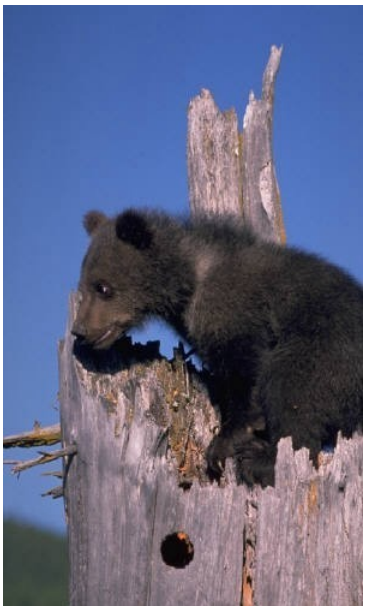
Jerome Cranston



Understanding Grizzly Bears Using GIS

Abstract

The Foothills Model Forest (FMF) is a not-for-profit partnership conducting research on sustainable forest management. The objective of the Foothills Model Forest Grizzly Bear Research Project (GBRP), one of the primary research initiatives at the FMF, is to provide resource managers with the necessary knowledge and planning tools to ensure the long-term conservation of grizzly bears in Alberta. The GBRP has collected 45,000 bear locations over 6 years from GPS radio collars, and uses ESRI software tools to model grizzly bear habitat and study the effects of human activities on grizzly bear behavior, health, and survival. Current analyses include the correlation of environmental variables, such as road density, habitat fragmentation, and vegetation, with biological indicators such as hormone levels, reproductive rates, and mortality.

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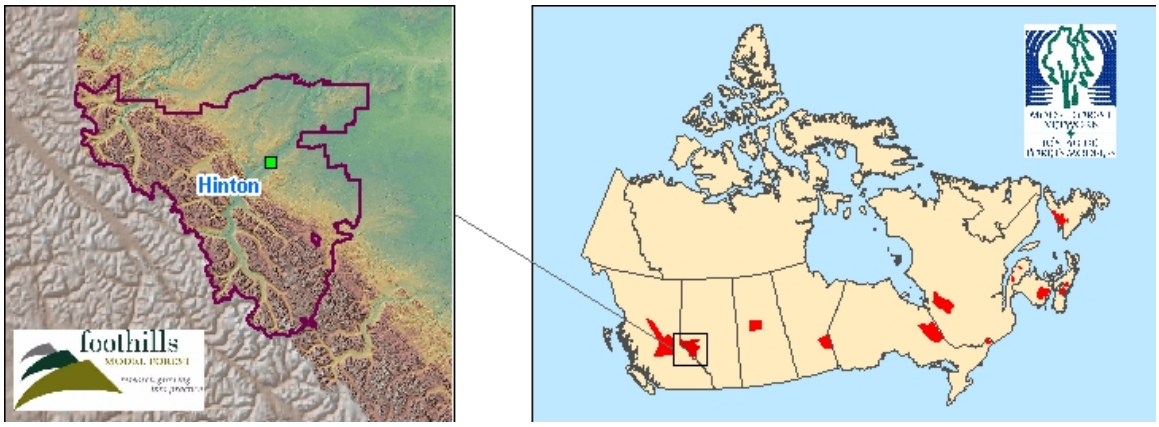
UNDERSTANDING GRIZZLY BEARS USING GIS

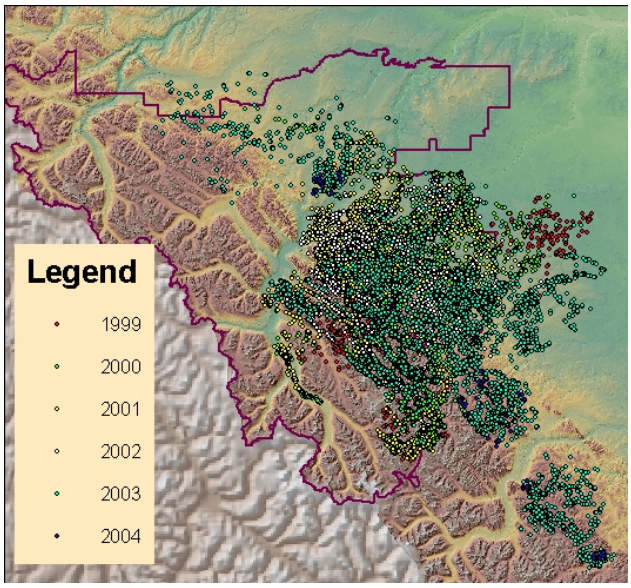
The Foothills Model Forest (FMF) is a not-for-profit corporation conducting research into sustainable forest management. Established in 1992, the FMF is one of a network of 11 model forests across Canada. Located in west central Alberta, the FMF encompasses 2.75 million hectares of alpine and boreal forest on the eastern slopes of the Canadian Rockies, and includes Jasper National Park, Wilmore Wilderness Park, Weldwood of Canada Ltd, Hinton Division's Forest Management Area, and other crown lands. Research areas include forest growth and yield, fisheries and watersheds, and natural disturbance, among others.



Map1: Canada Model Forest Network

One of the primary research initiatives at the FMF is the Grizzly Bear Research Project (GBRP). Now in its sixth year, the objective of the $4 million study, funded jointly by industry and government and directed by biologist Gordon Stenhouse, is to provide resource managers with the necessary knowledge and planning tools to ensure the long-term conservation of grizzly bears in Alberta. A conservation strategy is critical to the survival of this species, as grizzly bears face considerable pressure from human presence and habitat alteration.

