

Atlin Northern Mountain Caribou Habitat Modeling and Cumulative Human Impact Assessment

Cumulative Effects Toolkit: A Guide for Managers

Report prepared for

The Taku River Tlingit First Nation

by Rick Tingey

Jean Polfus

Kimberly Heinemeyer

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ATLIN NORTHERN MOUNTAIN CARIBOU HABITAT MODELING AND CUMULATIVE HUMAN IMPACT ASSESSMENT

CUMULATIVE EFFECTS TOOLKIT

Version 1.0

This toolkit provides directions and guidance for managers to assess future development impacts on the Atlin herd of northern woodland caribou. The computational tools run in ArcGIS spatial software package and are capable of dynamically updating underlying caribou habitat quality when the user inputs data about specific development scenarios.

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REPORT PREPARED FOR

Taku River Tlingit First Nation
P.O. Box 132
Atlin, BC V0W 1A0

REPORT BY

Rick Tingey¹
Jean L. Polfus¹
Kimberly S. Heinemeyer¹

COVER PHOTO CREDITS

Jean Polfus (top left, TRTFN Territory sign, bottom left, bottom middle, middle), Wibke Peters (bottom right), Kevin Cannaday (caribou on road). Drawing of caribou by Jean Polfus.

¹ Round River Conservation Studies, 284 West 400 North, Suite 105, Salt Lake City, UT 84103; Rick Tingey: ricktingey@roundriver.org; Jean Polfus: jeanpolfus@gmail.com; Kimberly Heinemeyer: kim@roundriver.org

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Introduction

The Atlin herd of northern mountain woodland caribou occurs in the territory of the Taku River Tlingit First Nation (TRTFN). Recent population modeling has indicated the Atlin herd has low productivity and is likely declining, and there is a need to understand how potential future development might affect habitat selection of the herd. New innovations in spatial modeling and remote sensing facilitate analyses of potential alternative land use scenarios at various planning scales, inform cumulative effects assessments and aid in the selection of project alternatives that minimize effects on valued resources such as caribou. The GIS toolkit presented here uses information from previously developed habitat models for the Atlin caribou herd to assess the influence of new proposed human infrastructure on habitat quality and predict the future reduction in habitat quality in areas near new human developments. This tool will allow managers, such as the TRTFN, to make informed decisions about the effects of proposed projects on the Atlin caribou herd. The interface with ArcGIS is intended to allow for flexibility and easy updating of human infrastructure layers, including real or hypothetical projects. This provides a dynamic evaluation of habitat quality through simple metrics that measure the loss of habitat quality across analysis units.

Cumulative Effects

Understanding the interactions of multiple development types across large temporal and spatial scales is important for predicting how future developments may impact populations. Different types of human disturbance, such as roads or mines, are likely to have varying degrees of influence on the strength of avoidance and have the potential to interact in a cumulative manner with habitat quality and local population dynamics (Polfus 2010). The total magnitude of the effect depends both on the total area converted as well as the temporal scale of the exposure to development activity (Johnson and St-Laurent 2011). Single isolated activities may have a trivial impact on ungulate behavior or demography (Oehler et al. 2005), while effects that are large-scale and accumulate over time generally have a larger impact on populations (Nellemann and Cameron 1998). In this way, a single road may be individually inconsequential, but the combined impact of multiple roads and development complexes can be significant over time (Spalding 1994, Jeffrey and Duinker 2000, Scott 2007). Current management policy, which often attempts to mitigate impacts by restricting development through timing or seasonal restrictions,

is unlikely to mitigate environmental degradation from increasing development pressure. The scale and measured process of piecemeal development as well as the lack of standardized approaches to cumulative effects assessments can make qualifying impacts measured with various methodologies (ranging from very complex cumulative effects simulators like ALCES which integrate distribution and demographic data to simple questionnaires, interviews, and trend analyses) very difficult (Krausman 2011). This highlights the need for relatively simple, intuitive and implementable approaches for monitoring how new developments will affect habitat quality.

Northern Mountain Woodland Caribou

Woodland caribou (*Rangifer tarandus caribou*) are distributed throughout the extent of the boreal forest in Canada and require large expanses of relatively undeveloped landscapes to persist (Apps and McLellan 2006). Additionally, woodland caribou are valued culturally by many Canadians and First Nations, making their conservation an important national issue. Due to increasing levels of human infrastructure development and declines throughout their range (Vors and Boyce 2009), woodland caribou have been federally listed under the Species at Risk Act (SARA). The level of risk designated by SARA varies between woodland caribou ecotypes. Ecotypes are defined by adaptations to different environments that require particular movements and feeding behavior (Bergerud 1978, Heard and Vagt 1998, Spalding 2000). In the southern portions of Alberta, British Columbia (BC) and the boreal forests of Canada, the southern mountain and boreal ecotypes of woodland caribou are listed as threatened due to habitat loss associated with oil, gas, mining, and forestry extraction (Wittmer et al. 2005a, Apps and McLellan 2006, Schaefer and Mahoney 2007). Human development has altered predator-prey relationships causing declines and recently, extirpation of some herds (Wittmer et al. 2005b, Hebblewhite et al. 2010). By providing young seral forests that are



preferred by moose (*Alces alces*) and wolves (*Canis lupus*), human activities increase caribou vulnerability to predation through the mechanism of apparent competition (James and Stuart-Smith 2000, James et al. 2004, DeCesare et al. 2010).

The northern mountain woodland caribou ecotype occurs in local populations throughout the Yukon, Northwest Territories and northwestern BC. Human development in the northern population's range has not impacted caribou habitat to the same extent as it has in southern regions of Canada. However, even in remote regions inhabited by northern mountain woodland caribou, hunter overharvest, habitat loss and fragmentation from forestry and energy development, human-induced changes to predator-prey communities and proliferation of road and snowmobile networks have, to varying degrees, contributed to population declines. These declines prompted federal managers to list northern mountain woodland caribou as a *species of special concern* in 2004 under SARA (Kinley and Apps 2001, Thomas and Gray 2002, Seip et al. 2007, Northern Mountain Caribou Management Planning Team 2009).

The Atlin Northern Woodland Caribou herd's range encompasses 11,594 km² east of Atlin Lake to Teslin Lake along the Yukon-BC border (Figure 1). The herd relies heavily on low-elevation mature lodgepole pine forests in the winter and high elevation alpine and subalpine habitats in the summer (Heinemeyer et al. 2003). Caribou have always been a culturally important source of meat and other animal products for the TRTFN and TEK indicates that the herd once numbered in the tens of thousands (Heinemeyer et al. 2003). As caribou numbers declined in the early 20th century with the advent of firearms (Spalding 2000), many First Nation hunters switched to moose as a primary game species. In the early 1990s, concerns for population declines of the Atlin caribou herd and the Carcross/Squanga and Ibex herds (collectively known as the Southern Lakes population) led many First Nation hunters to reduce or eliminate their harvest of caribou. Monitoring efforts indicate that the two Yukon herds appear to be recovering, while aerial surveys indicate that the Atlin herd has maintained a stable or decreasing population with a low calf recruitment of 21 ± 3 calves:100 females (Bergerud and Elliott 1998, Heinemeyer 2006).

Resource Selection Function Habitat Modeling

Quantitative habitat models were developed as part of a project in collaboration with the TRTFN, the University of Montana and Round River Conservation Studies from 2008-2010 (Polfus et al. 2010). The project objective was to use an innovative combination of quantitative

habitat modeling approaches to determine the effect of cumulative human developments on the Atlin herd of northern mountain woodland caribou. To support this effort, we collaborated with the University of Calgary to develop a landcover classification for the range of the Atlin herd based on satellite imagery. The landcover classification improved on previous forest cover land models, and the new product was used in the development of seasonal caribou habitat models.

To understand the cumulative impacts of current and potential future human development on caribou habitat we developed summer and winter resource selection function (RSF) models at 2 spatial scales with data from 10 caribou collared with global positioning system (GPS) units provided by the BC Ministry of the Environment. RSFs use a statistical framework to quantify habitat relationships by comparing use of spatial resources relative to their availability. When an animal uses a resource in the landscape disproportionate to its availability, selection is assumed. When use is less than availability, the model predicts avoidance of that resource. The models assume that areas that are selected by caribou have high habitat quality, because they provide the conditions necessary for individual and population persistence (Hall et al. 1997, Garshelis 2000). We assessed cumulative human impacts by estimating the zone of influence (ZOI) avoided by caribou around several types of human development (roads, mines, cabins and hunting camps, and the town of Atlin).

