Deer habitat in a visualized programming environment

Donald G. Morgan, Marvin Eng, Rick E. Page, and R. Scott McNay,
British Columbia Forest Service, Research Branch, 31 Bastion Square,
Victoria, BC, V8W 3E7 Canada

Abstract

We are using an object-oriented decision support system spreadsheet that links habitat models directly to the GIS maps required to determine interspersion of habitat requirements. Advantages include interaction in real time, and models are complete (any necessary level of complexity can be incorporated) with open architecture. Validation of the various black-tailed deer (*Odocoileus hemionus columbianus*) models is facilitated with the use of 10,000 actual telemetry locations of deer on Vancouver Island. Prediction accuracy is higher than with other models used in the past.

Introduction

To achieve wildlife management objectives in increasingly modified landscapes, integrated habitat management has had to increase in scope and scale. In coastal British Columbia, for example, approximately 100,000 black-tailed deer (*Odocoileus hemionus columbianus*) died from lack of appropriate winter habitat during the severe winter of 1968-69. Rapid and wide-spread harvesting of winter habitat was believed to have contributed to the catastrophic event. Consequently, to maintain long-term population viability for black-tailed deer, managers needed a better understanding of seasonal habitats required over large areas. In response to the immediate need for management action, old-growth forests were temporarily deferred from harvesting in some areas on Vancouver Island. Still, resolution of conflict between forest managers who want to maximize fibre extraction from forests, and wildlife managers wishing to maximize wildlife habitat values, required the initiation of black-tailed deer research two decades ago. We present a brief review of this modelling evolution, ultimately leading to implementation of an object-oriented model (OOM). We introduce some key concepts of object-oriented programming and discuss its application in wildlife habitat modelling.

Our review is based on an investigation of habitat use by 31 radio-collared, black-tailed deer located weekly ($\underline{n}$ = 7623 re-locations) at a 225 km^2 area of the Nanaimo River watershed on south-eastern Vancouver Island, BC, Canada (McNay and Doyle 1987). Once entirely old growth, this area is presently a mixture of old growth, second growth, and recent clearcuts. Steep U-shaped valleys are oriented east to west providing favourable topography for deer winter range. Throughout most modelling efforts, the availability of nutritious forage (in all seasons) and the proximity of cover from snow (in winter) represent the main model components. That emphasis was derived from the knowledge that deer survival is limited by their ability to over-winter in a healthy state (Harestad et al. 1982, Bunnell 1985). In winter, forest cover provides both thermal protection and snow interception that maintains forage availability. The accessibility and quantity of winter cover becomes critical during severe winters when the energetic costs of movement escalate (Parker et al. 1984) and quality of forage declines (Rochelle 1980).

The value of food and cover varies with season and topography following seasonal trends in soil moisture and nutrients as those factors are modified by elevation and aspect. Need for food and cover also varies seasonally and with deer sex and age class (Parker et al. 1993). The seasonal variations are complicated because winter weather in coastal BC is ephemeral with severe winters reoccurring once in 18 years. As a result, the need for, and the suitability of, a site varies between years depending on winter conditions. Expansion of site-specific habitat characteristics into temporally dynamic conditions led to the need to model summer habitats and both mild- and severe-winter habitats. Also, three different migration tactics have been associated with these seasonal habitats, each with their own specific patterns for use of space (McNay and Bunnell this vol.). Hence, spatial constraints at two scales (i.e., between seasonal ranges, and between food and cover within a seasonal range) have been recognized as important aspects of black-tailed deer ecology.

Wildlife habitat models are an attempt to abstract the natural history of a species to explain the spatial and temporal variations in terms of biotic and abiotic components. Some modelling difficulties arise because processes occur at a variety of temporal and spatial scales. Also, habitat use is affected by various behavioural and population regulating factors such as inter- and intra-specific competition, population structure, recruitment, dispersal, predation, and site fidelity. Lags in response to habitat changes may hide evolutionary, stable habitat-use tactics through a variety of climatic fluctuations such as cyclical severe winters. Simplification of these obviously complex relationships affecting black-tailed deer natality and mortality is necessary to understand and integrate deer habitat needs into forest management.

