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Use of Microcomputers for Planning and Managing Silviculture Habitat Relationships

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Foreword

Resource managers in the United States and Canada must face increasing demands for both timber and wildlife. Demands for these resources are not necessarily incompatible with each other. Management objectives can be brought together for both resources to provide a balanced supply of timber and wildlife. Until recently, managers have been hampered by lack of technique for integrating management of these two resources. The goal of the Habitat Futures Series is to contribute toward a body of technical methods for integrated forestry in British Columbia in Canada and Oregon and Washington in the United States. The series also applies to parts of Alberta in Canada and Alaska, California, Idaho, and Montana in the United States.

Some publications in the Habitat Futures Series provide tools and methods that have been developed sufficiently for trial-use in integrated management. Other publications describe techniques not yet well developed. All series publications, however, provide sufficient detail for discussion and refinement. Because, like most integrated management techniques, these models and methods have usually yet to be well tested, before application they should be evaluated, calibrated (based on local conditions), and validated. The degree of testing needed before application depends on local conditions and the innovation being used. You are encouraged to review, discuss, debate, and-above all-use the information presented in this publication and other publications in the Habitat Futures Series.

The Habitat Futures Series has its foundations in the Habitat Futures workshop that was conducted to further the practical use and development of new management techniques for integrating timber and wildlife management and to develop a United States and British Columbia management and research communication network. The workshop-jointly sponsored by the USDA Forest Service and the British Columbia Ministry of Forests and Lands, Canada--was held on October 20-24, 1986, at the Cowichan Lake Research Station on Vancouver Island in British Columbia, Canada.

One key to successful forest management is providing the right information for decision making. Management must know what questions need to be asked, and researchers must pursue their work with the focus required to generate the best solutions for management. Research, development, and application of integrated forestry will be more effective and productive if forums, such as the Habitat Futures Workshop, are used to bring researchers and managers together for discussing the experiences, successes, and failures of new management tools to integrate timber and wildlife.

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Abstract

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"Microcomputers aid in monitoring, modeling, and decision support for integrating objectives of silviculture and wildlife habitat management. Spreadsheets, data bases, statistics, and graphics programs are described for use in monitoring. Stand growth models, modeling languages, area and geobased information systems, and optimization models are discussed for use in modeling. Decision aids and expert systems for decision support are examined. Advantages of microcomputers include availability, transportability, and usability. Disadvantages include the building of unvalidated models, lack of software standards, and need for updating data bases. We present a case example of an expert system that evaluates regional priorities for managing habitat for black-tailed deer in coastal British Columbia.

Keywords: Microcomputers, stand growth models, wildlife habitat models, expert systems, monitoring, inventory, decision support.

Contents

Introduction

Computers have traditionally been used in both silviculture and wildlife management to store and manipulate data and to model a variety of stand, habitat, and species characteristics. This traditional use has been greatly supplemented in recent years by the evolution of microcomputers. This paper outlines some of the existing and potential uses of microcomputers to aid in the interface between silviculture and wildlife habitat management and recommends some areas for development in the near future.

The scope of this paper applies to silvicultural planning, including stand-level prescriptions and harvest scheduling, as well as to management of habitat for wildlife. Microcomputers are also proving useful in other areas of timber and wildlife management that are not discussed here. In timber management, these areas include logging systems, road engineering, inventory modeling, and economic assessments; in wildlife management, these areas include population modeling, analysis of survey data, and home range analysis.

For the purposes of this paper, a microcomputer is defined as any small, self-contained computing system costing less than $10,000. Such systems typically consist of a system unit, which includes the central processing unit (the brains of the system); one or more floppy diskette or hard-disk storage units; a keyboard; a monitor; and various output devices such as a printer or plotter.

Use of Microcomputers

Computers have been used for a variety of purposes in resource management, including resource planning (Schrueder and others 1976, Field 1977, Schuler and others 1977), modeling of species-habitat relationships (Schamberger and others 1982, Lancia and Adams 1983), assessing cumulative effects (Holthausen 1986), and modeling forest stand development (Dale and Hemstrom 1984). Kickert (1984) provided a long list of published computer models used in the environmental biological sciences.

Most of these applications have required access to mainframe or mini-computers. Many of these programs, however, are rapidly becoming available for use on microcomputers. Recent symposia on resource modeling (for example, Cairns and others 1979, Verner and others 1986) reviewed many types of models and analysis tools that are designed for use on computers, including microcomputers. As microcomputers decrease in price and increase in capability, such uses will continue to proliferate. Microcomputers will likely prove to be especially valuable tools in three domains: monitoring, modeling, and decision support (fig. 1). The following sections discuss these three uses.

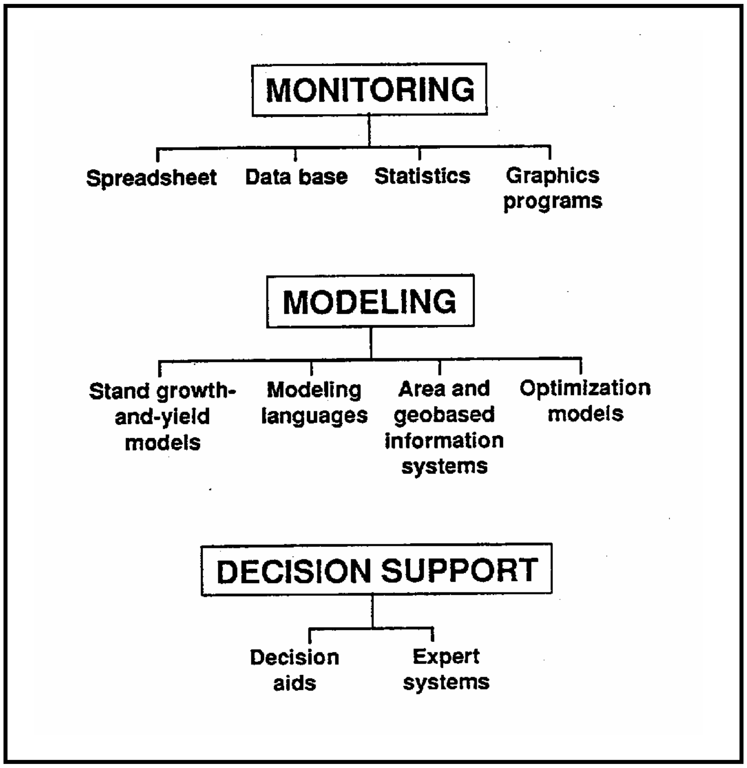

Figure 1—Types of microcomputer programs available for silviculture-habitat management and planning.