GIS is an essential tool for increasing understanding of grizzly bears within the study area, and for extending this understanding to managers seeking to accommodate the needs of grizzly bears in land and resource planning. The GBRP has collected 45,000 grizzly bear locations using GPS radio collars, as shown in Map. 2. By overlaying these points with landscape models in a GIS, questions relating to grizzly bear movement, interaction, habitat, and population viability can be readily explored. Innovative cartographic visualization tools such as 3D Analyst, World Construction Set (WCS), and Visual Nature Studio (VNS) help to communicate the research findings to a wider audience.



Map 2: Grizzly Bear GPS Locations

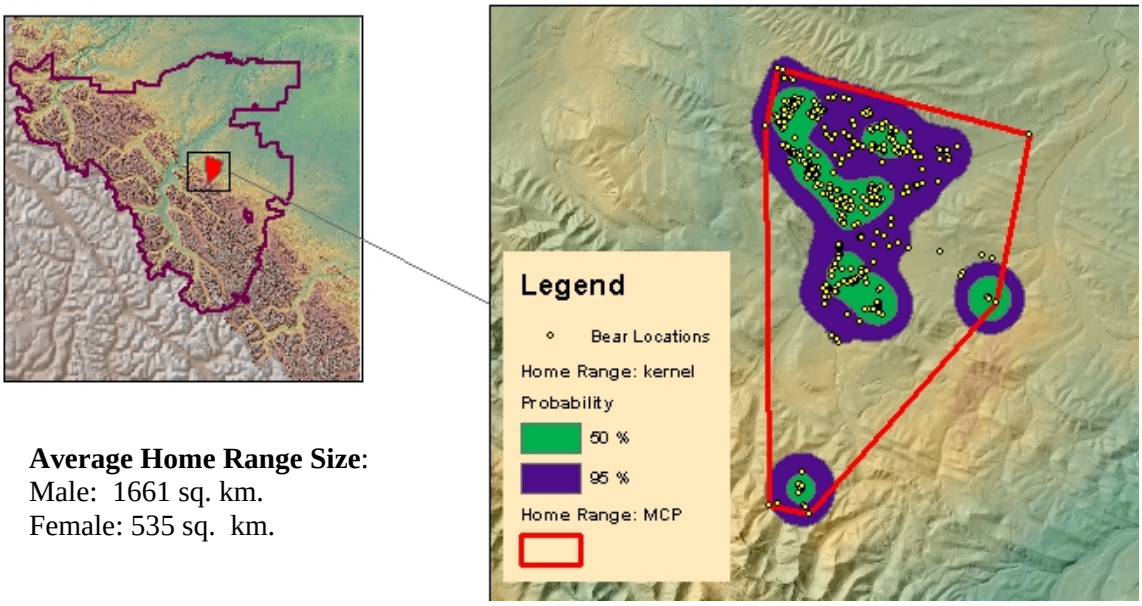
Grizzly Bear Modeling

Spatial grizzly bear data comes primarily from GPS collars. To date, 56 bears have been captured in snares, or through aerial darting, and fitted with GPS radio collars and radiotelemetry ear tags to aid in aerial tracking. Some bears are also equipped with temperature sensors and digital cameras. Other information collected during capture includes DNA samples, health and biometric data (Fig. 1). Collars are programmed to collect GPS fixes every 4 hours, and can be triggered to fall off by remote control for later retrieval. Stored waypoints are uploaded every few weeks to airborne receivers.

Fig. 1: Capture (Photo by: J. Saunders)

Location data is stored as UTM coordinates in a Microsoft Access database and converted to coverage format using an Arc Macro Language™ (AML) script. Maps are created using ArcGIS 8.3 running on a Windows NT platform. Other AMLs[1] perform validation checks, compile and analyze home range coverages, and calculate statistics on bear movement.

Home range polygons, both MCP (Minimum Convex Polygon) and kernel, are generated using the Animal Movement extension of ArcView 3.2. The MCP is a simple polygon enclosing the outermost points of a set, whereas the kernel is a contour on a point density surface within which is a specific probability of finding a point. The kernel home range is considered a better reflection of a bear's actual territory than the MCP, as it is less likely to be influenced by outlier points, as shown in Map 3.



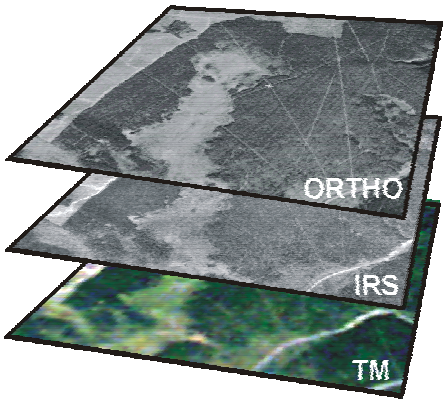
Average Home Range Size:
Male: 1661 sq. km.
Female: 535 sq. km.

