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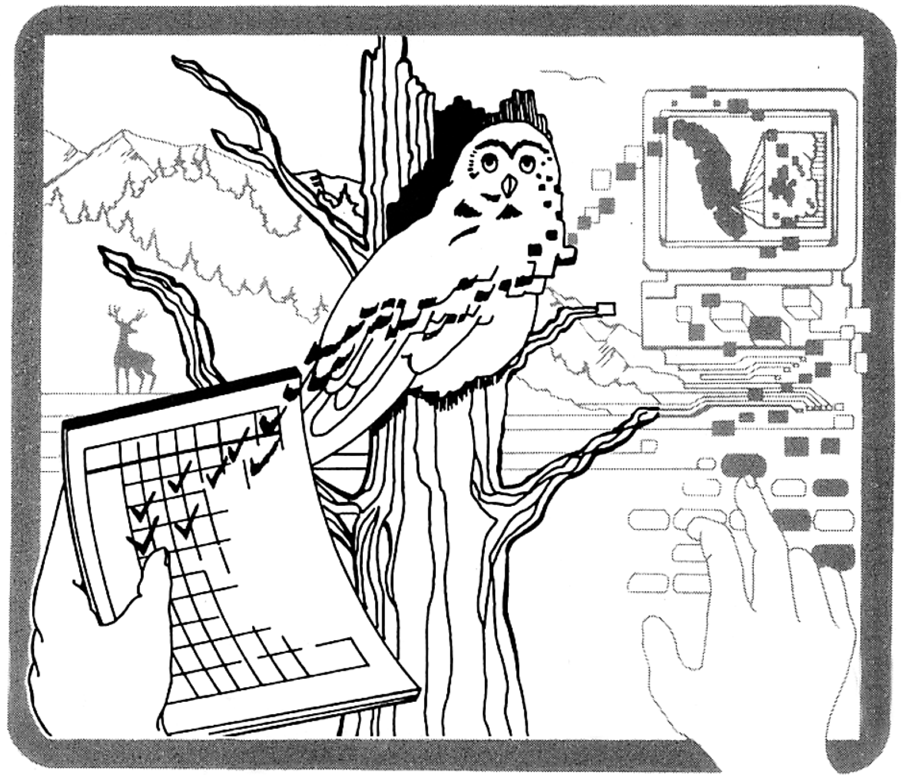

Assessing and Planning the Spatial and Temporal Features of Black-tailed Deer Habitat

Marvin Eng
B.C. Ministry of Environment,
Lands and Parks
Wildlife Branch
780 Blanshard Street
Victoria, B.C.
V8V 1X5

Scott McNay
B.C. Ministry of Forests
Research Branch
31 Bastion Square
Victoria, B.C.V8W 3E7

Doug Janz
B.C. Ministry of Environment,
Lands and Parks
Fish and Wildlife Branch
2569 Kenworth Road
Nanaimo, B.C.
V9T 4P7

Laurie Kremsater
University of British Columbia
Faculty of Forestry
270-2357 Main Mall
Vancouver, B.C.
V6T 1W5

Ian MacDougall
B.C. Ministry of Environment,
Lands and Parks
Fish and Wildlife Branch
2569 Kenworth Road
Nanaimo, B.C.
V9T 4P7

Rick Page
B.C. Ministry of Forests
Research Branch
31 Bastion Square
Victoria, B.C.
V8W 3E7

SUMMARY

The lack of integration between the activities of forest and wildlife managers has often led to conflict. In 1980, a cooperative research program between the B.C. Ministries of Environment and Forests was begun to help resolve one such conflict: the fate of valuable old-growth timber set aside as winter habitat for black-tailed deer on the south coast of British Columbia. Previous approaches to resolving this conflict have included the ‘‘referral system’’ and the ‘‘interdisciplinary team approach.’’ These methods could be described as reactive and proactive, respectively. Both these methods are labor-intensive and based on manual interpretation of paper maps.

We describe an alternative approach called the Habitat Assessment and Planning (HAP) tool. The HAP tool is a series of micro-computer based models that allow wildlife and forest managers to incorporate the spatial and temporal aspects of wildlife habitat while developing habitat plans and operational forestry plans. The HAP tool consists of three models: 1) regional priorities, 2) watershed assessment, and 3) management options. These models are designed to be used in an iterative fashion to increase the benefits of habitat management. The structure and operation of the tool is discussed.

An example application of the regional priorities model and the watershed assessment model is discussed. The results of the example application of the prototype regional priorities model indicated several improvements that could be made to the model. Current development efforts for the HAP tool are focused on the watershed assessment model. We describe how a geographic information system is used to model winter habitat quality for black-tailed deer. We also show how the resulting habitat quality maps can assist managers in making decisions about habitat management needs and the impact of forest harvesting scenarios on deer habitat quality.