Model history

Word models

Historically, operational forestry plans were reviewed for negative impacts on wildlife. Managers consulted paper maps to determine landscape suitability for winter deer habitat and altered stand harvest prescriptions to accommodate required deer winter range. Important factors such as topography, cover, seasonal food availability, and habitat interspersion were manually identified. These knowledge-based decision word models provided realistic and useful results but lacked quantitative measures of proximity and interspersion of habitat types (McNay et al. 1987).

Binary models

An expert system called Prospector II (Campbell et al. 1982) was used to quantify word model rules in a binary format. Five winter habitat categories were identified: quality of food, quality of cover, suitable aspect, proximity to food, and proximity to cover. Habitat types were assigned a 0 or 1 based on their suitability to deer. Spatial needs of black-tailed deer were incorporated into the model by including the proximity-to-food and proximity-to-cover variables, thus altering the value of a habitat unit based on proximity of a habitat patch to food or cover (McNay et al. 1987). For each habitat patch a final score was generated by summing up the binary variables for the five habitat categories.

GIS models

GIS-based models expanded upon the binary variable technique by assigning expert-derived habitat scores to the habitat categories. The original model of winter habitat suitability is described in Eng et al. (1989). Food and cover are required on a daily basis and must be available in close proximity. The closer these habitat types are together, the higher quality that area is for black-tailed deer. The ability of a specific site to provide quality food and cover is constrained by elevation and aspect. Higher-altitude northern slopes retain snow for longer periods, and at greater depths, decreasing the quality of those sites. Polygons representing different ecosystem types within the study area were classified according to vegetation successional stage. An expert-based scoring system, between 0 and 1, was applied to the sites to describe forage and cover qualities under different weather conditions. The resulting map contained the scores of mild-winter food and cover and severe-winter food and cover for each polygon. Maps of distance buffers were generated around favourable food and cover polygons. The width of these buffers was related to the likelihood that a deer would move a certain distance under different seasonal conditions as indicated by previous research (Kremsater and Bunnell 1989).

Aspect and elevation polygons for the study area were manually delineated on 1:50,000 scale topographical maps. Field biologists scored combined aspect/elevation polygons from 0 to 1 based on expected heat loading for each polygon.

Maps of each of the scored habitat categories were combined in the GIS to generate a composite map. The resulting data from the composite map were exported to a data base where a model equation was applied to the habitat category data in each habitat polygon for severe [1] and mild [2] winter scenarios:

$$Qsev= (((1-(1-F)**1.0*(1-C)**1.0)**0.5)**1.5 *SFD**0.75*SCD**0.75)**0.333*AE \quad [1]$$

$$Qmild= (((1-(1-F)**1.6*(1-C)**0.4)**0.5)**1.5 *MFD**0.75*MCD**0.75)**0.333*AE**0.5 \quad [2]$$

where:

Qsev = habitat quality value in severe winter conditions; Qmild = habitat quality value in mild winter conditions; F = the winter food quality rating; C = the winter cover quality rating; SFD = the proximity to quality food severe winter rating; SCD = the proximity to quality cover severe winter rating ($C \geq 0.7$); MFD = the proximity to quality food mild winter rating; MCD = the proximity to quality cover mild winter rating ($C \geq 0.1$); and AE = the combined aspect/elevation rating.

To clarify the model equation, if the food and cover rating for a habitat polygon is high, then the location has the potential to be of high quality to black-tailed deer as expressed by the inverse geometric mean of these two scores (i.e., the food score and the cover score). Alternatively, if a habitat polygon has high quality black-tailed deer cover and is in proximity to a polygon with quality food, then it too would be scored as high quality deer habitat. Similarly a habitat polygon would be scored high if it has high quality food and is close to quality cover. This compensatory relationship is expressed in the modelling equation by using the weighted geometric mean of scores for a) the average value for food and cover, b) the distance to food, and c) the distance to cover. Aspect and elevation are limiting factors; therefore, the weighted geometric mean of food and cover and their proximity to food/cover was multiplied by a combined aspect and elevation score to generate the final score for severe or mild winter conditions within an individual habitat polygon.