Results of the RSF analyses indicate that caribou avoided multiple types of human development. We also found that selection decisions were made by caribou in a hierarchical fashion with increased sensitivity to human developments at the larger scale. At the larger landscape scale, we found caribou avoided high use (plowed/paved) roads by 2 km and low use roads by 1 km in both summer and winter. Caribou avoided the town of Atlin by 9 km in winter and by 3 km in summer. Significant avoidance of mines (2 km) and cabins and hunting camps (1.5 km) was only observed during summer, potentially because the level of human activity on the landscape increases significantly in summer due to ease of access to the road and ATV networks and seasonally active placer mines. Full results of the habitat models are available at: http://www.roundriver.org/index.php?option=com_content&view=article&id=67&Itemid=57.

Cumulative Effects Toolkit

The Cumulative Effects Toolkit provides the means to explore the potential effects of different human use scenarios (hypothetical or real) on caribou habitat quality within the range of the Atlin caribou herd. The toolkit expedites the creation of zones of influence (ZOI) around proposed developments and uses the ZOI to inform RSF-based habitat models and maps. The ZOI is the area around different development types (e.g., mine, road, etc.) that is used less than expected by caribou. The ZOI buffer distances used in the toolkit are based on analyses completed by Polfus et al. (2010). The habitat summary and graphing tools enable the user to spatially track and analyze the cumulative effects of potential and realized human development on caribou habitat through time and space. Modeling different land use scenarios provides managers the ability to evaluate a project or several project alternatives to gain insights into the impacts of a proposed development or the relative impacts of different project alternatives.

The first tool (Zone of Influence Designer Tool) allows the user to import a proposed development into the tool, build appropriate ZOI for each project component (e.g., road, mine, etc) and for the overall project (cumulative ZOI). The second tool uses the ZOI scenarios created with Tool 1 to generate RSF habitat models that depict the predicted habitat quality within the new ZOIs. Because areas within the “scenario” ZOI are predicted to be used less by caribou than expected, the habitat quality decreases. The RSF model calculates amount of habitat quality lost based on a number of factors. Each RSF habitat scenario is tied to a specific ZOI scenario. Using these first two tools, users can model a series of development scenarios across the landscape and the changes in habitat quality that are associated with each scenario. The third tool summarizes the habitat models to a set of spatial analysis units (hexagons), which provide the spatial framework to record cumulative effects on habitat quality over time and at multiple scales. The fourth tool in the set enables the visualization of habitat change in graph form by comparing habitat reference quality (current condition) with the predicted habitat quality based on the ZOI scenario of choice, at multiple scales.

The framework used to develop the Cumulative Effects Toolkit can be easily adapted to other areas and has the potential to help other governments, First Nations and management boards to model the impact of cumulative effects on caribou in other regions. Further, the tools can be modified to examine habitat associations of other important species affected by human infrastructure.

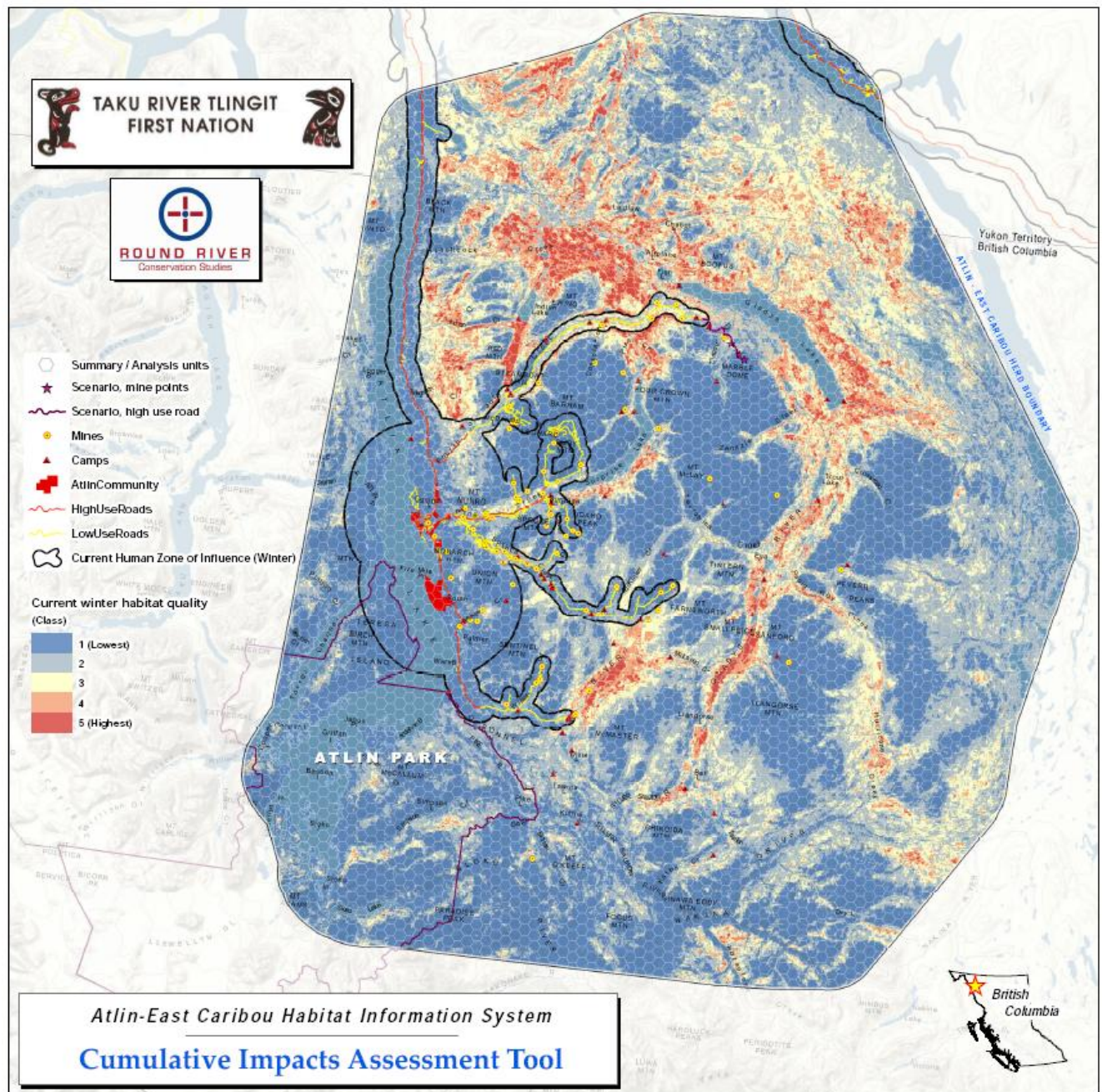



Figure 1. Home range of the Atlin herd of northern mountain woodland caribou on the border of the Yukon Territory and British Columbia, Canada. The map shows the current human winter ZOI (black outline) and background habitat quality used as the baseline reference condition by the cumulative effects tools.

Cumulative Effects Tools

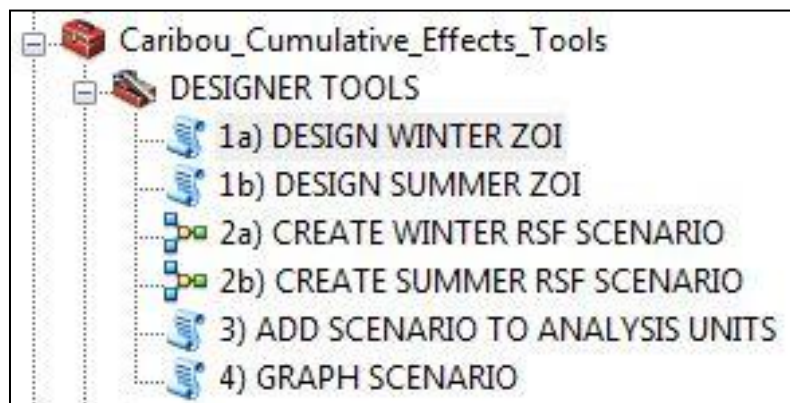
The spatial analysis tools are written for ArcGIS 10, using Python 2.6 and ArcGIS Model Builder. The tools reside in an ArcToolbox ,  as shown below. The following is a description of the key functionality provided by each tool in the set.