Monitoring

In resource management, monitoring is gathering field observations through space and time to test (1) if management directions are being followed as intended and (2) if expected or assumed responses to specific management activities are indeed occurring. In general, the microcomputer can help with these objectives by providing a flexible medium for data storage, retrieval, analysis, and display. The main audiences that may use a microcomputer for assessing monitoring data are both technical specialists and less technically oriented program managers. The objective of assessing monitoring data by microcomputers would be to obtain statistical analyses and summaries and to have friendly, user-oriented access to a data base of resource and management conditions.

Monitoring information intended to track the execution of management or planning direction may consist of many case examples and management results. For example, several timber sale areas may be checked to determine if regional guidelines for maintaining streamside riparian zones are followed. The accumulated information from such a review would help determine the occurrence, kind, and extent of any infractions.

For the second kind of monitoring, information intended to test the expected responses to management direction may consist of observations gathered in carefully designed observational or statistical studies. As an example, the expected results of correctly implementing guidelines for maintaining streamside riparian zones may be the perpetuation of suitable habitat for anadromous fish. Monitoring studies can provide counts of spawners, which the manager may use to determine the efficacy of this management guideline. The result of such a study is a data base or a table of numbers showing fish counts through time, which would be compared with desired or anticipated results. From this step, a computer is a useful tool for reducing and analyzing the data.

Spreadsheets—The simplest tool available on microcomputers for analyzing tabular data, as from a monitoring effort, is the spreadsheet. Spreadsheets are essentially large tables of numbers with labels for rows and columns. Commercially available spreadsheet packages (for example, 1-2-3 [see Appendix for company names of software] and many so-called integrated packages such as Symphony and Framework) may be used to track monitoring data such as stand area and project cost by management unit, year, and objective. Both silvicultural and wildlife management data can be easily integrated into the same spreadsheet or merged across different spreadsheets for concurrent analysis. Spreadsheets, surprisingly, are an excellent and elegant tool for developing population models. The electronic spreadsheet was originally devised to track the flow of money through economic balance sheets. This is identical in concept to the "flow" of individuals through a population. For example, the USDA Forest Service, Pacific Northwest Region, has developed a life table for spotted owls as a spreadsheet model (Marcot 1987).

Data-Base Management Systems—Another tool for analyzing data is the data-base management system. Many commercially available data base management systems are easy to learn and to query. Some systems (for example, O&A, Guru, and R-Base V with the Clout natural language interface) provide natural-language query systems. With these systems, the user can access the data and create tabular and statistical summaries by typing questions, such as:

> How many habitat improvement projects on the Olympic National Forest were done in conjunction with silvicultural activities or were jointly funded with timber management dollars? Show only activities over $5,000 and sort by year.

By building such data bases over time, the stored files become an archive of historical records. Trends over time can then be easily displayed, as with the above example query. A natural language interface (HAL) is also available for use with the 1-2-3 spreadsheet.

Another advantage of storing monitoring data in a user-oriented relational data-base system is that users can ask questions that before they had not thought of asking or had been infeasible to answer. For example, producing a summary chart showing both the funded habitat improvement projects by management unit, year, and source of funding and the percentage of original targets met for that year and unit may take several hours to compile either by hand or by less-flexible data-base systems often found on larger computers. The same summary could be produced with one run on a microcomputer with a state-of-the-art data-base management system. The advantage of these data-base management systems is that many variations of a query can easily be examined when monitoring a management program.

Statistical Packages—Some monitoring data will need to be more intensely analyzed to discern spatial or temporal trends or statistical differences among observed and expected outcomes. A number of powerful statistical packages are available for microcomputers (for example, SYSTAT, STATPAK, and Statgraphics), including some that until recently required large mainframe computers to run (for example, SPSS/PC+, BMDP, and SAS). Many of these packages have numerous nonparametric, time series, and multivariate descriptive and test statistics. A wide variety of user-oriented programs can rapidly be developed that use these statistical packages. An example is the development of habitat-assessment models that analyze use and availability of resources for deer or elk. If shared, these programs will greatly reduce the need for programming on the part of the individual specialist.

Graphics Packages—With medium- and high-resolution color graphics, the microcomputer can produce visual summaries of statistical analyses, including three-dimensional plots. This greatly facilitates interpretation and documentation of the data. Such capabilities are usually not available on mini- or mainframe computer systems. Software available on microcomputers that produce three-dimensional plots of data include Boeing Graph.

In summary, many tools are commercially available for the microcomputer that would be useful for analyzing monitoring data. These tools include spreadsheets, relational data bases, statistical and graphics tools, and user-designed custom programs. Many of these tools offer user-oriented features such as graphics, menus, windows, color, and English language capabilities. Such features help users to learn the systems and to overcome fears of or biases against computer-aided assessment of monitoring data.

Modeling

A second use of microcomputers for assessing and managing timber and wildlife resources is modeling. The audience using microcomputers for modeling stand conditions, growth, yield, and other forest management activities, as well as for modeling the response of wildlife species to various stand and habitat conditions, is likely to be specialists and technicians.