Some unfortunate limitations became obvious with the standard GIS approach to wildlife modelling. Considerable effort was required to modify the model to respond to changes in any of the input data. For example, if a habitat score needed adjustment, new maps had to be generated, overlays redone, and new evaluations made. Any "game playing" to investigate model sensitivity was severely limited by the time required to assess results. Finally, successive overlays resulted in very complex maps so any mistakes made with the input data were usually hidden.

Object oriented modelling

The rules of previous models were translated into an OOM environment to reduce the effort required in adjusting model parameters. Parameter adjustment was deemed the next step in learning more about the natural history of black-tailed deer.

Objects in habitat modelling

Objects are polymorphic, so the same message can be sent to different objects and they will respond in their own unique fashion. Objects are "building blocks" to more complex objects that inherit information from their parts but represent it in a new form. They maintain dependence so that changing building-block objects changes the more complex object that contains them. In short, interactions between objects do not have to be re-evaluated since they are updated automatically.

Objects in habitat modelling can take on a variety of forms. A single piece of data such as elevation at a point, or collections of data like deer telemetry locations or maps of deer cover, can be represented as objects. Functions can be applied to data to generate new objects such as buffers around habitat units. Elaborate formulas can be applied to a series of maps to create even more complex objects.

Object-oriented modelling environment

We used a decision support system based on OOM called Facet (Facet Decision Systems Inc., Vancouver, BC), that operates much like a traditional spreadsheet. The habitat model described above, and all of its components, were treated as one complex object. Cells of the spreadsheet contained objects, such as numbers, data, formulas, images, maps, nested spreadsheets, and model expressions. Another advantage of Facet is that spreadsheet cells could be combined with more power than in a traditional spreadsheet using mathematical and statistical expressions. Hence, spreadsheet cells can be examined as numeric data, maps, or graphs simultaneously. Changes in the spreadsheet update the data, maps, and graphs automatically, similar to a traditional spreadsheet. As one cell in the spreadsheet changes, other cells dependent on it are re-calculated. Processing time is improved by updating only the data, maps, and graphs currently displayed; other nested spreadsheets or maps are updated only when they are invoked.

Deer and their habitat as objects

Each map layer (quality of food, quality of winter cover, distance to food, distance to cover, and aspect/elevation) was encapsulated as an object within its own spreadsheet. It could be displayed as a map or as habitat polygons scores. The main spreadsheet accessed the underlying objects and combined them with severe- and mild-winter modelling equations.

Generic maps were created for habitat polygons, elevation, and aspect by converting the original GIS vectors into polygonal rasters in the Facet system. A matrix data structure was used to represent the polygonal raster, where a matrix position corresponded to an individual raster position within the study area. Specific thematic maps were generated by using a look-up table (LUT) to access a remote data base containing the thematic scores for specific polygons. The LUT uses the spatial coordinates for polygon identity codes as the link to the data base. Matrix values, for a particular theme, were derived by assigning the value at the study area raster position to a corresponding matrix position. Figure 1 shows the results of a LUT being used to access a data base containing food scores to generate a food quality map.

Food scores could be changed and compared with the original scores in graphs and maps to examine relationships and thresholds. A graph of adjusted food scores compared to original scores is presented in Figure 2. Habitat model results changed simultaneously so that the influences of