Tool 1: Zone of Influence Designer

The first tool in the set allows the user to design and visualize the ZOI around a proposed project based on input points, lines or polygons that represent different types of developments (e.g. new mines, roads, camps, etc), real or hypothetical. The tool is robust to scale-dependent representations of spatial features. For example, a mine could be represented as a point, or a polygon, depending on the scale or quality of the available spatial data. This tool gives the user flexibility in how these features are represented in the model. To design a ZOI scenario, the user must first obtain or create points, lines or polygons (any of these are optional) representing the development features being studied or modeled. These must be created prior to running the Tool.

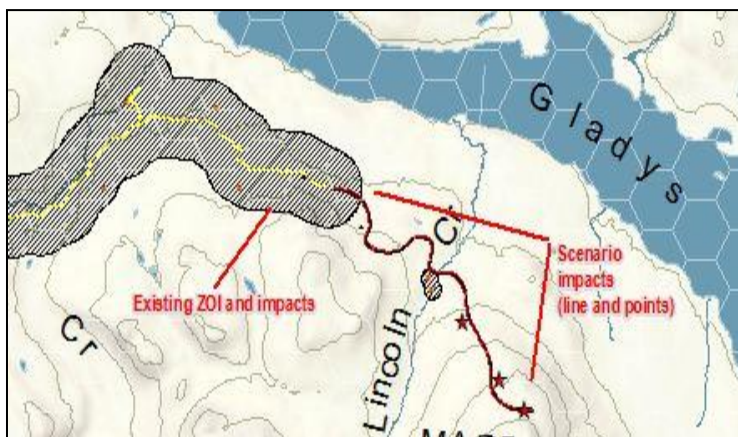
Running the ZOI Designer

To launch the tool click on *1a) DESIGN WINTER ZOI*, or *1b) DESIGN SUMMER ZOI*, depending on the season of interest. It is likely that for each development scenario, both summer and winter ZOI will be run to model the potential impact of the development on caribou throughout the year.



ZOI Designer Inputs

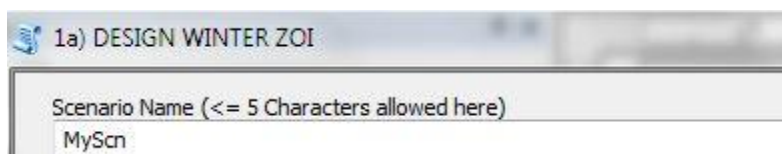
The following describes the process of populating the ZOI Designer Tool with the parameters needed to create ZOIs for a project scenario. The image below shows a hypothetical addition of a new road and three new mine locations (these new developments are termed scenario impacts).



Snapshot of ZOI Designer Tool spatial inputs

To develop a ZOI model related to the features shown above, follow the steps below:

1. First enter a name for the scenario in the first box of the tool dialog as shown below, to distinguish the resulting output data sets from those created by other scenarios. This name must be 5 characters or less.

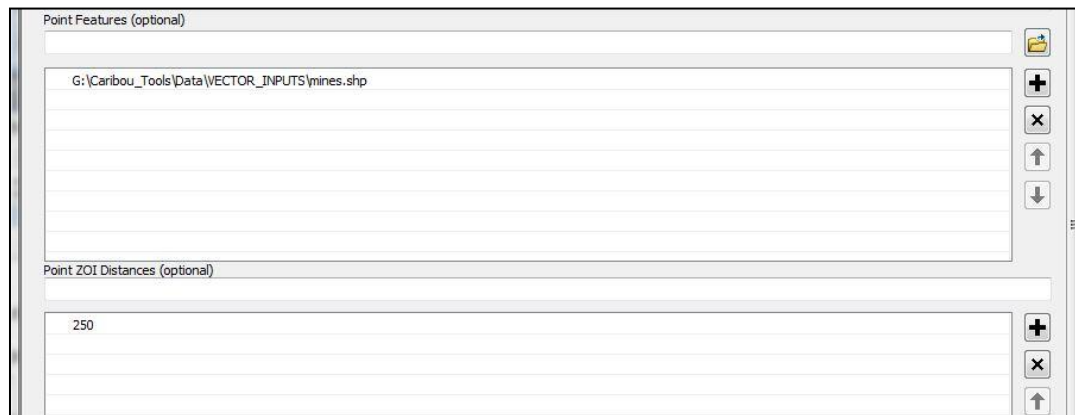


Snapshot of ZOI Designer Tool interface, scenario name input section

2. Browse to the spatial feature files representing the development scenario and input them into the tool dialog in the appropriate sections, depending on whether the features are points, lines, or polygons. Each feature type is entered into the tool separately, along with its corresponding ZOI, as determined by referring to Table 1 in Appendix A: Zone of Influence Distances by Development Type. Separate feature files should be entered for developments that have different ZOI buffer distances (e.g., major roads should be entered as one spatial feature with corresponding ZOI distance and minor roads entered with their own ZOI distance).

Point Features

Browse to the new point feature files to be included in the scenario (each feature type is optional, if there are no new point features to be included in the scenario, then skip this section and move on to line or polygon features). The file that is selected is added to the bottom of the *Point Features* list². Next, enter the corresponding ZOI distance associated with that type of feature for the specific season (e.g., in winter mines have a ZOI distance of 250 m), and click the “+” button to add the value to the list *Point ZOI Distances*.

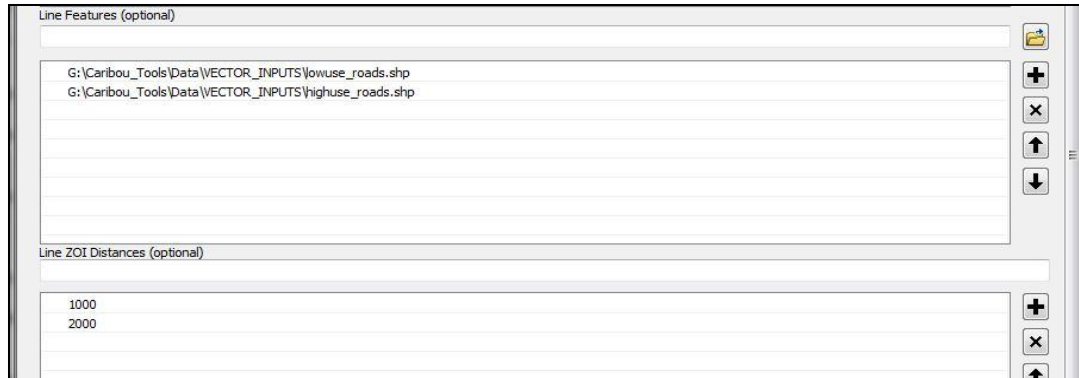


Snapshot of ZOI Designer Tool interface, point feature input section

Line Features

Browse to the new line feature files to be included in the scenario. The file that is selected is added to the bottom of the *Line Features* list. Next, enter the corresponding ZOI distance associated with that type of feature for the specific season (e.g., in winter high use roads have a ZOI distance of 2000 m), and click the “+” button to add the value to the list *Line ZOI Distances*.

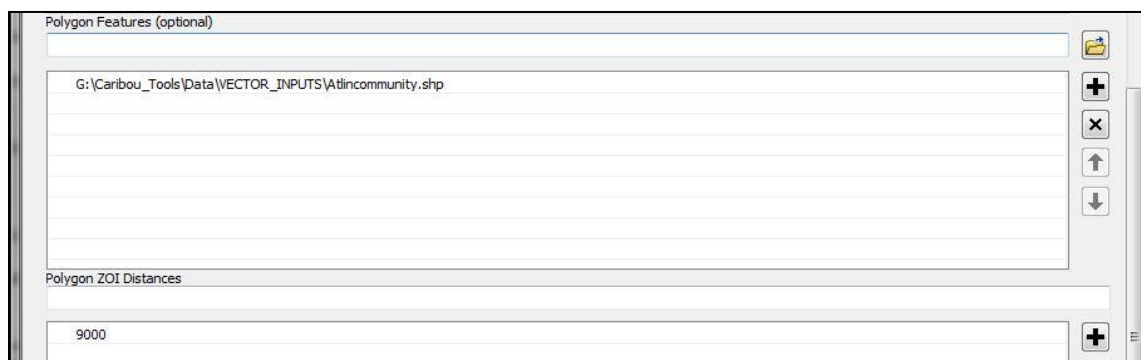
² **Note:** By default, the lists are populated with datasets that represent the current state of the human use landscape (e.g. current existing mines, high use roads, low use roads, camps, towns, etc). Leave these values in the list.