Stand growth-and-yield models—Microcomputers will become increasingly useful for developing models that predict response of tree growth to site conditions and the distribution and abundance of wildlife species to stand conditions. Such prediction and habitat assessment models may be founded on (1) statistical summaries of field data, such as with regression prediction equations, (2) theoretical relationships, or (3) some combination of the two approaches. Examples of stand growth models include Woodplan, Micro-DF-SIM, Stand Projection System (SPS), and FORCYTE. Examples of models of wildlife species response include Micro-HSI, which assesses habitat suitability for a variety of species and vegetation or habitat characteristics, and HIDE, which assess big-game hiding cover within forest stands. An example from British Columbia is a habitat handbook by Harcombe (1984).

Modeling Languages—Advantages of using microcomputers for modeling timber-wildlife relations are quick prototyping, easy development of demonstration systems, and quick turn-around of model output. Developing prediction models is aided by the many programming languages available for microcomputers. For quick simulation modeling, the high-level languages Smalltalk, Modula 2, and GPSS/PC are excellent environments. The simulation program SIMCON is used in British Columbia, Ministry of Forests and Lands. SIMCON is available in FORTRAN on the mainframe and in BASIC and PASCAL for Apple, IBM, and TRS Model 100 microcomputers and compatibles. Additionally, many traditional programming languages, such as Fortran-77, and many variants of Basic and Pascal are available.

For development, an interpreter is useful, and for final execution, a compiler is essential. Interpreters allow the program to run without reducing the entire program code at once into a machine-readable file; this is convenient when a program is being written or changed. Compilers translate entire program code to a form that is readily understandable by the machine and that runs much faster than interpreted programs. Also, math coprocessors, which are optional circuit chips that greatly speed mathematical computations and enhance precision, may prove useful for some applications with many calculations.

Area Models—A class of models that can be used on microcomputers to assess timber-wildlife relations is area models. Area models, which include cumulative effects or cumulative impacts models, are designed to assess the combined effect on wildlife species from either a variety of management activities or activities conducted over a broad area.

Area models may also include automated mapping systems, also called geographic information systems (GIS's). Several GIS packages are available for use on microcomputer, including pMAP, TerraPak, and PAMAP GIS. PAMAP GIS is being tested for use by the Inventory and Research Branches of the Ministry of Forests and Lands, British Columbia. In addition, video systems may be used with microcomputers to produce high-resolution map images.

Cumulative-effects area models include Micro-DYNAST and FSSIM (Forest Structure Simulator), a DYNAST-type model that is available for use on Data General minicomputers (Holthausen and Dobbs 1985). Models that integrate stand growth, cutting cycles, and habitat response by wildlife species include those evaluated by Lancia and Adams (1983), Smith and others (1981), Barrett and Salwasser (1982), and Bunnell (1974).

Optimization Models—Another class of models that may help plan for joint timber and wildlife objectives is optimization models. An optimization model is used to determine the best combination of allocating various resources, given that values are described for each resource. In optimization modeling, usually some overall objective is defined, such as maximizing present net value of timber. Limitations to meeting that objective are described in the model as "constraints"; planning requirements for providing wildlife habitat are usually defined in such optimization models as constraints. Optimization models usually provide a mathematical solution that provides the greatest return for the objective, given the constraints. Optimization models are inherently insensitive to spatial allotments but may serve to provide overall planning direction for an area. Disadvantages of optimization models include the need for identifying a main objective (instead there may be multiple objectives) and the requirement to "constrain" the main objective (such as economic value of timber) by what may also be desired objectives (such as providing for wildlife habitat). For example, the result may be an optimal allocation of timberland for maximizing present net value of timber but may not be an optimal allocation of wildlife habitat.

The Forest Service has developed many of its Regional and National Forest resource plans with a linear optimization model called FOR PLAN. Whereas FORPLAN has traditionally required a mainframe computer to operate, a recent version will run on a microcomputer.

A newer optimization model called TIMPRO-FORMAN will run on IBM-compatible personal computers (Cooney 1987). TIMPRO-FORMAN integrates assessments of timber yield, investment analysis, and wildlife management. The output is an optimal mix of management strategies and schedules for joint timber and wildlife management. The model can track up to five types of benefits for a forest with multiple stands, multiple rotations, and mutually exclusive crops.

Decision-Support Systems

A third area in which microcomputers will prove increasingly useful is decision support. Decision support refers to providing tools that can be used to evaluate existing information to aid decisionmaking. Decision-support tools do not make decisions for the user; they suggest potential outcomes and alternative actions. They can also be valuable for helping direct research by focusing on the information necessary to improve decisions (for example, Coulson and Saunders 1987). Decision-support tools may best help staff directors, supervisors, and line decisionmakers.

Decision-Aiding Systems—Several kinds of software already discussed may be useful in decision support. These include user-friendly information bases that may be queried with English sentences and questions. Also, much "what-iffing" can be done with spreadsheets and simulation models, although the director or decision-maker may need to rely on technically capable staff for such uses. Additionally, specialized decision-analysis software is available for microcomputers. Such software includes ES/P Advisor, Light year, and Arborist. ES/P Advisor and Light year help rank alternative decisions and explore their consequences. Arborist creates decision trees and can be used to explore how decisions would be affected by various potential outcomes and their likelihoods of occurring.

Expert Systems—A growing class of tools for microcomputers to aid analysis and decisionmaking in resource management is expert systems (also called knowledge-based systems), for example, Coulson and Saunders 1987, White and others 1985, Marcot 1986. An expert system is a computer program that uses rules to solve a problem in a narrowly defined realm as well as a human expert. Expert systems often incorporate heuristic or general guiding knowledge into the rules as well as specific facts and formulas. They also show the likelihoods of various outcomes being true. Expert systems may be usable by many audiences. For example, resource managers may use an expert system to assess and prescribe habitat conditions for wildlife, given various silvicultural options for manipulating vegetation.