Map 3: Grizzly Bear Home Ranges, MCP and Kernel

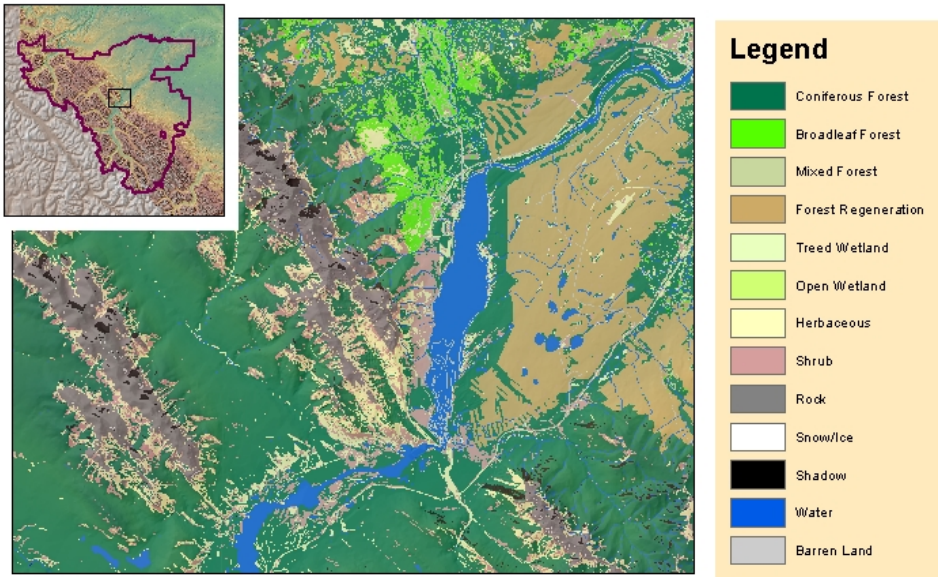
[1]developed by Julie Duval of the FMF

Landscape Modeling

What does the landscape look like to a grizzly bear?



While aerial orthophotos of the study area provide a useful cartographic aid, imagery collected from Landsat 7 TM satellites forms the basis of landscape modeling. Greg McDermid (2004) from the University of Calgary has created the Integrated Decision Tree (IDT) map by classifying the raw imagery into 13 land cover classes. The classified image is then combined with vector GIS layers such as hydrography (streams), linear access features (roads and seismic cutlines), energy facilities such as pipelines and well sites, and AVI (Alberta Vegetation Inventory), a fine-scale forest cover and vegetation layer. This approach ensures that the map includes smaller features that may be missed by the 30m-resolution satellite images. Vegetation plots are also established in the field to verify the IDT classifications. A portion of the map is shown below.



Map 4: Integrated Decision Tree (IDT) Land Cover

The IDT map (Map 4) is then combined with grizzly bear points by Scott Nielsen of the University of Alberta to create the Resource Selection Function (RSF) maps (Nielsen, 2004). The RSF raster is a probability surface that reflects the relative attraction of a particular location to a bear (Fig. 2). The RSF subdivides land cover classes according to aspect, elevation, proximity to other features, etc. and assigns a selection coefficient to each polygon based on a comparison of the number of points predicted to randomly fall

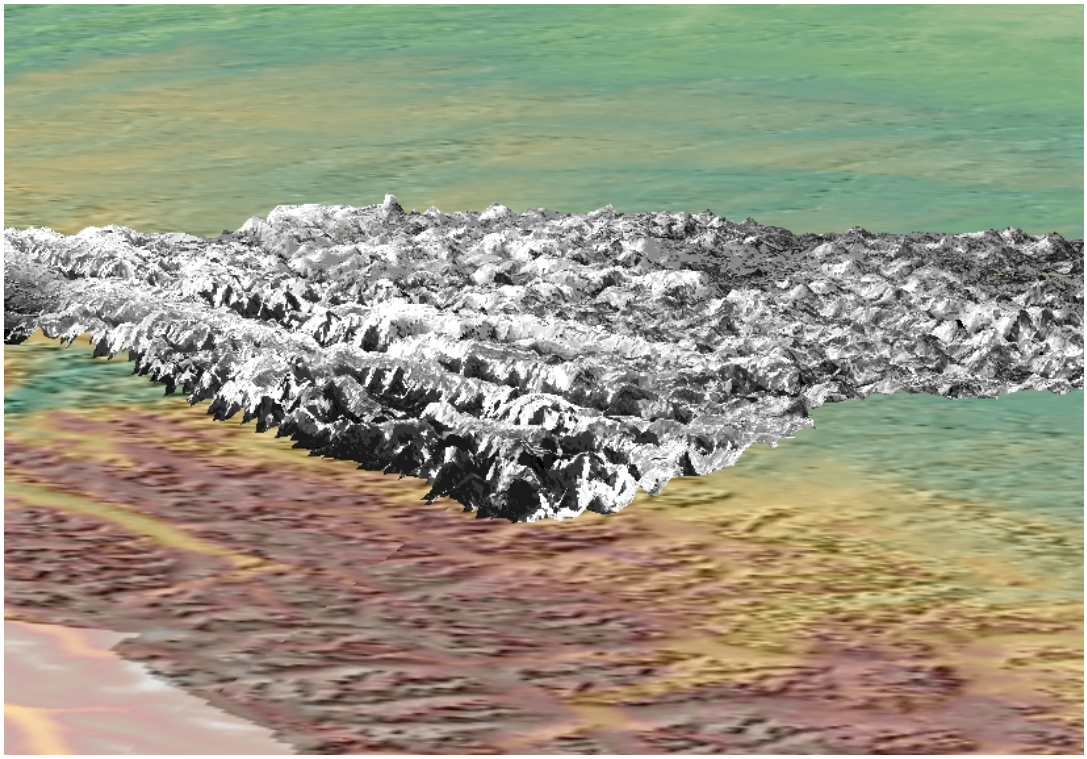


Fig. 2: Resource Selection Function (RSF) surface

inside it, with the actual distribution of bear points. A randomly chosen subset of the bear data is withheld for later model validation and refinement. The RSF map is not a habitat map per se, as the term “resource” refers to any natural features used by a bear, whether a berry patch selected for food, a fallen tree used for denning, or a forest canopy for cover (Nielsen, 2004). Since resource selection varies widely by age, sex, and season (Nielsen, 2004), RSF maps are generated separately for each sex-age group (adult male, adult female, and subadult) and season (preberry and postberry).