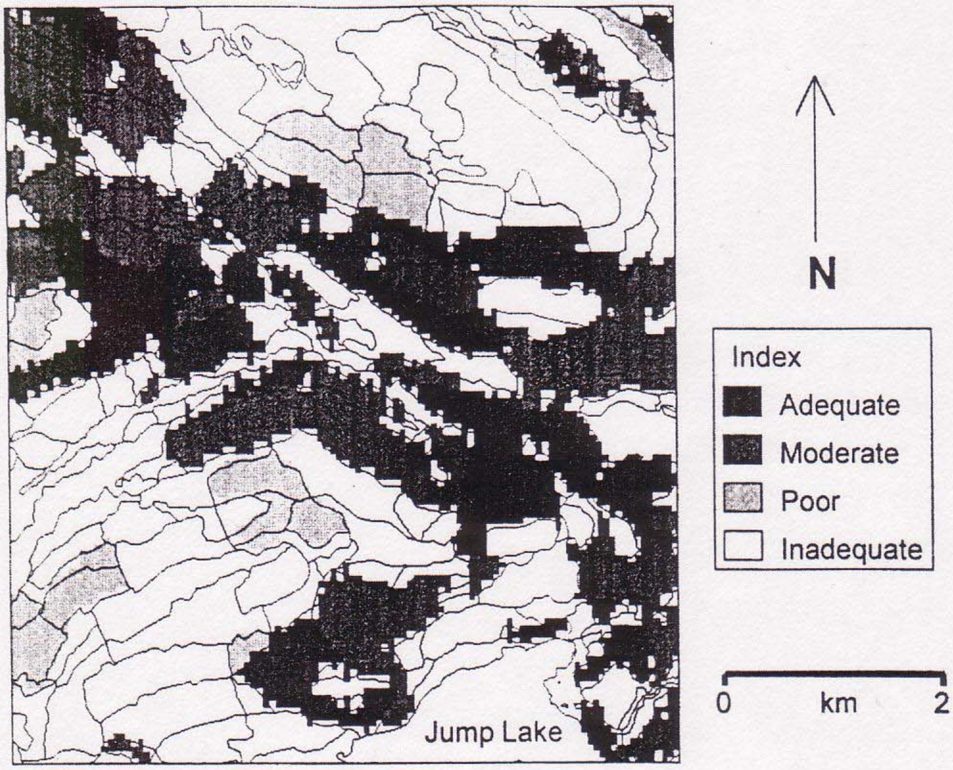

Figure 1. Black-tailed deer food quality map in the Nanaimo River watershed.

score modification could be assessed. In this way, food scores could be interactively fine-tuned and model sensitivity examined. Similar operations were performed on aspect and elevation.

Maps representing the distance to high quality food and cover habitat were generated by using a linear decay function from the boundary of a high quality polygon to the assumed maximum movement based on season and snow depth. These 'distance to' maps inherited data from the cover or food maps, so that when they changed, they immediately affected the proximity maps since they were subclasses of the food and cover maps. Finally, black-tailed deer locations were also modelled as objects. Season-specific telemetry data were used to calibrate the Facet model. Deer locations were compared with habitat availability within the study area to examine the relationship of habitat use and availability. Individual-based population models could, in the future, be combined into overall population response and data-driven empirical habitat models generated. Figure 3 shows the results of the original model equation used to assess the components in the object-oriented programming spreadsheet format.

Advantages of object-oriented models

To summarize, the habitat model could be presented as real-world constructs, reducing its apparent complexity and hence increasing its accessibility to those not trained in the technical aspects of GIS operation. Among the specific advantages we found working with OOP are the following: a library can be maintained of methods and objects for future projects; data can be updated and extended, facilitating maintenance of the model; new data can be used in the model with a minimum of adjustment necessary; and, since the model is contained within a single programming environment, future work will not require a paper chase to try and determine the steps taken to generate the model, promoting reusability.