Marcot (1986) presented two demonstration expert systems for predicting the presence and abundance of bird species given vegetation characteristics of young-growth stages of Douglas-fir forest and discussed their validation (Marcot 1987). The advantage of expert systems is the distribution of scarce expertise among users who require access to, but personally lack, such expertise. Expert systems can run on portable microcomputers, so the expertise can be taken into the field and not be limited to an office setting.

Many software packages for building expert systems (expert-system shells) are available for microcomputers (Simons 1986), including EXSYS, RuleMaster 2, 1st-CLASS, The Deciding Factor, and PROSPECTOR. PROSPECTOR is an expert-system shell that consists of The Deciding Factor rule program plus a mapper; it can be used to assess the spatial distribution of attributes with an expert-system model. Expert systems may also be constructed from the high-level languages PROLOG, OPS5, and LISP, although this would entail considerable programming knowledge and technique. The Forest Service is using EXSYS to develop rule sets for projecting the viability of populations of spotted owls *(Strix occidentalis)* given various alternatives for timber management. They are also using 1st-CLASS to develop species identification keys. The British Columbia Ministry of Forests and Lands is exploring the use of PROSPECTOR and The Deciding Factor to assess priorities for managing black-tailed deer *(Odocoileus hemionus columbianus)* habitat (McNay and others 1987), as discussed in the example below.

Advantages and Disadvantages of Microcomputers

The advantages to using microcomputers over larger computers or over hand computation relate, in part, to the evolution of hardware and software. Microcomputers and software useful for assessing timber-wildlife relations as discussed above are becoming increasingly available and transportable. These systems are small and can be configured with a high degree of computing and storage capabilities. Much software, especially operating systems and programming languages, are more or less standardized, so that programs or data developed on one system can be used on another. Also, software vendors are beginning to provide the capability to share data files among different kinds of software. For example, 1-2-3, Symphony, dBase III, Reflex, and SAS provide the capability to read files created by other data-base packages. Thus, data can be moved between packages much easier than moving a data file between mainframe computers.

Other advantages include the degree of user-friendliness of programs, especially for information storage and retrieval, and the ease of porting software across geographic areas and types of systems. Perhaps the greatest advantages of microcomputers are that commercially available software is much less expensive than that for mainframe computers-often 1 0 times less-and that microcomputer software is much easier to use and is generally of higher quality. Competition among companies writing and selling microcomputer software has served to bolster the quality. Mainframe software is typically written by the hardware vendor, is usually specific to particular computer models, and is sold with little or no competition. Also, three times as many microcomputers exist than mainframe systems. This large market has generated the need for better quality software.

A few cautions are in order, however. Because microcomputers are easy to use and programs are easily developed, poorly conceived information systems and unvalidated models may proliferate (Thomas 1986). Also, standards are lacking for programming languages, storage media, central processing units, and graphics. The latter may limit compatibility of programs between systems. Other limitations of microcomputers may include cost, the updating and dispensing of information bases to dispersed users, and the fears some associate with this new technology.

Case Example: An Expert System for Assessing Priorities for Managing Deer Habitat in British Columbia

Background

Problems of integrating the management of timber and black-tailed deer in coastal British Columbia are summarized by Nyberg and others (in press). Efforts to resolve the management conflicts and improve integrated management have taken many forms, ranging from site-specific management recommendations (for example, Nyberg and others, in press) to large-scale planning tools (for example, Nyberg and Janz 1987). One tool alone is unlikely to be suitable for resolving all issues that arise at the interface of timber and deer management.

The management of black-tailed deer in coastal British Columbia, from the perspective of the forester, is an example of a management objective lacking a particular target, such as a deer population level or yield. Conversely, deer management does not normally include timber harvest objectives. The integration of such nontarget resource objectives into forest or deer management plans is frequently delayed by a lack of effective education and communication between resource managers. Managers, sometimes inexperienced and frequently unfamiliar with nontarget resource issues, need the means of making regional-level management decisions quickly and effectively.

We (R. Scott McNay and R.E. Page) perceived a need to provide regional managers with a tool for making decisions in the management of habitat for black-tailed deer in coastal British Columbia. We chose an expert systems model for a personal com puter as the structure for such a decision-aiding tool (McNay and others 1987). The expert-systems approach was intended to help set regional priorities to determine where to focus habitat management efforts. The benefits of an expert systems approach in this case include the following:

1. aiding effective communication between deer managers and timber managers in a common technical language,
2. sharing information about deer habitat between deer managers and timber managers and for educating inexperienced professionals,
3. advising both deer managers and timber managers of the most efficient way to allocate efforts to manage deer habitat, and
4. providing a permanent record of management decisions to be consulted to facilitate adaptive management strategies.

Structuring the Problem as a Decision Hierarchy

Step 1: Setting the problem context

The first step was to explicitly define the problem as evaluating a particular management area as to whether black-tailed deer habitat should be a management concern. Also, reasons for concluding whether or not deer habitat should be a concern needed to be specified and documented.

The problem as defined was particularly amenable to representation by an expert-systems approach, which functions best when the problem is narrowly defined, when the expertise to solve the problem is scarce and needed, and when the solution is characterized by the use of rules of thumb or subjective weights. Our defined problem satisfied all three criteria. We developed the evaluation model with the expert system "shell" The Deciding Factor, a commercially available software package. Through a simple editor, The Deciding Factor easily handles input from someone running the model (a consultation), produces clearly intelligible conclusions, and documents the logic used to reach those conclusions. The shell forces the manager to work through a set of hypotheses that flow from the general to the specific. The general hypothesis in the case of integrating objectives for managing both coastal timber and coastal black-tailed deer habitat was "habitat suitability should be a concern to deer and timber managers." That main hypothesis was described in turn by a series of support hypotheses, which had their own supporting and more specific hypotheses (fig. 2). Choosing the main hypothesis was the first step in creating a decision hierarchy because the hypothesis defined the problem and set the scope of the exercise.

