% FRT Levels.



Specific problems identified/encountered; potential remedies:

The Crown-wide predicted and potential range models use the Crown boundary as defined by the Crown Managers Partnership, not the Crown LCD project. As a result, the data sets are not wall to wall. When subject matter experts are assembled, additional datasets will have to be incorporated, particularly for the southern portion of the Crown.

Feature: Wolverine (*Gulo gulo*)

Brief Description of feature: A reclusive yet charismatic carnivore, the wolverine is the largest terrestrial weasel. Wolverines tend to inhabit high elevations and cover vast home ranges. Some individuals make very lengthy dispersal movements. Because females excavate dens to bear kits in late winter, early snowmelt, driven by global temperature increases, may impact reproduction and therefore population stability. We used three data layers, each from unique sources, to characterize relative habitat quality (Table 7).

Figure 24: Map of final scoring for Wolverine

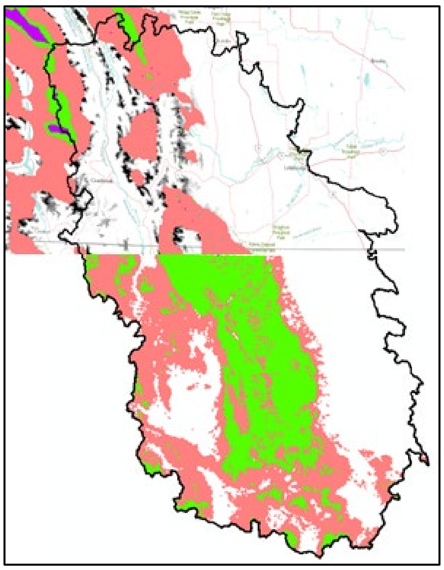


Table 7: Wolverine Input Data Table

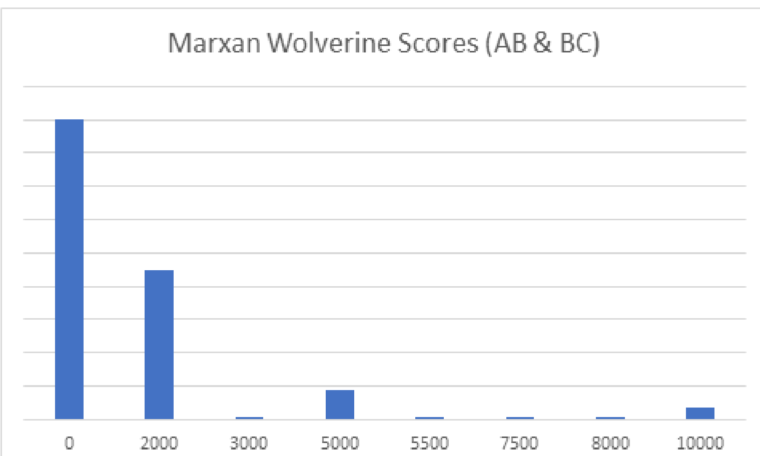
Source File	Provider	Jurisdiction	Data Type	Final File Name
MTNHP_CMP_Predicted_Habitat_Suitability_WOLV.shp	MNHP	MT	Modeled Vector	MT_WOLV_for_Marxan_Scenario1.shp
Gulo_Density_Surface.tif	Mowat	AB, BC	Modeled Raster	AB_WOLV_for_Marxan_Scenario3.shp
Clevenger_CCoC_photo_data_14-16_complete.xlsx	Clevenger	AB, BC	Point (Camera Stations)	BC_WOLV_for_Marxan_Scenario3.shp

Wolverine data processing:

MT: MTNHP_CMP_Predicted_Habitat_Suitability_WOLV: assign a score of optimal suitability 10,000; moderate suitability 5,000; low suitability 2,000; unsuitable 0 (zero)

AB & BC: Gulo_Density_Surface.tif: Used Raster Calculator to convert source to a 4 bit unsigned integer grid. Reproject to Project projectionand reclassify to: gulo_dens_rcl where integer-converted values were scored: 8-10 = 10000; 4-7 = 5000; 1-3 = 2000; 0 = 0; Clevenger_CCoC_photo_data_14-16_complete2.xlsx/: Created a point shapefile from XY wolverine detection data; used Total_Sess field as estimate of relative importance to wolverine. Buffer Clevenger_wolverine_detections.shp by 800 m radius to indicate WOLV use a larger area than the single-point camera station; add field: score (short integer); using Select by Attribute and Field Calculator, score WOLV_obs values of 1 = 3,000, WOLV_obs values of 2 = 5,500, and Wolv_obs values of 3 = 8,000.