Analysis

The most powerful feature of GIS is the ability to do spatial overlays of discrete datasets. This technique has allowed GIS to provide answers to many of the questions posed by the GBRP. Some of the major research questions are:

- ***How do home range characteristics relate to grizzly bear health?***

Home ranges for each bear (95% kernel) were analyzed to determine statistics for IDT land cover distribution, and characteristics such as road density, greenness (as derived from Landsat 7), and fragmentation.

It was found that there is a strong negative correlation, for example, between population level survival rates and road density, as calculated by the Spatial Analyst density function (Boulanger, 2003). Bears are attracted to areas of high road density because of foraging

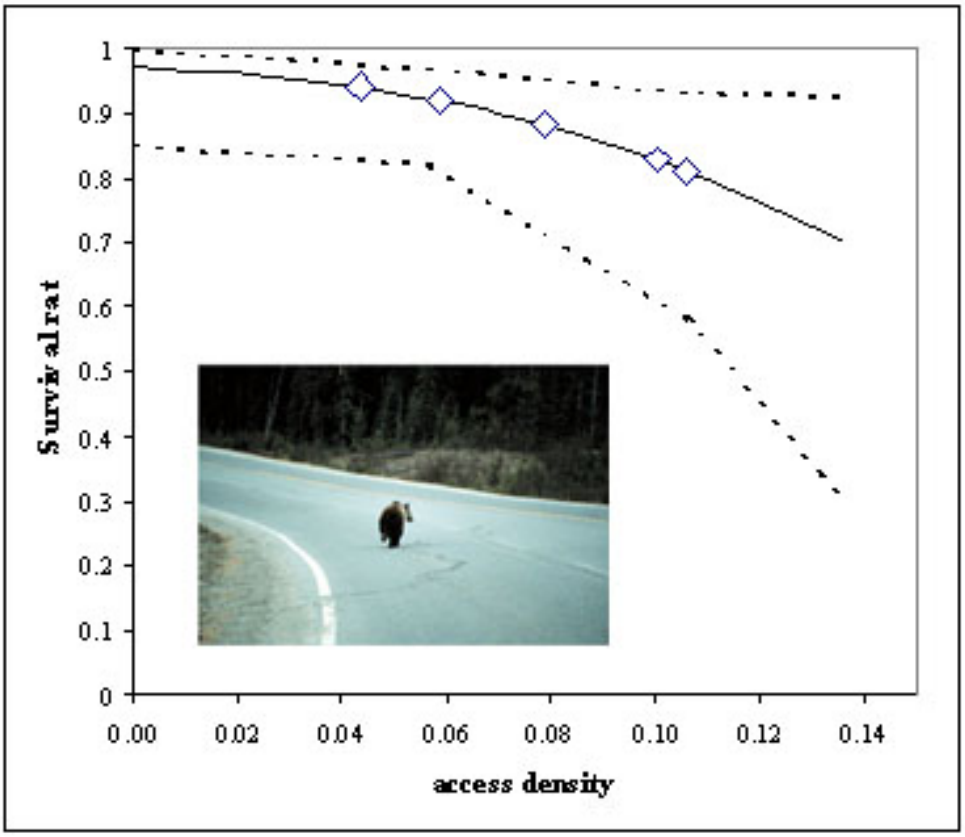


Fig. 3: Survival Rate vs. Access Density

opportunities along roads and in associated cutblocks (Gibeau and Heuer, 1996) where they are vulnerable to poaching and vehicle collisions. Fig. 3 shows how survival rates decrease with increasing road density, expressed in km/km^2. Dashed lines indicate confidence intervals.

- ***How can locations be distinguished between travel and use?***

A bear's speed is determined by an AML that calculates the Euclidian distance[2] between successive points for each bear and divides it by the time interval between them. Rate of movement can be symbolized by extruding each path segment in ArcScene, as illustrated below.