Snapshot of ZOI Designer Tool interface, line feature input section

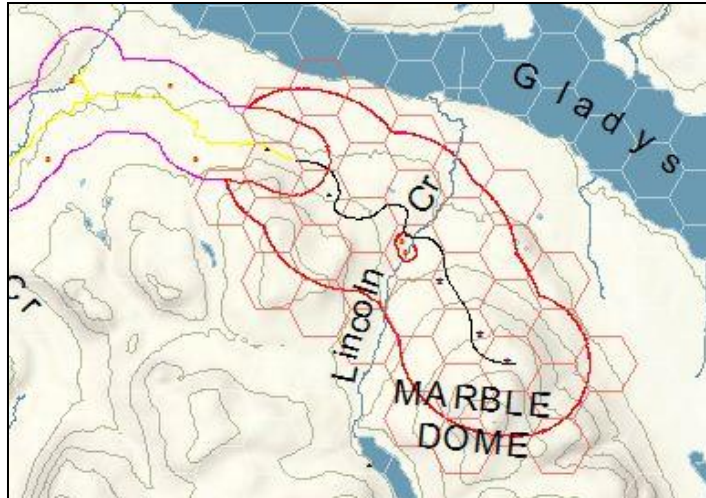
Polygon Feature

Browse to the new polygon feature files to be included in the scenario. The file that is selected is added to the bottom of the *Polygon Features* list. Next, enter the corresponding ZOI distance associated with that type of feature for the specific season (e.g. in winter communities have a ZOI distance of 9000m), and click the “+” button to add the value to the list *Polygon ZOI Distances*.



Snapshot of ZOI Designer Tool interface, polygon feature input section

- Once the parameters listed above have been entered, click “ok” to run the tool. The tool will apply the appropriate ZOI to each scenario feature, combine the individual point/line/polygon ZOIs into a single cumulative ZOI and format the output appropriately for input into the RSF Creator Tool (Tool 2). Outputs that depict the new cumulative ZOI (current ZOI + scenario ZOI) and the newly impacted areas will be added to the ArcMap display for visualization.



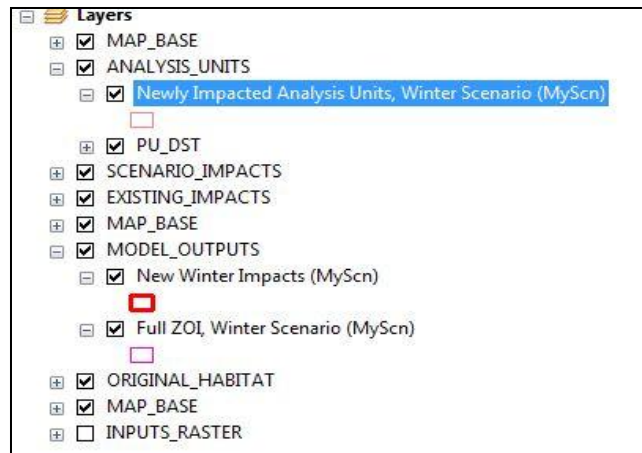
Snapshot of ZOI Designer Tool outputs in map.

ZOI Designer Outputs

The ZOI Designer Tool generates data depicting the spatial influence of human activities on caribou habitat quality. Output files are as follows:

1. *ZOI Polygon*. This layer represents the cumulative ZOI (current ZOI + scenario ZOI), and is added to the display as *Full ZOI, Winter Scenario (MyScn)*, where *MyScn* is the scenario name entered by the user in step 1.
2. *New Impacts Polygon*. This layer represents the new areas affected by the ZOI scenario that were previously unaffected by human use. It is added to the display as *New Winter Impacts (MyScn)*.
3. *New Impacted Analysis Units Layer*. This layer represents the hexagon analysis units that were affected by this scenario, and is added to the display as *Newly Impacted Analysis Units, Winter Scenario (MyScn)*. See next page for further explanation.

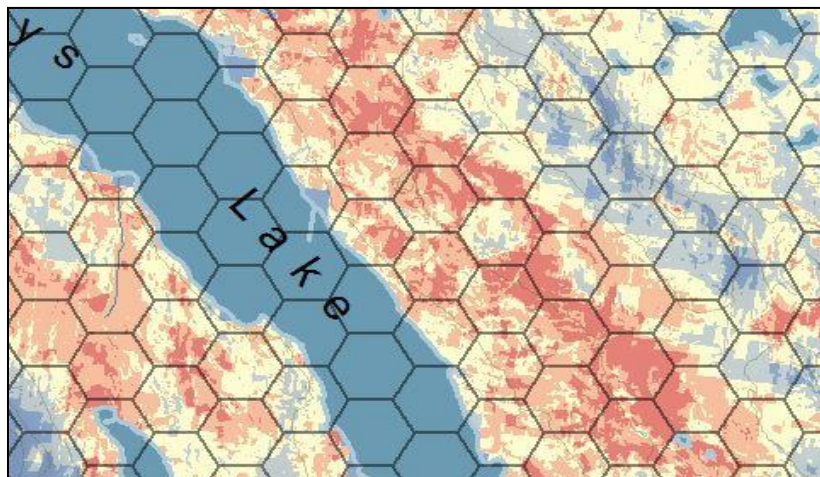
If the summer ZOI Designer Tool was executed, these output layers would reflect the spatial expression of the summer ZOI definitions (see Table 1 in Appendix A: Zone of Influence Distances by Development Type).



Snapshot of ZOI Designer Tool polygon outputs, added to the ArcMap Table of Contents

Analysis Units

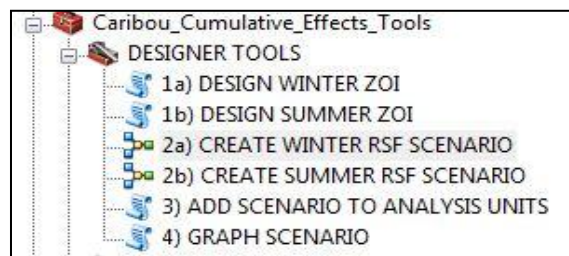
In addition to the creation of scenario ZOI (outputs 1 and 2), the ZOI Designer Tool adds an output based on analysis units (AU) which are the set of hexagonal polygons of standard size that cover the study area. The *New Impacted Analysis Units Layer* identifies which AUs were impacted by the scenario. This allows the changes in habitat quality in a specific parcel of land (hexagon) to be recorded across a series of development scenarios and can be used in query-building later in the analysis. The AUs provide a uniform spatial unit to describe the change in habitat quality at the local scale (comparison of individual AUs) or at other regional scales (comparisons between groups of AUs). The AU data layer is available to the user in the ArcMap table of contents as the layer name “Analysis Units”. See Tool 3 for further description of how to analyze the AUs.