Figure 25: Histogram of scoring for Wolverine by jurisdiction.



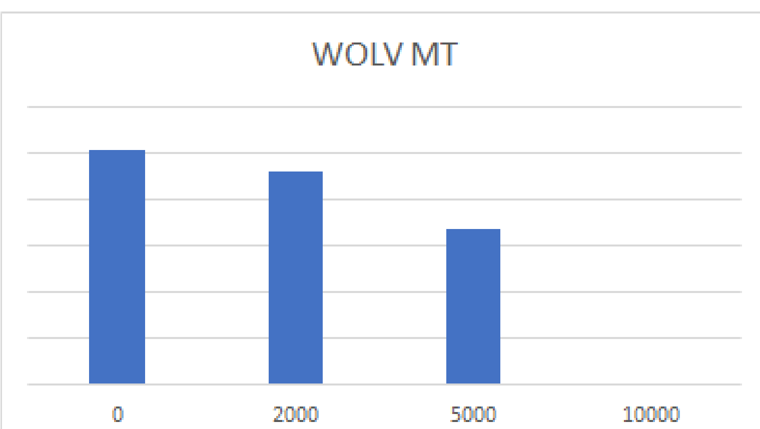
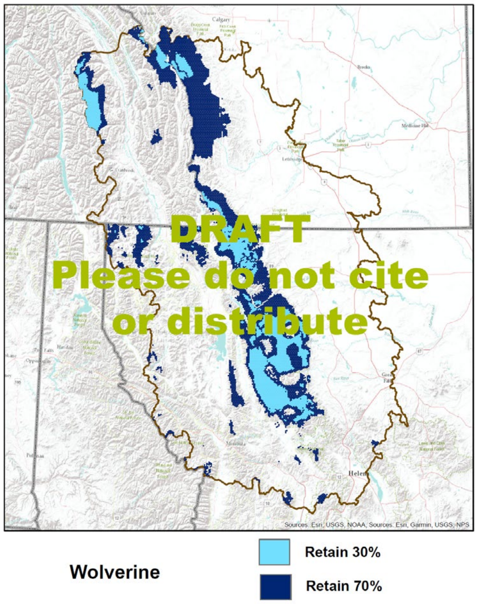


Figure 26: Marxan Output map for Wolverine feature at the 30% and 70% FRT Levels.



Specific problems identified/encountered; potential remedies:

Though disparate in terms of source and jurisdiction, wolverine data and marxan analysis produced output as reasonably expected. Additional data exploration is warranted during normal Phase Two analyses.

Feature: Canada Lynx (*Lynx canadensis*)

Brief Description of feature: Reclusive felid carnivore; associated with early seral forest. Listed as Threatened in the US. Data sparse and disparate among jurisdictions. Montana data are from MTNHP and FWS (critical habitat). AB and BC data includes some camera station observations and interpretations based on climate-niche models.