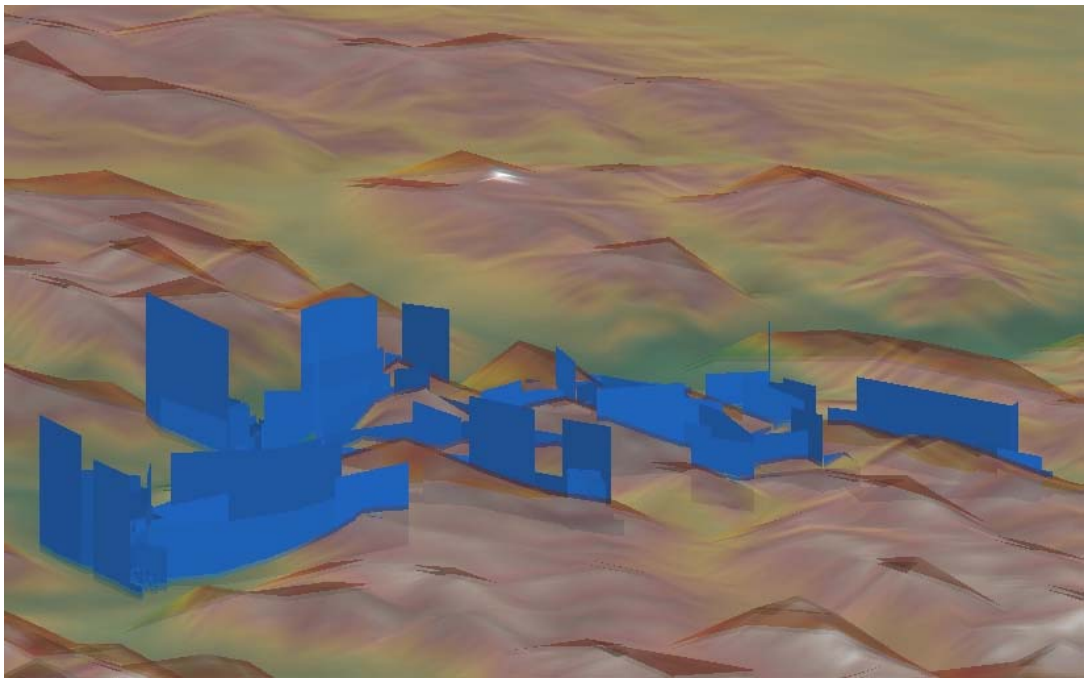


Fig. 4: Average Speed

[2] The distance *d* between points (x_1y_1) and (x_2y_2) is given by $d = [(x_2-x_1)^2 + (y_2-y_1)^2]^{1/2}$

A histogram of average speed by land cover class is shown below.

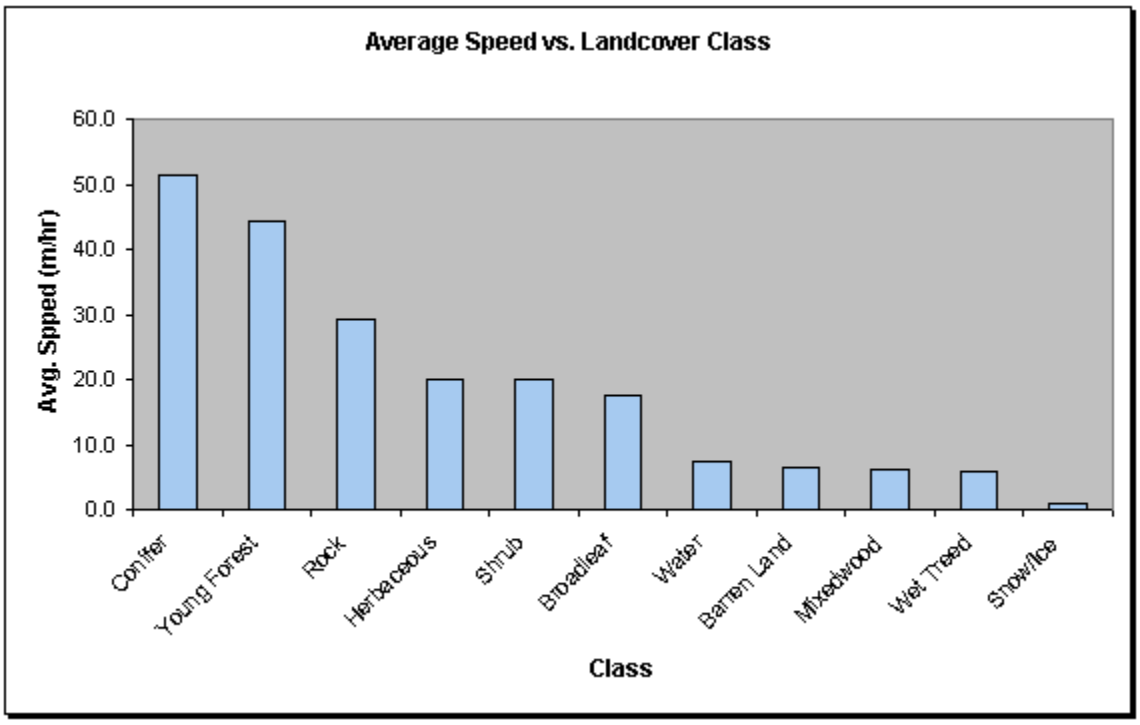
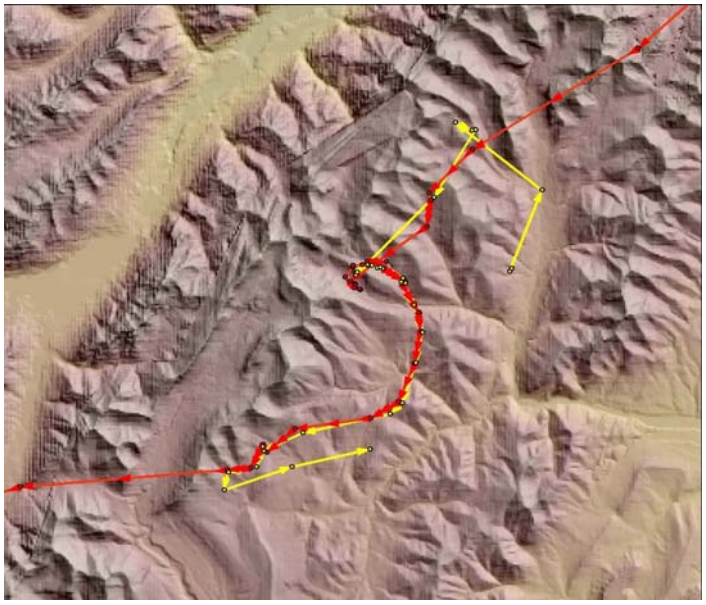


Fig. 5: Average Speed vs. Land Cover Class

The chart shown in Fig. 5 suggests that bear movement is slower in areas with greater food supply, such as shrub, herbaceous, and riparian polygons (and roadways, which are classified by the IDT map as barren lands), whereas bears tend to travel more quickly through areas where food or cover is sparser, such as coniferous and regenerating forests.