Snapshot of hexagonal analysis units used to spatially summarize changes in habitat quality

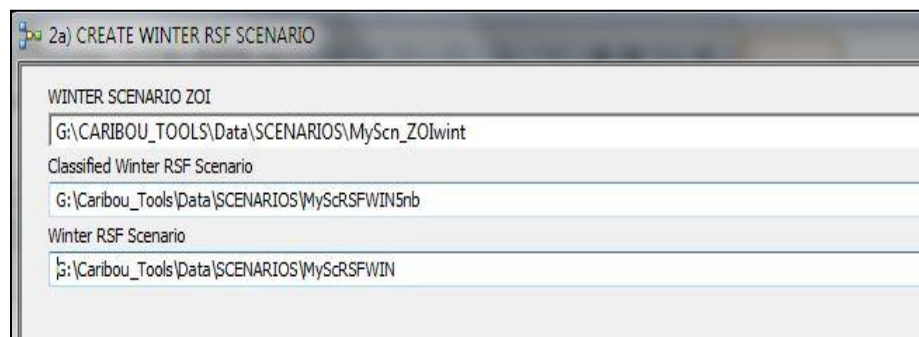
Tool 2: Resource Selection Function Habitat Model Creator

The Resource Selection Function (RSF) Habitat Model Creator Tool (RSF Tool) maps the change in habitat quality under different scenarios using RSF model parameters previously developed for the Atlin herd (Polfus et al. 2010). The earlier Background section provides a brief description of the models being used, and Polfus et al. 2010 provides a complete description. The RSF Tool creates new RSF (habitat quality) maps that are based on the ZOI scenarios created using Tool 1. Caribou habitat quality is reduced in areas of close proximity to various anthropogenic features, and any RSF model that is created using a project ZOI scenario will predict the change in habitat quality related to that specific scenario. Tools 1 and 2 can be used to create a series of land use change scenarios to assess relative impacts across different project alternatives, or to predict the potential effects across different project phases. The tools can also be used to track and monitor real developments to maintain a database that depicts the current state of habitat quality across the herd's range.



Running the RSF Habitat Model Creator

To launch the tool, click on *2a) CREATE WINTER RSF SCENARIO* or *2b) CREATE SUMMER RSF SCENARIO*, depending on the season for which habitat quality will be modeled. The following dialog box will be displayed, asking the user to browse to the ZOI scenario created previously and prompting for output names for the two RSF models to be created by this tool.

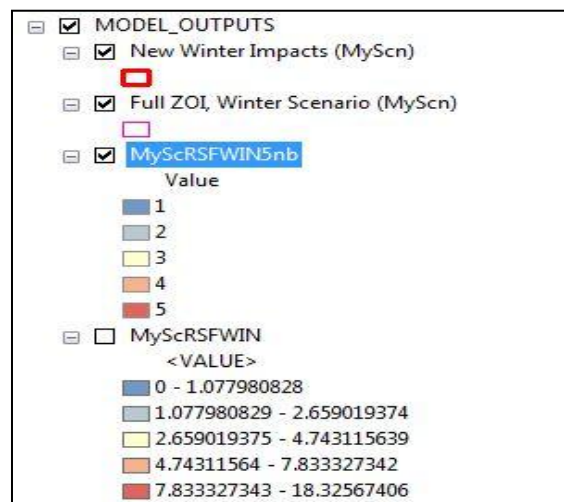


RSF Tool Inputs

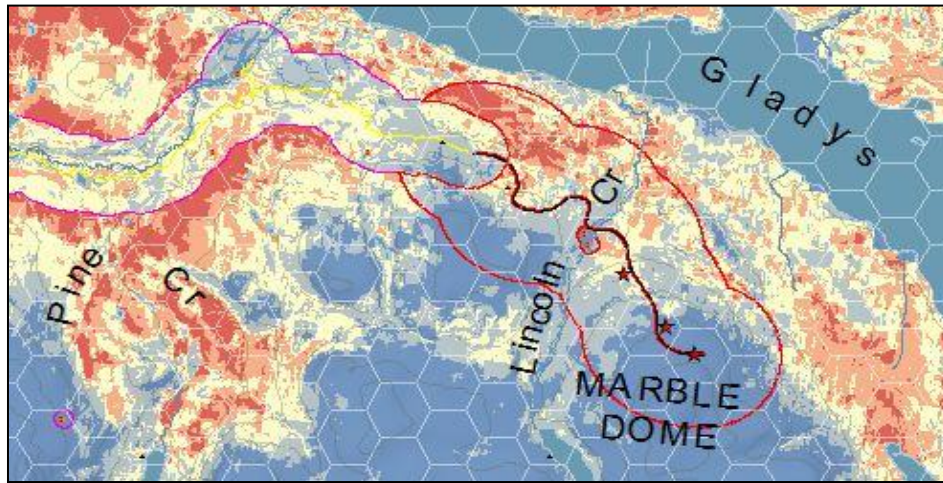
RSF Habitat Model Creator Outputs

The RSF Tool generates habitat models depicting caribou habitat quality in winter or summer, based on a specific ZOI input using Tool 1. These RFS models can be compared to the original (or reference condition) models to visualize and quantify the habitat change based on a given ZOI scenario. Output files are as follows:

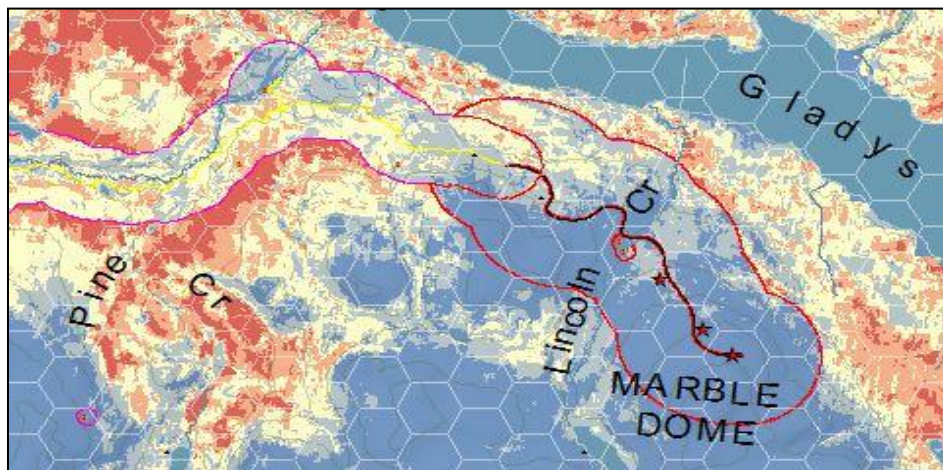
1. *Resource Selection Function model raster.* This is a raster dataset containing continuous values across space that describes the relative level of habitat quality at any given location.
2. *Classified Resource Selection Function model raster.* This is a raster dataset representing 5 natural classes based on the values found in the RSF output above. Example maps are shown on the next page.



Snapshot of RSF Tool raster outputs, in Table of Contents

Original Habitat Quality Map

Map of the original (reference condition) winter habitat quality where blue represents low quality and red represents high quality habitat.

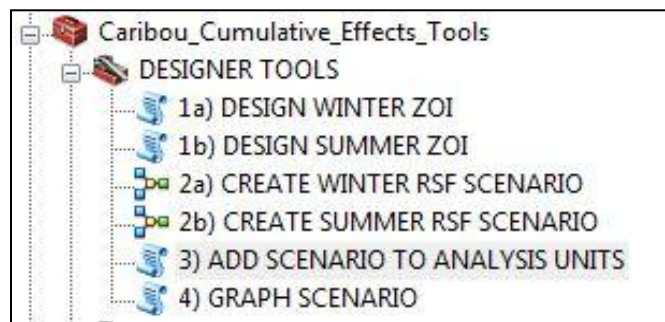
Scenario Habitat Quality Map

Map of the scenario (modeled with the new ZOI from Tool 1) winter habitat quality.

The area inside the red outline is the area that has been impacted in this scenario. It is clear that the spatial distribution of the 5 habitat classes has changed within this area. The highest value class (red) is all but removed and is replaced with lower quality habitat. The following tools allow the user to determine how much habitat in each habitat quality class (hectares of each) change in each scenario.

Tool 3: Add Scenario to Analysis Units

The Add Scenario to Analysis Units Tool enables the comparison of the change in habitat quality between the current (reference) state and the scenario created using Tools 1 and 2. This comparison is facilitated by calculating the amount (hectares) of the 5 habitat quality classes that occur within each of the analysis units (AU) that cover the study area. The AUs are a set of hexagonal polygons of standard size that cover the study area and provide a uniform spatial unit for use in describing habitat quality change at the local scale (comparison of individual AUs), or at other regional scales (comparisons between groups of AUs).