Figure 27: Map of final scoring for Canada Lynx

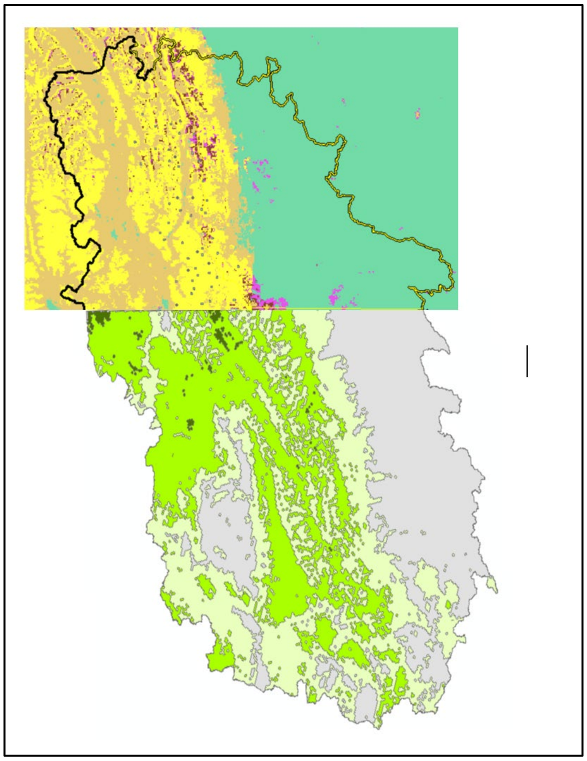


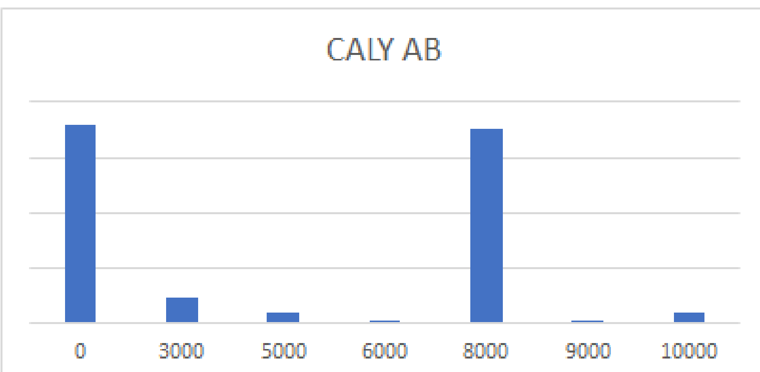
Table 8: Canada Lynx Input Data Table

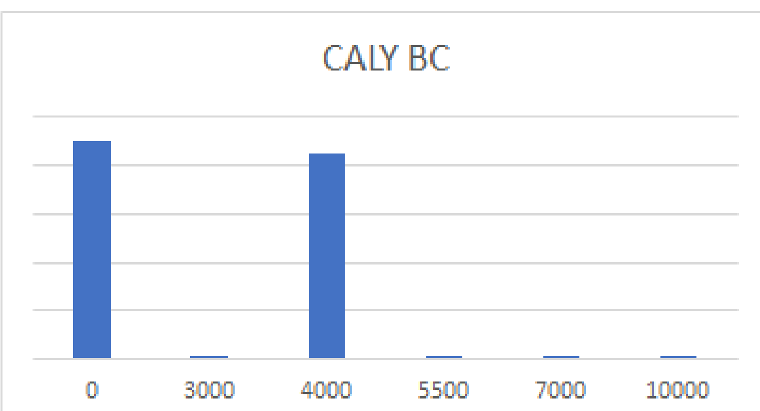
Source File	Provider	Jurisdiction	Data Type	Final File Name
MTNHP_Predicted_Habitat_Suitability_CALY.shp	MNHP	MT	Model Vector	CALY_feats_S2c.csv
Lynx_CH.shp	USFWS	MT	Modeled Vector	FWS_CrownLCD_CriticalHabitat_CALY
Canadian Lynx Climate Niche Model	Gostout	AB, BC	Modeled Vector	gost_caly_rcl

AB_Snow_layer	Gov't of Alberta	AB, BC, MT	Modeled Raster	ab_snow_rcl
Clevenger_CCoC_ photo_data_14-16_complete2.xlsx	Clevenger	AB, BC	Point (Camera Stations)	clev_caly_alb

Canada Lynx data processing: MT: Scored suitability model (unsuitable = 0; low suitability = 2000; moderate = 5000; optimal = 10,000) and critical habitat (critical habitat = 1500) and added for final scores. AB & BC: scored Canadian Lynx Climate Niche Model (stable or contraction = 4,000; expansion = 0); scored mosaic.tif (spring snow persistence model) using Reclass by Ascii to reclass the 17 values as follows: 0-5 = 5000; 6-10 = 3000; 11-14 = 1000; 15-17 = 0; buffered confirmed lynx camera station records by 800m and score polygons based on number of 'captures' (CALY_obs values of 1 = 3,000, CALY_obs values of 2 = 5,500, and CALY_obs values of 3 = 8,000); then overlaid/added resulting output for final scores.