- ***How often do bears associate?***

Another AML script cursors through the points in the database and searches for bear pairs that have been within 500m of each other within 3 hrs, the criteria for a non-random association. Statistical methods are used to distinguish between static interactions, resulting from concurrent use of travel corridors or food patches, and dynamic interactions, in which bears interact deliberately for mating or other biological reasons. It was found that bears spent, on average, 10% of their time associating with other bears Stenhouse et al, 2004). Same-sex associations were considerably shorter than male-



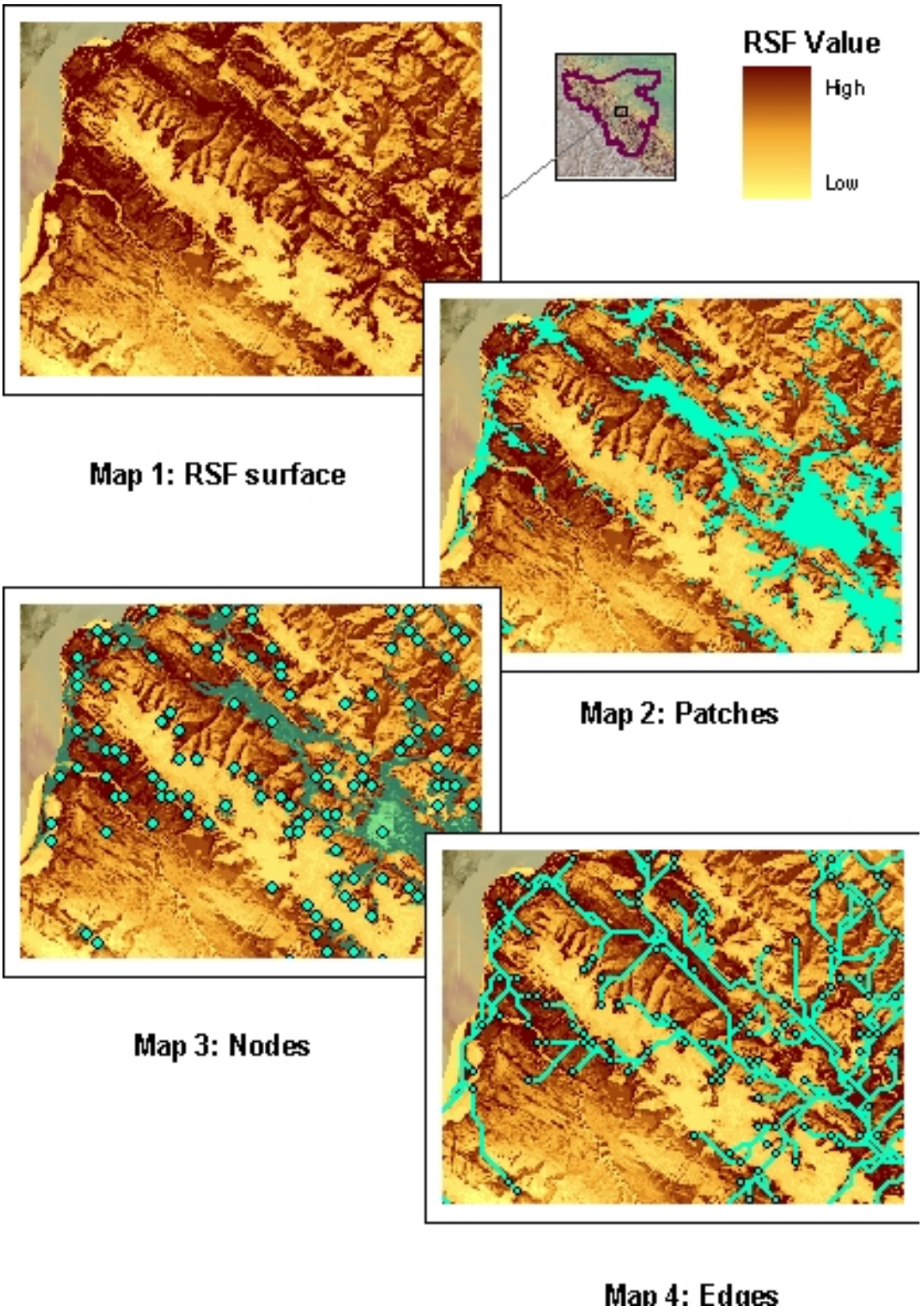
female associations. Male bears interacted with an average of 1.8 partners per year, female bears with only 1.2 partners. Map 5 shows the path of a male bear (in red) as it follows a female (in yellow) over a 4-day period in the summer of 1999.

Map 5: Association

- ***Is the landscape becoming fragmented?***

A major concern in conservation biology is whether the proliferation of roads and cutblocks is reducing bear habitat to isolated islands (Schwab, 2003; Rosenberg et al, 1997; Beier and Noss, 1998). To model and quantify landscape connectivity, Barb Schwab of the University of Calgary turned to a branch of mathematics known as graph theory, originally used to model transportation and utility networks (Schwab, 2003). On an RSF grid, pixels with an RSF score greater than 1.5 standard deviations above the mean are converted to polygons known as patches. The centroid of each patch is generated and is called a node. Every node is then connected to every other node by lines, called edges, that follow a least-cost path along the RSF surface. The collection of edges and nodes is called a graph.