Running the Add Scenario to Analysis Units tool

To launch the tool, click on 3) *ADD SCENARIO TO ANALYSIS UNITS*. The following dialog box will be displayed, asking the user to choose the season for which AU summaries will be created, as well as the scenario name to use when creating field names in the AU attribute table, and whether or not to export the AU attribute table to Excel for use in external analysis.

A screenshot of the '3) ADD SCENARIO TO ANALYSIS UNITS' dialog box. It contains the following fields and options:

Season	Winter
Scenario Name (<= 5 characters)	scn1
Export AU Table to Excel?	No

Add Scenario to Analysis Units Tool Inputs

Add Scenario to Analysis Units Tool Outputs

The AU habitat summaries are calculated in separate fields in the AU attribute table related to each of the 5 habitat quality classes. These summaries can be automatically exported to Excel for further inspection if desired by the user. By default, the AU table contains summaries of the amount of each habitat class that currently exists in each AU, as shown below in the “reference condition” habitat summaries. Each row in the table describes values related to a single AU, therefore reading left to right across a table row paints a picture of the spatial habitat composition of that unit.

unit_id	RSFWIN_ORI	RSFSUM_ORI	RSFWIN_CL1	RSFSUM_CL1	RSFWIN_CL2	RSFSUM_CL2	RSFWIN_CL3	RSFSUM_CL3	RSFWIN_CL4	RSFSUM_CL4	RSFWIN_CL5	RSFSUM_CL5	Wimp_ORI	Simp_ORI
195	2982.8601	67.980003	0.09	93.239998	54.450001	0	27.719999	0	10.62	0	0.36	0	0	0
196	4282.0898	123.647	2.97	199.98	186.92999	0	10.08	0	0	0	0	0	0	0
197	129.481	22.969	199.89	199.89	0	0	0	0	0	0	0	0	1	1
198	1962.91	118.733	149.13	199.53	46.799999	0	3.6	0	0	0	0	0	1	1
237	3860.3501	98.651001	0	126.27	61.919998	0	60.75	0	3.6	0	0	0	0	0
238	5100.4302	173.935	0.99	199.71001	159.84	0	38.790001	0	0.09	0	0	0	0	0
239	15.8886	29.5959	199.98	199.98	0	0	0	0	0	0	0	0	1	1
240	1386.95	112.831	191.16	200.07001	8.28	0	0.63	0	0	0	0	0	1	1
241	3263.24	115.289	76.860001	199.89	107.64	0	14.22	0	1.17	0	0	0	0	0
242	6418.3398	871.84601	7.38	199.8	99.989998	0	65.699997	0	26.639999	0	0.09	0	0	0
243	4523.3701	1619.1801	42.75	198.53999	103.32	1.35	52.470001	0	1.35	0	0	0	0	0
244	3921.9399	1992.45	12.06	194.94	161.91	5.13	25.469999	0	0.63	0	0	0	0	0

Snapshot of “reference condition” fields in the AU attribute table.

Reference condition field names: The field names are included in the AU attribute table by default, as they describe the current condition of the landscape.

Unit_Id - Unique numeric codes for each analysis unit

RSFWIN_ORI – Total raw winter RSF model value, summed across all raster cells that fall in the AU

RSFSUM_ORI – Total raw summer RSF model value, summed across all raster cells that fall in the AU

RSFWIN_CL1 – Number of hectares of Class 1 winter habitat in each AU (the lowest value habitat class)

RSFSUM_CL1 – Number of hectares of Class 1 summer habitat in each AU (the lowest value habitat class)

RSFWIN_CL2 – Number of hectares of Class 2 winter habitat in each AU

RSFSUM_CL2 – Number of hectares of Class 2 summer habitat in each AU

RSFWIN_CL3 – Number of hectares of Class 3 winter habitat in each AU

RSFSUM_CL3 – Number of hectares of Class 3 summer habitat in each AU

RSFWIN_CL4 – Number of hectares of Class 4 winter habitat in each AU

RSFSUM_CL4 – Number of hectares of Class 4 summer habitat in each AU

RSFWIN_CL5 – Number of hectares of Class 5 winter habitat in each AU

RSFSUM_CL5 – Number of hectares of Class 5 summer habitat in each AU

WImp_ORI –Units that have winter habitat that is currently impacted by land use, identified by “1”

SImp_ORI –Units that have summer habitat that is currently impacted by land use, identified by “1”

The Add Scenario to Analysis Units Tool populates the table with similar fields related to the user's development scenario. Below is an example of the additional fields that are added to the AU table by the Add Scenario to Analysis Units Tool, assuming the user specified "Scn1" as the name for this scenario.

unit_id	Scn1RSFWIN	Scn1RSFSUM	Scn1WINC1	Scn1WINC2	Scn1WINC3	Scn1WINC4	Scn1WINC5	Scn1SUMC1	Scn1SUMC2	Scn1SUMC3	Scn1SUMC4	Scn1SUMC5	Scn1_WImp	Scn1_SImp
1058	7792.4102	417.69601	0	105.48	326.16	145.08	11.25	199.98	0	0	0	0	1	1
1059	5414.5898	705.39099	12.78	237.96001	172.8	39.240002	3.15	199.8	0	0	0	0	1	1
1148	5301.27	782.71997	20.52	207.72	225.99001	0.72	0	199.89	0	0	0	0	1	1
1149	7911.75	614.83698	13.95	179.10001	111.24	179.28	72	199.8	0	0	0	0	1	1
1236	875.66498	8526.6299	180.99001	36.540001	1.08	0	0	14.31	222.3	193.05	39.240002	0	1	1
1238	3549.8601	531.57501	40.77	302.76001	23.49	0	0	199.98	0	0	0	0	1	1
1323	1300.49	10981.2	176.22	45.18	4.05	0	0	0.09	166.86	293.22	75.599998	0	1	1
1324	1179.95	1189.15	184.41	30.780001	0	0	0	191.42999	16.74	0	0	0	1	1
1325	2113.95	1200.16	135.53999	128.7	0	0	0	176.22	47.34	0	0	0	1	1
1326	6756.9302	905.65601	11.79	193.5	186.84	100.08	21.15	198.81	2.52	0	0	0	1	1
1411	3724.0901	2960.8799	34.650002	291.06	56.970001	3.24	0	131.13	137.7	0	0	0	1	1
1412	995.88702	6423.04	192.24001	15.48	0	0	0	8.28	369.72	20.52	0	0	1	1

Snapshot of "scenario condition" fields in the AU attribute table.

Scenario condition field names:

Unit_Id - Unique numeric codes for each analysis unit

Scn1RSFWIN – Total raw winter RSF model value, summed across all raster cells that fall in the AU

Scn1RSFSUM – Total raw winter RSF model value, summed across all raster cells that fall in the AU

Scn1WINC1 – Number of hectares of scenario Class 1 winter habitat in each AU (the lowest value habitat class)

Scn1SUMC1 – Number of hectares of scenario Class 1 summer habitat in each AU (the lowest value habitat class)

Scn1WINC 2 – Number of hectares of scenario Class 2 winter habitat in each AU

Scn1SUMC 2 – Number of hectares of scenario Class 2 summer habitat in each AU

Scn1WINC 3 – Number of hectares of scenario Class 3 winter habitat in each AU

Scn1SUMC 3 – Number of hectares of scenario Class 3 summer habitat in each AU

Scn1WINC 4 – Number of hectares of scenario Class 4 winter habitat in each AU

Scn1SUMC 4 – Number of hectares of scenario Class 4 summer habitat in each AU

Scn1WINC 5 – Number of hectares of scenario Class 5 winter habitat in each AU

Scn1SUMC 5 – Number of hectares of scenario Class 5 summer habitat in each AU

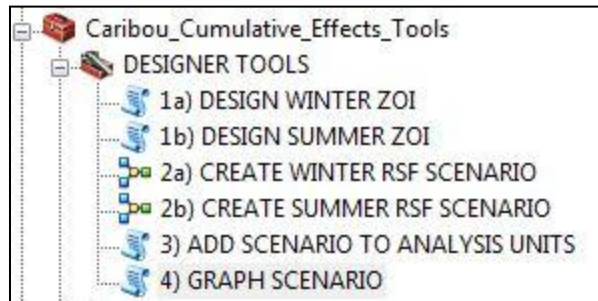
Scn1_WImp – Units that have winter habitat that is newly impacted by this land use scenario, identified by "1"

Scn1_SImp – Units that have summer habitat that newly impacted by this land use scenario, identified by "1"

Comparing the scenario summary fields with the reference condition summary fields allows the user to evaluate the magnitude of the change in habitat quality due to each scenario. By examining the AU units which are newly impacted by the scenario (identified by the fields "Scn1_WImp" and "Scn1_SImp") the user can determine the size of the impacted area for each scenario. As stated previously, each row in the AU attribute table describes values related to a single AU, therefore reading left to right across the table depicts the habitat composition of that unit. As additional scenario summaries (or real land use changes) are added to this table using tools 1-3, an emergent picture of the change in habitat quality for each AU is effectively recorded through time.