Figure 28: Histogram of scoring for Canada Lynx by jurisdiction.





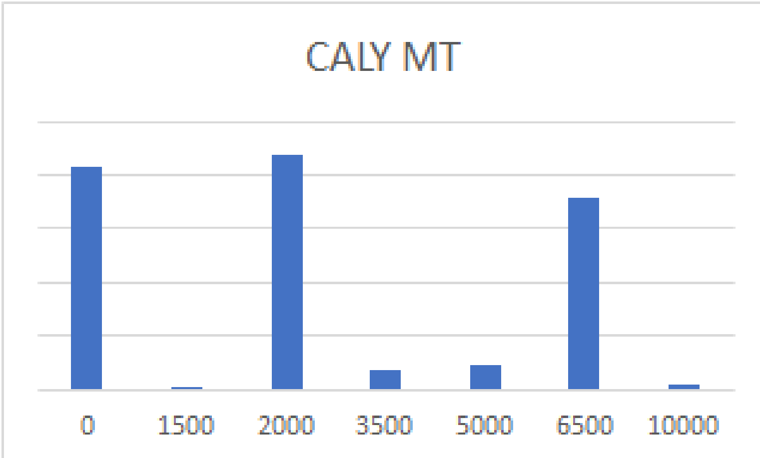
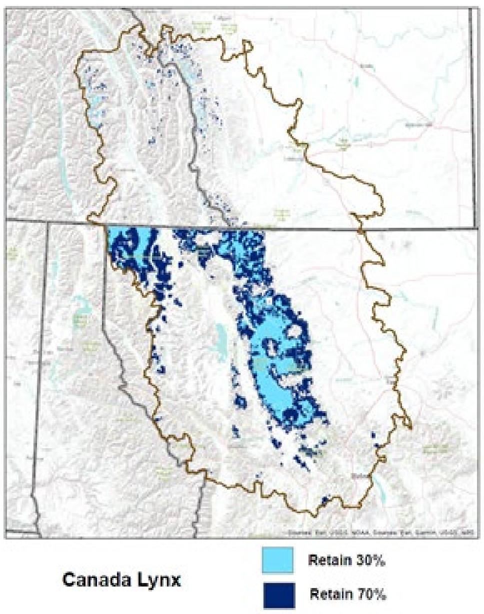


Figure 29: Marxan Output map for Canada Lynx feature at the 30% and 70% FRT Levels.



Specific problems identified/encountered; potential remedies:

Data acquired for AB and BC marginally adequate for confident scoring. Gross interpretations of the climate niche model and spring snow persistence model need to be calibrated to forest cover (preferably early and mid-seral forest). Data across sources and jurisdictions need to be normalized to general more reliable, standardized inputs for Marxan.

Feature: Grizzly Bear (*Ursus arctos horribilis*)

Brief Description of feature: Large mobile omnivorous carnivore, now restricted to a small portion of the historic range. Listed as threatened in the US. Of high concern for conservation and human-interaction reasons. Montana data are from MTNHP observations and suitability model. AB and BC-specific modeled core habitat and telemetry relocations. We also used CMP-provided hair snag station data and occupancy models.

Figure 30: Map of final scoring for Grizzly Bear.