The degree of connectivity of the graph is expressed by the α index, which is the ratio of the actual number of edges in a graph with *x* nodes, to the maximum possible number *y*. If the length of an edge is greater than a specified "threshold distance," such as the average daily movement of a bear, the connection is deleted from the graph, and the connectivity index is correspondingly reduced.



Map 6: Graph Theory patches, nodes, and edges

The following histogram (Fig. 6) shows the distribution of bear points around edges and was created by buffering the edges by increments and intersecting the buffers with bear points. It is apparent that there are significantly more bear points within 100m of the graph theory edges than would be expected by chance.

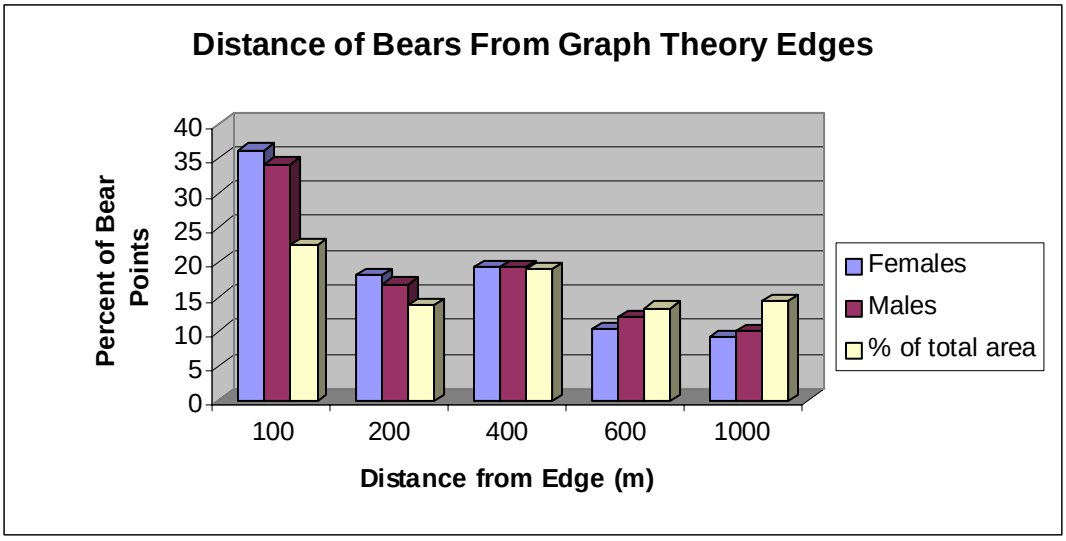


Fig. 6: Distribution of Bear Points Around Graph Theory Edges

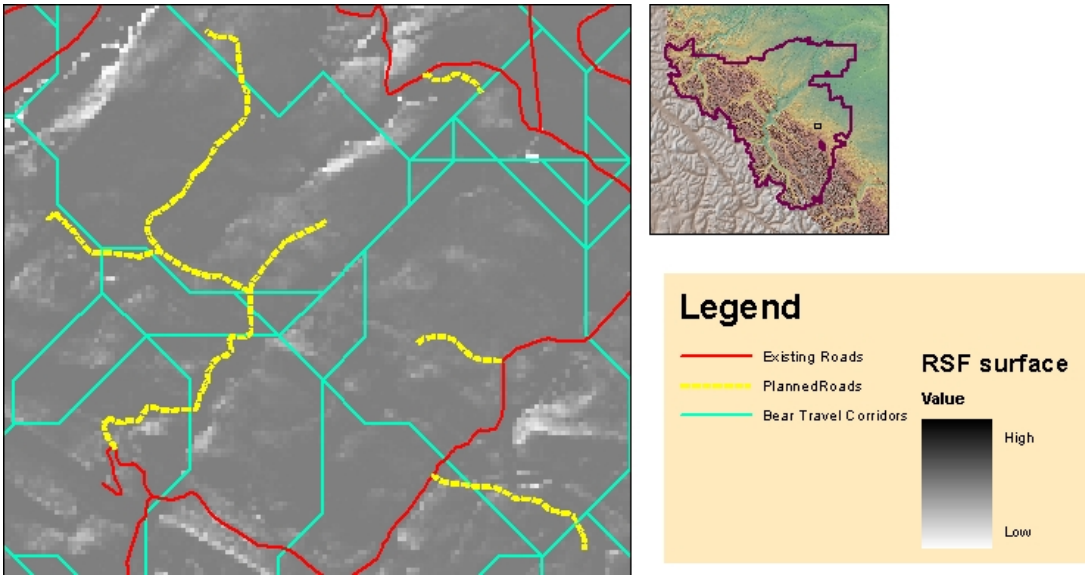
- ***What are the long-term consequences for bear populations of future human development?***

The Forestry Corp., in Edmonton, Alberta, worked with researchers to apply a spatial scenario modeling tool called Patchworks, developed by Spatial Software Solutions, to determine the impact of future development scenarios on grizzly bear populations. The program allows the user to define parameters such as average cutblock size, target volumes, and biodiversity goals (forest age class distribution).With each iteration the model constructs roads, well sites, and forestry cutblocks on a digital landscape, from which RSF maps can be derived. This analysis is currently in progress and results have not yet been published.

Visualization

The value of the research done at the FMF would be lost without the means to communicate it to a wider audience. GIS lends credence to the adage that "a picture is worth a thousand words," by presenting complex scientific findings in clear and aesthetically pleasing images. Recent advances in 3D imaging (3D Analyst, WCS) and animation (VNS) take the traditional medium of maps into the third and temporal dimensions.