Associated with the clear advantages is higher initial development time and cost for

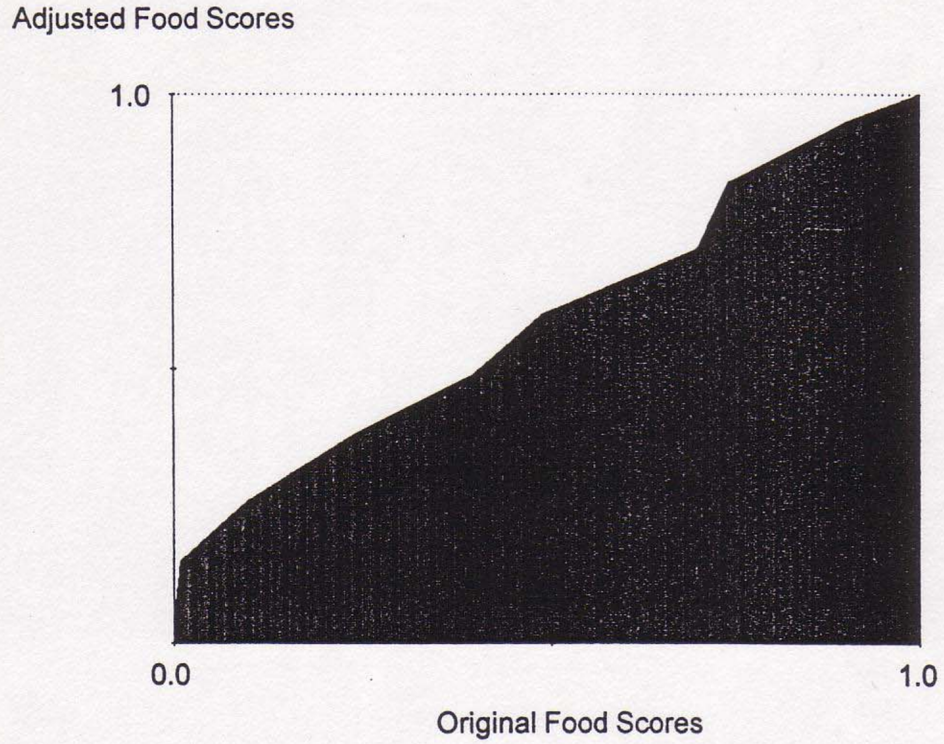

Figure 2. Comparison of original scores of food quality and adjusted scores.