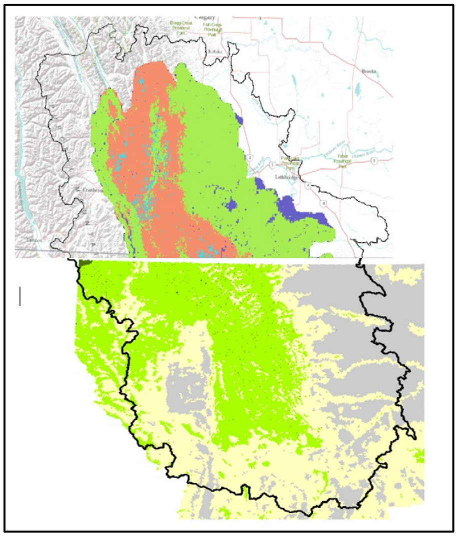


Table 9: Input Data Table for Grizzly Bear

Source File	**Provider**	**Jurisdiction**	**Data Type**	**Final File Name**
MTNHP_Predicted_Habitat_Suitability_GBear.shp	MTNHP	MT	Modeled Vector	MT_GB_S1
MTNHP_ObsData_GBear.shp	MTNHP	MT	Points (observations)	MT_GB_S1
CMPGBMar21.shp	CMP	AB, BC, MT	Point (baited hair snag stations)	MT_GB_S1
Abmi_griz_core_habitat_gt9.shp	Miistakis Inst.	AB	Modeled Vector	Abmi_griz_core_habitat_gt9_alb.shp
GBOcc_CCE_06-2013.tif	CMP	AB, BC, MT	Modeled raster	

EVcollar_Relocs.csv	C. Lamb	AB, BC	Points (telemetry)	

Grizzly Bear data processing:

MT: MTNHP_Predicted_Habitat_Suitability_GBear.shp: assign a score of optimal suitability 10,000; moderate suitability 5,000; low suitability 2,000; unsuitable 0 (zero); CMPGBMar21.shp: remove hair snag sampling points where no bears were detected, assign a score of 10,000 to all detection points; buffer points by 350 m radius to indicate bear activity in the vicinity of the hair snag station; MTNHP_ObsData_GBear.shp; select all records where observation occurred after 1995; select records that do not intersect Crown LCD project area (use 'best available data' to characterize bear detections OUTSIDE of the CMP CCE in a way that parallels the hair snag sampling points INSIDE the CCE); buffer points by 350 m radius, assign a score of 10,000 to buffers;

AB: Abmi_griz_core_habitat_gt9_alb.shp: assign score of 2000 to all 114 polygons; lc_max_alb (Livingston Castle resource selection function (RSF) from GrizzlyBear.zip) multiply original value by 1000 (new value range from 1,000 to 10,000; reclass 'NoData' to 0 (zero);

BC: CMPGBMar21.shp: remove hair snag sampling points where no bears were detected, assign a score of 10,000 to all detection points; buffer points by 350 m radius to indicate bear activity in the vicinity of the hair snag station; selected 2,000 locations at random from the full 63,000 records in EVcollar_Relocs.csv; Added the 2000 record data set to Arc using Add XY data. Exported data and buffered the points by 350m to create; Assign a score of 10,000 to all detection points; Reprojected GBOcc_CCE_06-2013.tif to the project projection (GB_CCE_13_alb.tif) and then converted it to integer by multiplying (GB_CCE_13_alb.tif) by 10,000 in Raster Calculator creating (GB_CCE_13_in1.tif). Used INT (GB_CCE_13_in1.tif) in Raster Calculator to create (GB_CCE_13_int.tif); Used Reclass by ASCII to create (GB_CCE_13_rcl) using D:\Base_Data\CROWN_LCD\Features\GrizzlyBear\ GB_CCEmodel_marxan_recl.txt). The reclass converted integer values 0 to 0 (zero); 1 – 2000 to 2000; 2001 – 6500 to 5000; and 6501 – 8768 to 10000.

Figure 31: Histogram of scoring for Grizzly Bear by jurisdiction.