Step 2: Forming the word model

The second step was to create a word model of the variables that would enter into the evaluation. The word model:

1. helped define the resolution of the problem,
2. promoted a logical flow of ideas from a main hypothesis to more specific hypotheses,
3. defined the geographic area of interest and the scale of the problem,
4. helped to simplify how natural processes would be represented in the model, and
5. enabled a listing of important factors to consider in the model.

As the word model was constructed, we gained an appreciation for the assumptions that must be made to adequately represent the ecological processes. We also gained a holistic view of the problem to help us assess the relative weights for particular decisions within the hierarchy and relate those decisions to each other in a logical way.

The word model of the relations between black-tailed deer and their habitat was presented by Nyberg" and others (in press). Simply put, the word model expressed deer density as a function of individual deer condition; that is, in the word model, density was represented as a summation of energy acquisition and energy expenditure. Energy acquisition in turn was defined as a function of the types of available food, their seasonal nutrient and energy content, and their abundance. Energy expenditure was

Habitat suitability should be a concern to deer and forest managers if the most critical of the following three hypotheses applies.

- —Deer are a sensitive management issue if MOST of the following apply.
  - —Deer are restricted by predators.
  - —Societal demand for deer is high.
  - —Deer are usually common in the area.
  - —Accessability to the area is good.
  - —Winter severity is usually mild.
- —Topography is capable of supporting deer if the MOST CRITICAL of the following two applies.
  - —Summer and fall habitat capability is OK.
  - —Winter and spring habitat capability is OK if MOST of the following apply.
    - —Elevation is less than 1000 meters.
    - —The snowpack zone is low.
    - —The aspect is good for deer winter range.
    - —Slope is adequate.
- —Suitability is comparable to capability if the MOST CRITICAL of the following three applies.
  - —Winter habitat suitability is OK if ALL of the following apply.
    - —Adequate winter food is available.
    - —Adequate cover (thermal and snow) is available.
    - —Winter food and cover are juxtaposed.
  - —Summer habitat suitability is OK if ALL of the following apply.
    - —Adequate summer food is available.
    - —Adequate thermal and security cover is available.
    - —Summer food and cover are juxtaposed.
  - —Winter and summer habitat interspersion is OK.

Figure 2—A decision model for deer-habitat management concerns: should habitat suitability be a concern to deer and forest managers?

a function of down wood or snow depths that must be negotiated for the deer to travel between food and cover, the distance between food and cover, and the relative quality of thermal or security cover that is available. From these variables, the word model linked habitat conditions for deer to forest management because food abundance and quality, depths of down wood and snow (indirectly), distance between food and cover, and the quality of cover can all be affected by habitat management. Collectively, these variables represented the suitability of habitat to support deer.

The ability of land to provide deer habitat also was considered to be a function of physiographic parameters. For example, land above 1000 meters in a location with a severe winter climate is not able to provide good winter habitat for deer regardless of how the vegetation is managed. Elevation, slope, aspect, and winter severity were also in the list of variables. Finally, because research has found black-tailed deer to be relatively sedentary (Harestad 1979, McNay and Doyle 1987), we included a requisite that interspersion of seasonal habitats was required within a watershed.

By presenting our word model to both wildlife and forest managers in British Columbia, we found need for another facet of the word model. Some foresters were concerned that management designed to improve habitat suitability would be wasted in areas having high wolf populations or relatively little demand for deer. These concerns were recognized as short-term issues relative to habitat management. We included them, however, in the word model to set habitat management problems into a broader context and to allow the opportunity to assess the regional need for habitat management. Predators of deer, societal demand for deer, historic density of deer, accessibility to a particular location by resource users, and patterns of winter severity were included in the model to help describe the sensitivity of the habitat-management issue.

Step 3: Editing the decision hierarchy

The next procedure in developing the expert system was to translate the word model into a series of decisions, that is, a "decision hierarchy." The highest level decision, which was the final conclusion reached by the model, was defined as whether black-tailed deer should be considered a management issue in a particular area; lower level decisions in the hierarchy were defined to support or refute the highest level.

We used The Deciding Factor's "editor" to develop a decision hierarchy. This step required understanding the logical relations implicit in the word model so that various levels of decisions could be identified and specific hypotheses could be weighted according to their relative importance to the overall decision (fig. 2). Habitat quality should be a concern to deer and forest managers, for example, if: (1) deer are a sensitive management issue in the area, (2) the local topography is capable of supporting deer, and (3) the current suitability of the habitat is rated much lower than its potential (capability) to support deer (fig. 2).

In the structure of the model, the first two supporting hypotheses (that is, that deer are a sensitive management issue and that topography is capable of supporting deer) provide positive weight to the main hypothesis (habitat suitability is a concern). If deer are a more important issue in one area than another, then the quality of deer habitat would be of greater concern as well. Conversely, the third supporting hypothesis (that is, suitability is comparable to capability) provides negative weight to the main hypothesis. If deer habitat is already high quality, then habitat is not a concern. Only if habitat suitability is low relative to capability would habitat management achieve any significant benefits.

The program combines the weights given to each factor in deriving the overall conclusion of whether deer habitat should be a management concern in an area. The overall weight is limited by the value of the most limiting factor. For instance, if the deer resource value was the most limiting factor and this value was very low, even if habitat suitability was lower than capability, habitat management would not be needed because deer would not be valued.