Tool 4: Graph Scenario

The Graph Scenario Tool creates graphs of habitat change that compare the reference condition of habitat to development scenarios at two different scales: the local scale (areas that are newly impacted by the scenario); and the global scale (the home range of the Atlin herd). Quantifying habitat change at different scales allows planners to make decisions that address the local impacts on habitat quality as well as the cumulative effects to the herd range as a whole.



Running the Graph Scenario tool

To launch the tool, click on *4) GRAPH SCENARIO*. The following dialog box will be displayed, asking the user to choose the season for which AU summaries will be created, the scale at which to graph results (Local vs. Global) as well as the scenario name to use when creating the local and global habitat change graphs.

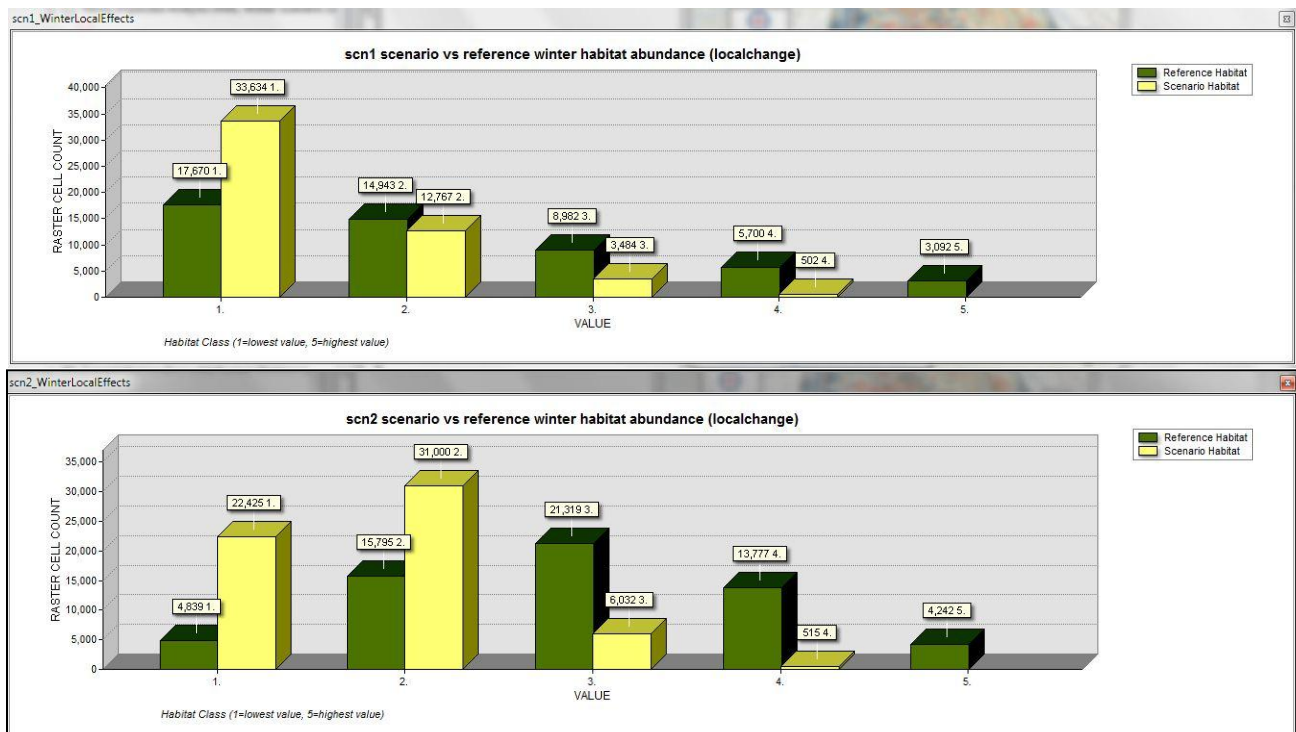
A screenshot of a dialog box titled "4) GRAPH SCENARIO". It contains three input fields: "Scenario Name" with the text "scn1", "Season" with the text "Winter", and "Scale" with the text "Local". Each field has a small icon to its left, likely for clearing or undoing the input.

Inputs to the Graph Scenario tool

Graph Scenario Tool Outputs

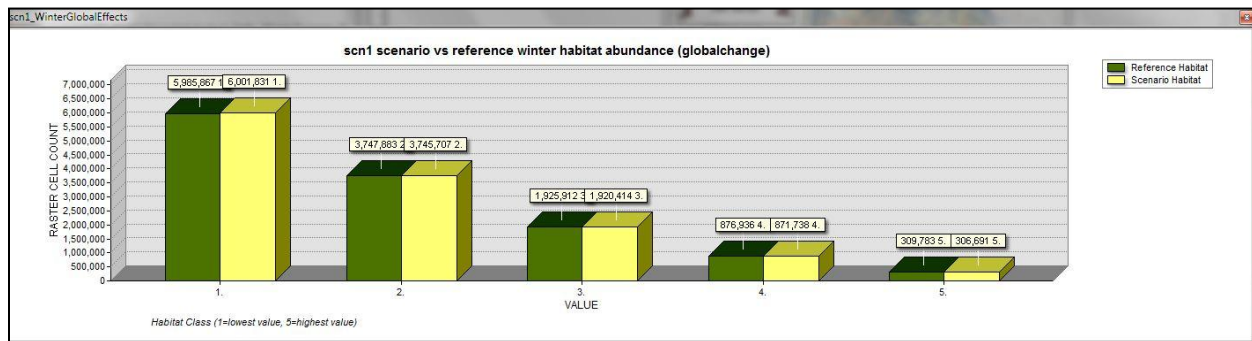
The Graph Scenario tool creates bar graphs that display the area (km²) of habitat in each of the 5 habitat quality classes for the reference condition alongside the area of each in the 5 habitat quality classes for the scenario condition. The Local Graph relates to the area impacted by the scenario and the Global Graph relates to the whole herd home range. Graphs are named based on the scenario name, season and scale for which they are created (e.g. *scn1_WinterLocalEffects*), and are output to the CARIBOU_TOOLS/ DATA/SCENARIOS/GRAPHS directory. Graphs are loaded into ArcMap using the *graph menu*, located under the drop-down menu view→graphs→load.

The Local Graphs shown below display the total area of habitat in each of the 5 habitat classes for the reference condition vs. scenarios 1 and 2. The two scenarios are in close proximity to one another and similar in terms of the number of hypothetical developments analyzed. However, they are quite different in terms of potential impacts on the area of high quality habitat. When the scenario bar (yellow) is lower than the reference bar (green), the scenario has less habitat (km²) in that habitat quality class than the reference condition. If high quality habitat is lost, then the yellow bars will be lower than the green bars for classes 3-5. This drop is associated with an increase in low quality habitat (classes 1 and 2). As you can see below, scenario 2 impacts more high quality habitat (classes 3-5) than scenario 1.



Thus, it is quite useful to be able to quickly compare the changes in habitat quality in each of the 5 habitat classes between two similar but spatially different land use scenarios.

Below is an example of a Global Graph that displays the area of habitat, by class, across the entire herd's home range. Thus, it is a snapshot of the cumulative impact of the user's newly modeled land use scenario on the total habitat available to the Atlin herd (in terms of the total area remaining in each of the habitat classes).