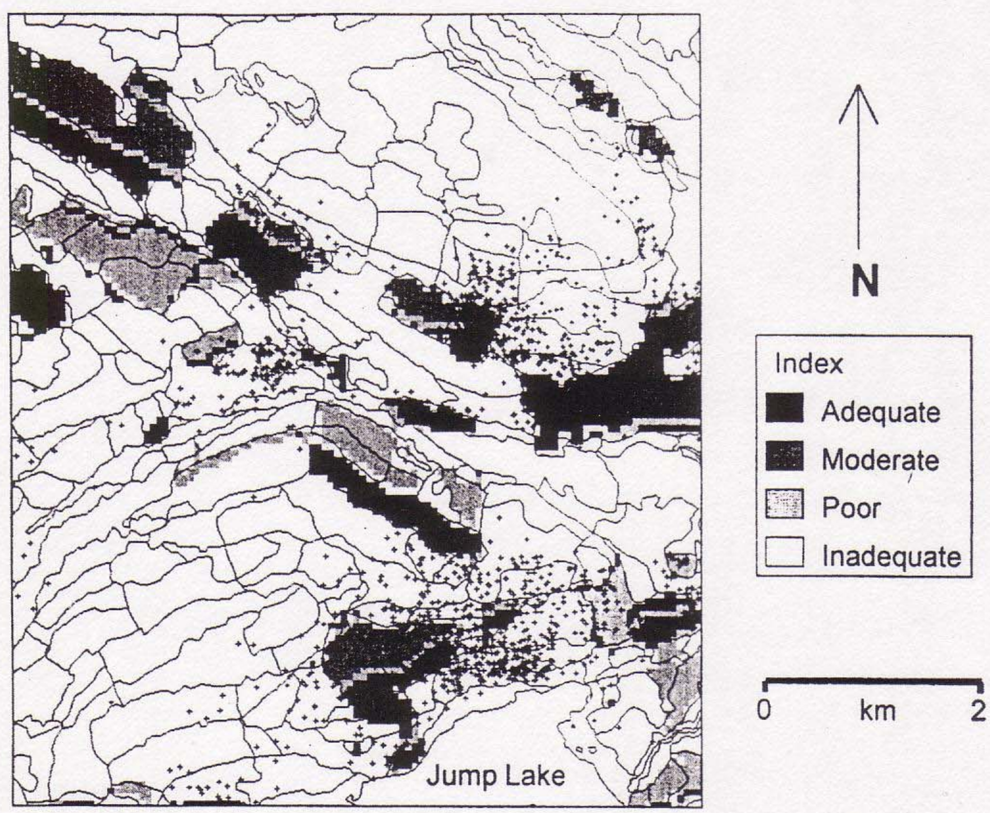

Figure 3. Telemetry locations (+) superimposed on mild winter habitat suitability for black-tailed deer.

the object-oriented model than with traditional GIS approaches. However, there is a lower maintenance cost resulting in better user interactions with the habitat model. Validation and updating of the model are far more efficient and models can be modified to incorporate dynamic programming goals, sensitivity analysis and adaptive management.

Conclusions

Object-oriented modelling allows us to look at spatial patterns and processes at a variety of scales. Data can be incorporated from remote sensing, GIS or global positioning systems. Landscape modification to site-specific calorific studies can be incorporated to help with our understanding of complex phenomena.

References

Bunnell, F.L. 1985. Forestry and black-tailed deer: conflicts, crisis, or cooperation. For. Chron. 61:180-184.

Campbell, A.N., V.F. Hollister, R.O. Duda, and P.E. Hart. 1982. Recognition of a hidden mineral deposit by an artificial intelligence program. Science 217:927-929.

Eng, M., S. McNay, D. Janz, L. Kremsater, I. MacDougall and R. Page. 1989. Assessing and planning the spatial and temporal features of black-tailed deer habitat. *In* Integrating timber and wildlife in forest landscapes: a matter of scale. Edited by J.B. Nyberg and W.B. Kessler. Minist. For., Victoria, BC. pp. 81-112.

Harestad, A.S. 1979. Seasonal movements of black-tailed deer on northern Vancouver Island. Ph.D. Thesis. Univ. of BC Vancouver, BC. 98 pp.

Kremsater, L.L. and F.L. Bunnell. 1992. Testing responses to forest edges: the example of black-tailed deer. Can. J. Zool. 70:2426-2435.

McNay, R.S. and R.E. Page and A. Campbell. 1987. Application of expert-based decision models to promote integrated management of forests and deer. Trans. N. Amer. Wildl. Conf. 52:82-91.

McNay, R.S. and D.D. Doyle. 1987. Winter habitat selection by black-tailed deer on Vancouver Island: a job completion report. BC Min. Environ. Parks and BC Min. For. Lands, Victoria, BC. IWIFR-34. 91pp.

Nyberg, J.B. and D.W. Janz (eds.). 1990. Deer and elk habitats in coastal forests of southern British Columbia. Special Rep. Series 5. Research, BC Min. of Forests. Victoria, BC. 310pp.

Nyberg, J.B., R.S. McNay, M.K. Kirchhoff, R. Forbes, F. Bunnell, and E. Richardson. 1989. Integrated management of timber and deer: coastal forests of British Columbia and Alaska. USDA For. Serv., Pac. Northwest Res. Sta., Portland, Oreg. Gen. Tech. Rep. PNW-GTR-226. 65pp.

Parker, K.L., M.P. Gillingham, T.A. Hanley, and C.T. Robbins. 1993. Seasonal patterns in body mass, body composition, and water transfer rates of free-ranging and captive black-tailed deer (*Odocoileus hemionus sitkensis*) in Alaska. Can. J. Zool. 71:1397-1404.

Parker, K.L., C.T. Robbins, and T.A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. J. Wildl. Manage. 48:474-488.

Rochelle, J.A. 1980. Mature forests, litterfall, and patterns of forage equality as factors in the nutrition of black-tailed deer on Vancouver Island. Ph.D. Thesis, Univ. of BC, Vancouver, BC. 295pp.