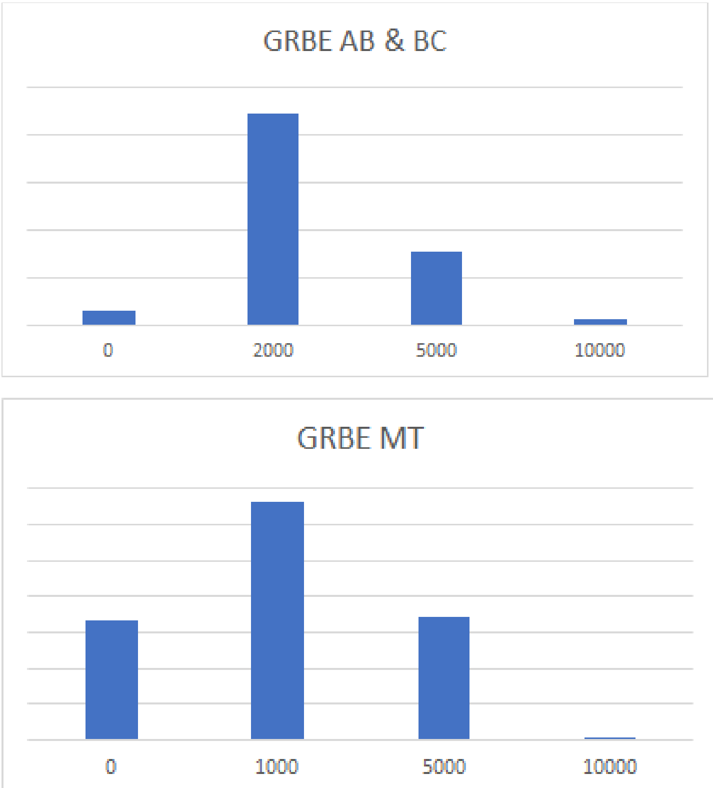
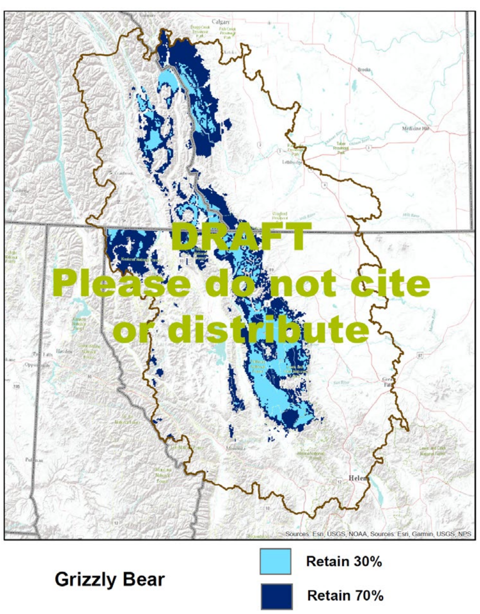


Figure 32: Marxan Output map for Grizzly Bear feature at the 30% and 70% FRT Levels.



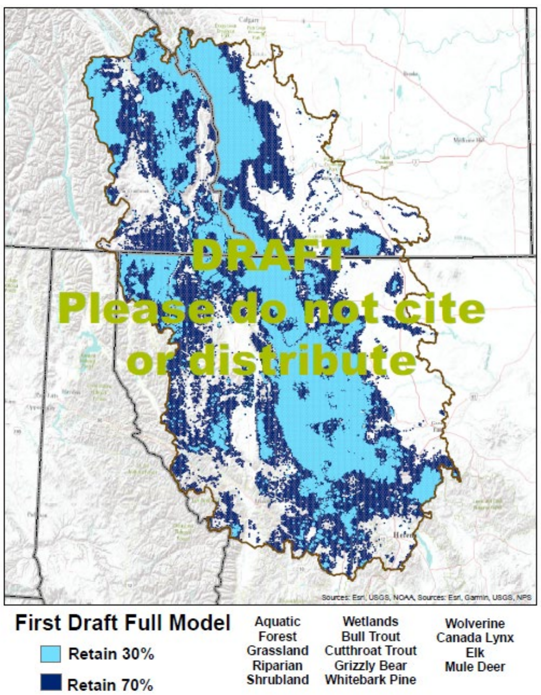
Specific problems identified/encountered; potential remedies:

1. Complete lack of data located for the northwest portion of Project Area (Purcell Mountains); need to extend data search.
2. Inconsistent data outside of CMP's CCE area.