Discussion

The tools presented here provide the means to evaluate the effects of potential developments or land use scenarios on caribou habitat using habitat models developed for this herd. The tools are provided to the user as discrete modules that perform specific functions in order to increase their flexibility. For example, if managers wanted to avoid impacting certain areas of habitat, Tool 1 (ZOI Designer) could be run multiple times in isolation to gain quick insight into the specific areas that might be impacted under several different land use scenarios, without having to run the full RSF habitat model for each scenario. This would allow managers to determine what management scenarios to explore in more detail.

Further, the tools can be modified to answer specific questions, address cumulative effects and monitor the progression of development in an area. This presents a number of interesting implications. For example, the ZOI that are created with Tool 1 (ZOI Designer) and the subsequent RSF habitat models that are generated by Tool 2 (RSF Tool) are both driven by the specific set of land use data features that are originally input into the Tool 1 dialog box. Thus, the Tool 1 user interface (dialog box) records the spatial data of each existing and potential development. Therefore, multiple contrasting views of the landscape can be constructed simply based on the set of features included in Tool 1:

1. Running the sequence of models based on the full set of human use data creates a view of the cumulative human footprint to date across the area, and the cumulative effects to date on caribou habitat.
2. Running the models based on the full set of current impacts plus the hypothetical development data creates a view of what the potential human footprint and habitat quality would look like in the future if the hypothetical development occurred. This provides the framework for comparing and quantifying potential developments for use in decision making.
3. Running the models based on a reduced set of human use features from what actually exists today creates a view of what the caribou habitat could look like if appropriate habitat restoration removed certain human disturbances from the landscape. This last scenario implies that tradeoffs between restoration efforts and developments could be examined. Thus a proponent of a development project could identify areas to restore, as an “ecological trade” for impacts that will be realized from a proposed development.

It is important to note that modeling development scenarios does not represent the actual impact on the Atlin herd of caribou because the model cannot include the full suite of confounding factors that influence habitat selection. The nutritional quality of forage, snow accumulation, climate, predation and proximity to human development all have varying degrees of influence on habitat quality. The spatial configuration of the ZOI scenarios could have unforeseen impacts. For example the distribution of the habitat quality classes may shift, resulting in a shift in wildlife distributions to new areas. This could be an important factor in decision making if, for example, a certain development scenario tends to create habitat patterns that result in animals moving through higher risk areas in order to reach higher quality habitats, in the short term, or seasonally. An example of this might be an area that becomes surrounded by developments, effectively leaving an island of suitable high quality habitat, surrounded by higher risk and lower quality areas that must be crossed.

Development scenarios should be used as exploratory analyses that in conjunction with the best available data, opinions of local experts and collaborations with various stakeholders help inform complicated land use decisions. Detailed, on-the-ground assessments of the habitat quality of any local area proposed for development is recommended to confirm the habitat model predictions.

Management Implications

The development of GIS based tools to evaluate dynamic habitat models was initiated by the TRTFN to help inform cumulative effects management and assessment. The tools will provide a powerful suite of management monitoring capability for the northern mountain caribou herd habitats in the traditional territory of the TRTFN. Additionally, portions of the Atlin caribou range have been identified as a new Protected Area under the recently completed Draft Land Use Plan for the Atlin Taku area. This new Protected Area was identified partially because of the importance of the Atlin caribou herd (as well as other species and TRTFN land use and cultural activities). The cumulative effects tools will be useful in monitoring the effectiveness of the Protected Area in maintaining caribou habitats and managing potential future impacts across the Atlin caribou herd range.

At a broader level, Environment Canada and the Canadian Wildlife Service are currently working with other agencies and with affected First Nations to develop a population-level

Management Plan for the extent of northern mountain caribou. It is anticipated that the cumulative effects tools described here will fall well within the management recommendations of this planning effort. In the longer term, we suggest that the cumulative effects tools may prove useful for application to other northern mountain caribou herds. This is particularly true because ecological conditions and data availability are likely similar between the Atlin herd and other adjacent herds within the northern mountain population, enabling transfer of the methods and approach. Further, we believe that the utility of the tools will make them of interest to other managers, and therefore assist in advancing collaborative management by providing a uniform approach and understanding of habitat and cumulative impacts affecting caribou. These tools will be available for other interested government agencies and First Nation governments, and we would offer outreach and training to inform interested parties in the potential utility of the framework to other herds. Finally, these tools can be easily adapted to help support management of other key wildlife species such as grizzly bears, mountain goats, stone sheep and moose.

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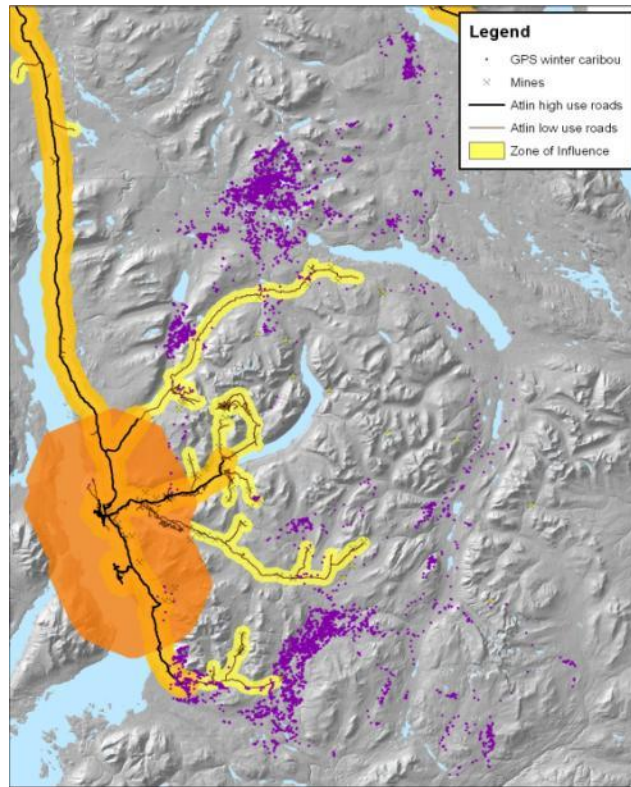
Appendix A: Zone of Influence Distances by Development Type

Reference for Tool 1 ZOI Creator

Within Tool 1 ZOI Creator, the user must enter the new point/line/polygon features and the corresponding zone of influence (ZOI) distances for each particular development type. This Appendix describes the development types and provides their associated distance buffers that should be entered into Tool 1.

Background

The ZOI is the area around human developments that caribou used less than expected when compared to other areas (Polfus et al 2010). This was measured by examining caribou locations from GPS collars. In the context of resource selection, avoidance does not indicate that caribou never occurred near developments like roads, the town of Atlin, mine sites or cabins and hunting camps, but rather, areas near these developments were used less than expected. The winter ZOI is shown to the right for the current conditions as analyzed by Polfus et al. 2010.



High Use Roads: Roads paved with chip-seal or blacktop surfaces and receive the highest amount of use, or roads that are plowed during winter. These include the Atlin highway, Surprise Lake road to Surprise Lake, Warm Bay road to Warm Bay, Lower Ruffner Mine road to lower McDonald Lake outlet bridge.

Low Use Roads: Gravel and dirt roads that are passable by 4 wheel drive vehicles excluding roads with very rough terrain and ATV trails. These include the road to Gladys Lake, Adanac mine access road, Spruce Creek road to Rose Creek cabin and O'Donnel River crossing, roads past Warm Bay to the O'Donnel River and along Wilson Creek.



Town: Town included residential development and businesses in Atlin and Five Mile Point.

Mines: Placer and hardrock mines that reported work costs of > \$50,000 to the Assessment Reporting Index System or were known to be active (had people working on site) during the summer.



Cabins or Hunting Camps: Remote cabins listed as trapline cabins or hunting camps as well as hunting camps that had active use along the road network.

Zone of Influence Buffer Distances

Each development type described above was avoided by caribou to varying degrees. The avoidance distances also varied by season. Use Table 1 for the correct distance buffer in the Tool 1 ZOI Creator.

Table 1. Seasonal ZOI for each development type that were developed using information from GPS collared caribou locations.

Development Type	Seasonal ZOI	
	Winter	Summer
High Use Road	2000 m	2000 m
Low Use Road	1000 m	1000 m
Town (Atlin)	9000 m	3000 m
Mine	250 m	2000 m
Cabin or Hunting Camp	-	1500 m