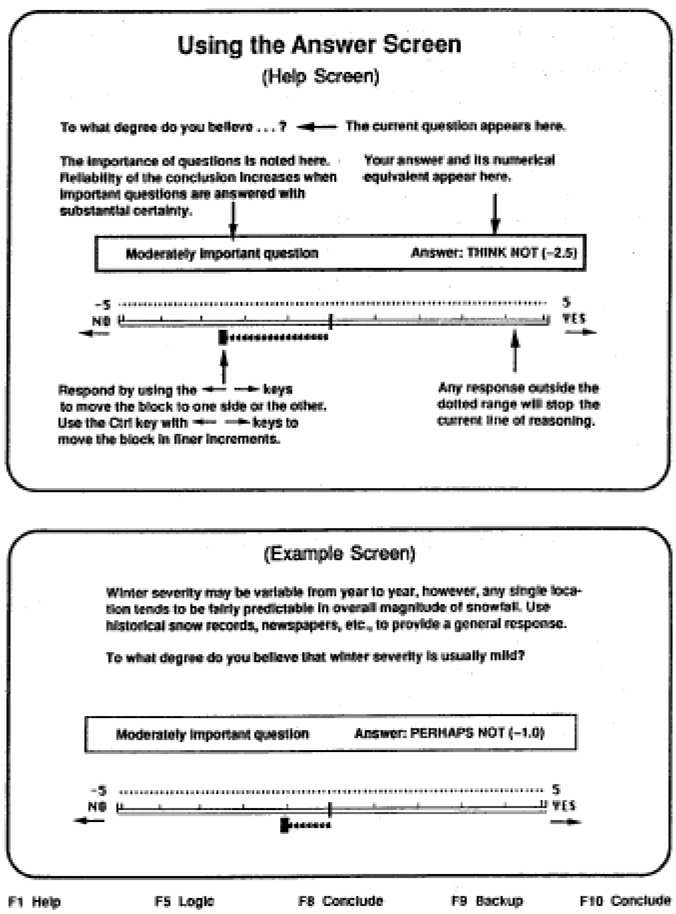

Figure 3—Question-and-answer session from The Deciding Factor expert system.

Step 4: Fine-tuning and evaluation

We used the "consultant" section of The Deciding Factor (fig. 3) to determine if the decision framework operated in the expected way and if each decision in the hierarchy contributed the appropriate weight to the main hypothesis. The model could not be expected to function perfectly because the process only mimics experts, and they can make mistakes. Rather, it was our expectation that a good expert-system model of this particular problem would consistently make decisions neither better nor worse than a human expert in this subject.

The deer habitat model was applied to an area on southern Vancouver Island where a 5-year study on deer habitat selection has recently been completed (McNay and Doyle 1987). The data and familiarity gained from that study provided an opportunity to fine-tune the model. The model results were (1) a simple ranking of the degree to which black-tailed deer habitat should be a management concern for smaller drainages within the main study area and (2) an indication of the factors limiting suitability of habitat. Drainages were ranked according to weights assigned to the various factors.

A full evaluation of the model operation and the utility of the expert system will be a continual process for years to come. The first step will be to individually ask seven deer biologists and deer habitat biologists to rank the current priority for habitat management in watersheds on Vancouver Island; a larger group of participants (including the experts) will then be asked to do the same with the expert-systems model (that is, the consultant). That would be a simple process of answering the questions raised by the consultant (fig. 3) until enough information has been gained for the consultant to reach a decision. Comparisons of the differences in the rankings and of the answers that create the differences will be used to improve the decision hierarchy.

Case Example Discussion and Conclusions

Priorities for deer habitat management in coastal British Columbia must be set by integrating objectives for both timber and deer management. Managers are frequently asked to make quick decisions regarding nontarget resources with sometimes limited knowledge of the issues. Expert systems can be used to support the decision process when specific expertise is scarce or when many factors need to be considered and documented in a complex decision. Nonexperts or inexperienced professionals can understand the overall logic underlying an expert evaluation because it is explicit and systematic. In practice, the model presented here could be used to rank regional priorities for deer habitat management or could be run with a future management scheme in mind to evaluate the potential effects of the plans.

Some aspects of the current model may require further development. An example is the need for more detail at the lowest level of information that describes how specific habitat factors (food, cover, food/cover juxtaposition, and seasonal habitat interspersion) contribute to habitat suitability. The relations of these factors to habitat suitability will eventually be refined in the model. Also, the model currently is sensitive neither to spatial arrangements of habitat factors nor to changes in these factors over time. Research is currently attempting to build these simulations into the overall model. Improvements in these aspects will help move habitat management decisions from reactive compromises to a strategic and cooperative planning process.

Recommendations for Future Development

Microcomputers will continue to be highly useful for prototyping and developing information and models of timber-wildlife relations. Specifically, the following areas should be especially considered for further development:

(1) Decision-support models, especially knowledge-based systems.

(2) Models of timber-wildlife habitat relations, especially models relating stand structure and habitat patch diversity to the distribution and abundance of wildlife species. Desirable characteristics of existing stand development models (for example, see Moeur 1986) and forest-wildlife relations models (for example, Raedeke and Lehmkuhl 1986, Brand and others 1986) currently available on larger computer systems should be incorporated into the creation of similar models on microcomputers.

(3) **Models integrating wildlife-silviculture prescriptions**, especially in the areas of integrated planning for habitat patch diversity and harvest scheduling. These models may make use of spatial analysis of the distribution of habitats and stand conditions over time. Such analysis can probably only be done efficiently on a computer.

New models of timber-wildlife relationships should take advantage of (1) the recent crop of user-friendly software, including relational data bases; (2) the use of color high-resolution graphics for image processing, especially in GIS and area analysis models; (3) the relative accessibility of high-level programming languages, such as PROLOG and Smalltalk, that can greatly facilitate model development; and (4) the use of statistical analysis packages for analyzing monitoring data. Cautions on the potential misuse of and overreliance on microcomputer-based models need to be stressed.