Synthetic Optimization Models (all features)

We compiled all processed data as described above into files appropriate for multi-feature optimization models. Since we used a single cost layer (Global Human Modification, Kennedy et al. 2020) we used Marxan (v. 10.8.1). As we continued exploratory modeling, we did not adjust any Marxan parameters. We term this initial output a “NULL model” and caution the reader the output has LOW ecological validity: these are test outputs to ensure data, software and our interpretations are aligned enough to move into Phase Two.

Figure 33: Marxan Output map for 14 priority conservation features at the 30% and 70% FRT Levels.



General Conclusions and Discussion

Phase One exploratory analysis demonstrated a transboundary optimization model for selected conservation features is achievable. It also demonstrated that additional preparation work is needed to generate scientifically defensible and ecologically reliable models. Developing models for each feature uncovered specific shortcomings in source data spatial extent, depth, and reliability. Although we evaluated almost 100 source data sets, those data resources collectively fell short of a holistic estimate of feature dispersion across the project area. Phase

Two must commence with a second round of data identification, acquisition and vetting (Table 10).

Table 10: Summary of additional data needs for Phase Two.

Feature	**Primary Data Gap**	**Actions to Address**
Forest	Age class/time since harvest	
Grassland	Finer resolution data (e.g., alpine vs. valley-bottom grasslands)	Potential further delineations based on elevation (DEMs)
Shrubland	Finer resolution data (e.g., alpine vs. valley-bottom shrublands)	Potential further delineations based on elevation (DEMs)
Riparian	Inconsistent data from AB, BC	Canvas subject matter expert panel; Technical Team
Aquatic	Uncertain if CEC data adequate	Find additional data; do some comparisons
Wetland	Higher resolution wetland depictions	Use 30 m CEC landcover data
Elk	Need MT reservation data	Continued outreach to subject matter experts
Mule Deer	Need MT reservation data	Continued outreach to subject matter experts
Bull Trout	Possible gap in data in Montana, near Cabinets	Canvas subject matter expert panel; consider models developed by Zeller et al.
Westslope Cutthroat Trout	Obvious data gaps for Confederated Salish and Kootenai Tribes' and Blackfeet Nation lands; hard data breaks at AB	Canvas subject matter expert panel; consider models developed by Zeller et al.
Whitebark Pine	Areas outside of the CMP definition of the Crown, particularly Montana	Canvas subject matter expert panel; Technical Team

Wolverine	Comprehensive location/ observation data or models for AB & BC	Canvas subject matter expert panel; consider models developed by Zeller et al.
Canada Lynx	Comprehensive location/ observation data or models for AB & BC	Canvas subject matter expert panel; consider models developed by Zeller et al.
Grizzly Bear	Location/observation data or models for northwest portion of project area (in BC)	Canvas subject matter expert panel; consider models developed by Zeller et al.

Lessons Learned and Transition to Phase Two

- Expanding the Project Area beyond the CMP's formal definition of the Crown of the Continent Ecosystem (CCE) led to data challenges. One potential solution is to constrain Phase Two analyses to the CMP definition of CCE.
- As expected, variation among data describing focal ecological features on either side of the Canada-US boundary is quite disparate.
    - In many cases data from the US side (wholly within the state of Montana) is relatively consistent due to consistent occupancy models provided by MTNHP.
    - Data acquired from Alberta and British Columbia tended to be from more diverse sources. Some data was consistent across the provincial boundary (and even south into MT). Other data were restricted to a province (i.e data from Alberta Environment and Parks) or to a researcher's study area, while other data (as was the case for elk) spanned across BC and MT.
- Our data collection for some features is spatially incomplete. For example, we did not uncover or acquire data for grizzly bear observations or models for the NW portion of the Project Area (Yaak and Purcell areas). These kinds of data inadequacies severely limit the utility of optimization models.
- Riparian (especially) and wetlands data from the single landcover source (CEC 250 m resolution) is inadequate. Seek finer resolution riparian data and use the CEC 30 m data for wetlands in Phase Two.
- All data shortcomings will be discussed and pursued with subject matter expert teams.

Citations

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