The FMF is presently in the second year of its third five-year phase. The objective of Phase III is "putting research into practice," by developing the findings from Phase I and II into practical tools for land and resource managers. The cartographic functions of GIS are central to this purpose. The following map shows how concepts such as RSF and movement corridors can be applied to forest development. To understand how forest development will impact on grizzly bears, a planned roads layer is superimposed on an



Map 7: Planned Roads

RSF surface and graph theory layer (Map 7). It is obvious that many of the proposed roads cut through high-selection habitat, and either bisect or overlie important travel corridors. By converting the planned roads to a raster and multiplying with the RSF

surface using the Spatial Analyst Raster Calculator, an RSF score can be calculated for each road segment. Fig. 7 depicts an ArcScene perspective of the planned roads and RSF surface shown in Map 7, with each line segment extruded by its cumulative RSF score. This allows planners to quantify the advantages of using alternate routes, or planning for winter-only access, when bears are denning.

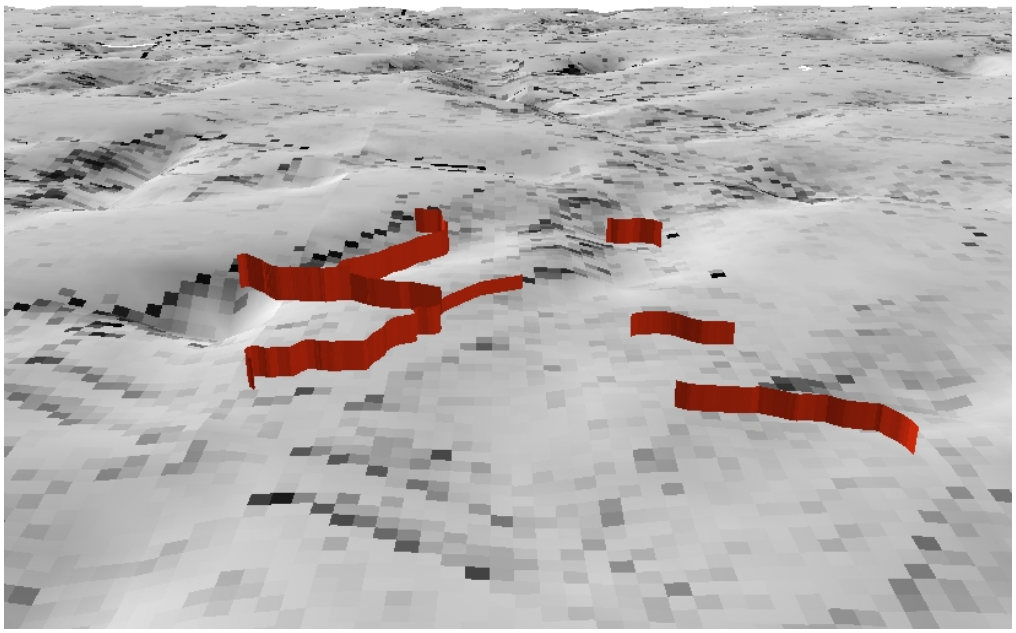
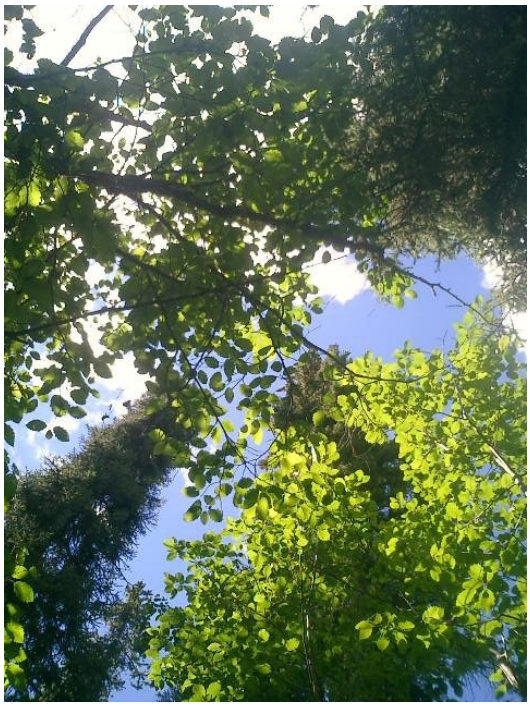


Fig. 7: Planned Roads on RSF Surface

CONCLUSION

The capability of GIS to store, query, analyze, and visualize data has been an integral part of grizzly bear research at the FMF. GPS location data from collared bears has been combined with digital landscape data from satellite imagery to create models suitable for analysis. This has enabled the GBRP to explore questions relating to grizzly bear movement, interaction, habitat, and population viability, and to communicate the results of this research to its intended users.



(Photo by: G007)

Fig. 8: What the Bear Sees

The picture on the left (Fig. 8) was taken with a digital camera mounted on a grizzly bear's GPS collar. Although it is the role of GIS analysts to represent real-world features as digital abstractions, pictures like this serve as a reminder that the subjects of this research are not just points on a map, but living creatures with their own homes, families, and personalities. GIS, like the collar-mounted digital camera, allows us to see the world through the eyes of a grizzly bear, and gain insight into the lives of these magnificent animals.

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Jerome Cranston
GIS Specialist
Foothills Model Forest
Box 6330
Hinton, AB
T7V 1X6
Ph. (780) 865-8260
email: Jerome.Cranston@gov.ab.ca
website: www.fmf.ab.ca