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References

Barrett, R.H.; Salwasser, H. 1982. Adaptive management of timber and wildlife habitat using DYNAST and wildlife-habitat relationships models. Abstract of paper presented at the 1982 Joint Annual Conference of the Western Association of Fish and Wildlife Agencies and the Western Division of the American Fisheries Society; 1982 July 21; Las Vegas, NV.

Brand, G.J.; Shifley, S.R.; and Ohmann, L.F. 1986. Linking wildlife and vegetation models to forecast the effects of management. In Verner, J.; Morrison, M.L.; Ralph, C.J., eds. Wildlife 2000 modeling habitat relationships of terrestrial vertebrates. Madison: The University of Wisconsin Press: 383-387.

Bunnell, F.L. 1974. Computer simulation of forest wildlife relations. In Black, H.C., ed. Wildlife and forest management in the Pacific Northwest. Corvallis, OR: School of Forestry, Oregon State University: 39-50.

Cairns, J.; Patil, G.P.; Waters, W.E., eds. 1979. Environmental biomonitoring, assessment, prediction, and management - certain case studies and related quantitative issues. Fairland, MD: International Cooperative Publishing House. 438 p.

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

Cooney, T.M.1987. Optimizing timber and wildlife. Journal of Forestry. 85: 11-13.

Coulson, R.N.; Saunders, M.C. 1987. Computer-assisted decision-making as applied to entomology. Annual Review of Entomology. 32: 415-437.

Curtis, R.O.; Clendenen, G.W.; Reukema, D.L.; DeMars, D.J. 1981. A new stand simulator for coast Douglas-fir: DFSIM user's guide. Gen. Tech. Rep. PNW-128. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 79 p.

Dale, V.H.; Hemstrom, M. 1984. CLiMACS: A computer model of forest stand development for western Oregon and Washington. Res. Pap. PNW-327. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 60 p.

Field, D.B. 1977. Linear programming: out of the classroom and into the woods. Journal of Forestry. 75(6): 330-334.

Fight, R.D.; Chittester, J.M.; Clendenen, G.W. 1984. DFSIM with economics: a financial analysis option for the DFSIM Douglas-fir simulator. Gen. Tech. Rep. PNW-175. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 22 p.

Harcombe, A.H. 1984. Wildlife habitat handbooks for British Columbia: problem analysis. Wildlife Habitat Research Report WHR-8. Victoria, British Columbia, Canada: Ministry of Forests. 236 p.

Hays, R.L. 1985. A users manual for HEP accounting software for microcomputers. Version 2. Fort Collins, CO: Western Energy and Land Use Team, U.S. Department of the Interior, Fish and Wildlife Service. (Chapters numbered separately).

Harestad, A.S. 1979. Seasonal movements of black-tailed deer on northern Vancouver Island. Fish and Wildlife Rep. R-3. British Columbia, Canada: Ministry of Environment. 98 p.

Holthausen, R.S. 1986. Use of vegetation projection models for management problems. In: Verner, J.; Morrison, M.L.; Ralph, C.J., eds. Wildlife 2000 modeling habitat relationships of terrestrial vertebrates. Madison: The University of Wisconsin Press: 371-375.

Holthausen, R.S.; Dobbs, N.L. 1985. Computer-assisted tools for habitat capability evaluations. Abstract of paper presented at Society of American Foresters Conference; 1985 July 30; Fort Collins, CO.

Kicken, R.N. 1984. Names of published computer models in the environmental biological sciences: a partial list and new potential risks. Simulation. 43: 22-39.

Kimmins, J.P. 1987. Forest ecology. New York: McMillan. 531 p.

Lancia, R.A.; Adams, D.A. 1983. Wildlife management using species-habitat relationships models. Proceedings of a National Workshop on Computer Uses in Fish and Wildlife Programs; 1983 December 5-7; Blacksburg, VA. Blacksburg, VA: Virginia Polytechnic Institute and State University. p. 188.

Lyon, L.J. 1987. HIDE2: Evaluation of elk hiding cover using a personal computer. Research Note INT-365. Odgen, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 2 p.

Marcot, B.G. 1986. Use of expert systems in wildlife-habitat modeling. In: Verner, J.; Morrison, M.L.; Ralph, C.J., ,eds. Wildlife 2000 modeling habitat relationships of terrestrial vertebrates. Madison: The University of Wisconsin Press: 145-150.

Marcot, B.G. 1987. Testing your knowledge base. AI Expert. 2: 42-47.

McNay, R.S.; Doyle, D.D. In press. Winter habitat selection by black-tailed deer on Vancouver Island: a job completion report. IWIFR-00. Victoria, British Columbia Ministry of Environment and Parks and Ministry of Forest and Lands.

McNay, R.S.; Page, R.E.; Campbell, A. 1987. Application of expert-based decision models to promote integrated management of forests and deer. Transactions North American Wildlife and Natural Resources Conference. 52: 82-91.

Moeur, M. 1986. Predicting canopy cover and shrub cover with the Prognosis-COVER model. In: Verner, J.; Morrison, M.L.; Ralph, C.J., eds. Wildlife 2000 modeling habitat relationships of terrestrial vertebrates. Madison: The University of Wisconsin Press: 339-345.

Nyberg, J.B.; Janz, D., tech. eds. In press. A handbook for managing deer and elk habitat in south coastal British Columbia. British Columbia, Canada.

Nyberg, J.B.; Harstad, A.S.; Bunnell, F.L. 1987. "Old-growth" by design: managing young forests for old-growth wildlife. Transactions North American Wildlife and Natural Resources Conference. 52: 70-81.

Raedeke, K.J.; Lehmkuhl, J.F. 1986. A simulation procedure for modeling the relationships between wildlife and forest management. In: Verner, J.; Morrison, M.L.; Ralph, C.J., eds. Wildlife 2000 modeling habitat relationships of terrestrial vertebrates. Madison: The University of Wisconsin Press: 377-381.

Schamberger, M.; Farmer, A.H.; Terrell, J.W. 1982. Habitat suitability index models: introduction. FWS/OBS-82/10. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 2 p.

Schrueder, G.F.; Rustagi, K.P.; Bare, B.B. 1976. A computerized system for wild land use planning and environmental impact assessment. Computer and Operations Research. 3: 217-228.

Schuler, A.T.; Webster, H.H.; Meadows, J.C. 1977. Goal programming in forest management. Journal of Forestry. 75(6): 320-324.

Simons, G.L. 1986. Expert systems and micros. New York: John Wiley & Sons, Inc. 247p.

Smith, T.M.; Shugart, H.H.; West, D.C. 1981. Use of forest simulation models to integrate timber harvest and nongame bird management. Transactions North American Wildlife and Natural Resources Conference. 46: 501-510.

Thomas, J.W. 1986. Wildlife-habitat modeling - cheers, fears, and introspection. In: Verner, J.; Morrison, M.L.; Ralph, C.J., eds. Wildlife 2000 modeling habitat relationships of terrestrial vertebrates. Madison: The University of Wisconsin Press: xix-xxv.

Verner, J.; Morrison, M.L.; Ralph, C.J., eds. 1986. Wildlife 2000 modeling habitat relationships of terrestrial vertebrates. Madison: The University of Wisconsin Press: 470 p.

Walters, C.J. 1982. SIMCON for the APPLE II microcomputer. Vancouver, British Columbia: Institute of Animal Resource Ecology, University of British Columbia. 15 p.

White, G.; Carpenter, L.; Anderson, D. 1985. Application of expert systems in wildlife management. Transactions North American Wildlife and Natural Resources Conference. 50: 363-366.

Williamson, J.F. 1983. Woodplan: microcomputer programs for forest management. In: Proceedings of a National Workshop on Computer Uses in Fish and Wildlife Programs; 1983 December 5-7; Blacksburg, VA. Blacksburg, VA: Virginia Polytechnic Institute and State University: 128-130.

Appendix—Software packages mentioned in the text listed by application.

Application	Software	Company or reference
MONITORING		
Spreadsheet		
	1-2-3	Lotus Development Corporation
	Symphony	Lotus Development Corporation
	Framework	Ashton-Tate
Database		
	dBase III	Ashton-Tate
	Reflex	Borland International
	O&A	Symantec Corp.
	Guru	Micro Data Base Systems
	R-Base	V Microrim
	Clout	Microrim
	Hal	Lotus Development Corporation
Statistics		
	SYSTAT	SYSTAT, Inc.
	STATPAK	Tucker, Dean F. [Date unknown]. Public domain. Computer Cartography Lab, Department of Recreation Resources Administration. School of Forestry Resources. North Carolina State University.
	Statgraphics	STSC
	SPSS/PC+	SPSS, Inc.
	BMDP SAS	BMDP Statistical Software, Inc. SAS Institute, Inc.
Graphics programs		
	Boeing Graph	Garrison Software
MODELING		
Stand growth-and-yield models		
	Woodplan	Williamson 1983
	Micro-DF-SIM	Curtis and others 1981, Fight and others 1984
	Stand Projection System (SPS)	James Arney, Applied Biometrics, Spokane, Washington
	FORCYTE	Kimmins 1987
Models of wildlife species responses to stand conditions		
	Micro-HSI	Hays 1985
	HIDE2	Lyon 1987
	Habitat handbook	Harcombe 1984

Modeling languages		
	Smalltalk	Various companies and versions.
	Modula 2	Various companies and versions.
	GPSS/PC	Minuteman Software. P.O. Box 171, Stow, MA 01775-0171.
	SIMCON	Walters 1982
Area and geobased information systems		
	pMAP	pMAP Software System. c1985. Spatial Information Systems, Inc., 12359 Franklin Street, Omaha, Nebraska. 66158.
	TerraPak	Forest Data Consultants
	PAMAP GIS	PAMAP Graphics Inc., Victoria, British Columbia
	Dynast	Barrett and Salwasser 1982
	FSSIM (Forest Structure Simulator)	Holthausen and Dobbs 1985
Optimization models		
	TIMPRO-FORMAN	Cooney 1987
DECISION SUPPORT		
Decision aids		
	ES/P Advisor	Expert Systems International
	Lightyear	Lightyear, Inc.
	Arborist	Texas Instruments
Expert systems		
	EXSYS	EXSYS, Inc. Radian
	RuleMaster 2	Corporation
	1st-CLASS	Programs in Motion
	The Deciding Factor	Channelmark.Corp.
	PROSPECTOR	Campbell and others 1982
High-level languages		
	PROLOG OPS5	Various companies and versions
	LISP	Various companies and versions
	Smalltalk	Various companies and versions
		Various companies and versions

Mentions of hardware:

International Business Machine (IBM)—PC
Tandy Radio Shack—Model 100 laptop

Marcot, Bruce G.; McNay, R.S.; Page, Richard E. 1988. Use of microcomputers for planning and managing silviculture-habitat relationships. Gen. Tech. Rep. PNW-GTR-228. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 19 p.

Microcomputers aid in monitoring, modeling, and decision support for integrating objectives of silviculture and wildlife habitat management. Spreadsheets, data bases, statistics, and graphics programs are described for use in monitoring. Stand growth models, modeling languages, area and goo-based information systems, and optimization models are discussed for use in modeling. Decision aids and expert systems for decision support are examined. Advantages of microcomputers include availability, transportability, and usability. Disadvantages include the building of unvalidated models, lack of software standards, and need for updating data bases. We present a case example of an expert system' that evaluates regional priorities for managing habitat for black-tailed deer in coastal British Columbia.

Keywords: Microcomputers, stand growth models, wildlife habitat models, expert systems, monitoring, inventory, decision support.

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