Plans for further development and eventual operational implementation of the HAP tool are discussed. We present the opportunities and constraints for implementation and some suggestions for overcoming constraints.

ACKNOWLEDGMENTS

The need to recognize spatial and temporal factors when assessing wildlife habitat has been implicitly recognized for years. A handful of biologists and managers in the U.S. Pacific Northwest and in British Columbia have acted as catalysts in making that principle not only explicit but a priority research topic for integrated management of timber and wildlife. We thank Don Eastman, Rick Ellis, Rick Holthausen, Bruce Marcot, Brian Nyberg, and Hal Salwasser for their support for the Habitat Assessment and Planning project and for their continued review of our progress. Habitat Assessment and Planning is funded by the Integrated Wildlife — Intensive Forestry Research program, a cooperatively funded and administered program of the B.C. Ministry of Forests, the B.C. Ministry of Environment, Lands and Parks, and the University of British Columbia.

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1.1 Planning for Integrated Management of Timber and Deer

Habitat management is commonly used to achieve wildlife population objectives. In British Columbia (B.C.) wildlife managers do not have direct control over the habitat manipulations that result from extensive forestry programs. Foresters, who do have the control, are often unaware of the effect of their activities on wildlife habitat. The resulting lack of integration of the two management activities (forest and wildlife management) has led to conflicts. The specific impetus for this project is a long-standing indecision over the fate of old-growth stands set aside as winter habitat for black-tailed deer (*Odocoileus hemionus columbianus*).

The issue has important economic and social implications. Currently on Vancouver Island, black-tailed deer winter ranges represent approximately 50 000 ha of old-growth timber that have been deferred from logging for up to 10 years. The estimated net value of this timber is more than $50 million (B.C. Ministry of Environment and Ministry of Forests 1983). Black-tailed deer are worth in excess of $5.2 million per year in total revenue from hunting (Reid 1985*a, b*) and probably the same amount in non-consumptive use (Reid *et al.* 1985). Within the coastal region of British Columbia, black-tailed deer receive 93% of the total hunter days allocated to all big game species (Reid 1985*a, b*). In addition, there is a substantial political lobby that advocates the incorporation of non-timber values into forestry plans.

More than 35 000 ha of coastal B.C. forests are harvested annually and the impact of forest management on deer habitat is both extensive and rapid. What was once predominantly old-growth forest is now a mosaic of even-aged stands of young conifers interspersed with patches of old growth. While site-specific habitat management techniques (Nyberg *et al.* 1989) can help managers resolve some conflicts, they are not sufficient. Managers also need to assess the implications of their actions in the context of regional and watershed-scale planning. Here, we address the issue of planning forestry and deer habitat management over areas larger than a ''site'' (stands of 10^2 ha).

Shifting focus from site-specific habitat management techniques to planning for entire watersheds (10^4 ha) is difficult because each habitat problem must be put in the context of the larger land base and the life-long habitat needs of the animals. Deer must move to obtain resources. They require different things at different times and in different places. For example, the proximity of spring forage habitat will influence the ultimate value of management to improve winter habitat quality. The spatial and temporal integrity of the planning exercise becomes essential.

Yet another problem arises because timber development and habitat management occur at very different ''operational'' planning horizons. Foresters usually allocate harvesting through a 5-year development plan process, base their activities on individual forest stands, and assess value as the volume of merchantable wood per unit of land. Deer habitat managers should plan over longer time frames (often 20 years or more), base their activities on watersheds, and assess value as supportable harvest levels. The difference in planning horizons is, once again, largely because deer must move to secure resources and trees do not. Because trees are stationary, inventory and area-based planning for the forestry values is both easier and less significant than it is for the wildlife values. How then does one integrate planning for two values when one is specific in time and space and the other is not?

We use black-tailed deer and coastal forestry as our example of problems in integrated planning. However, the issues raised extend beyond these to most geographic areas (not just B.C.) and to many other forest-dwelling animals.

1.2 Previous Approaches to Planning

Two planning approaches have been used to attempt integrated management of forests and wildlife in B.C.: the ''referral system'' and the ''interdisciplinary team'' approach.

The ''referral system'' is used predominantly. Responsibility for planning and conduct of logging and silviculture is delegated, in most coastal areas, to private firms with area-based cutting rights. Government agencies, led by the British Columbia Forest Service (BCFS) approve and monitor company programs. Companies have no responsibility for wildlife. Company plans are sent (“referred”) to the Ministry of Environment, Lands and Parks (MOELP) and the federal Department of Fisheries and Oceans for comment on wildlife and fishery impacts. The referral system discourages incorporation of deer habitat concerns early in the planning process and puts MOELP in a reactive position. The process stipulates short-term planning (usually a 5-year planning horizon) and forces wildlife managers to focus on a stand-by-stand scale; both are inappropriate for effective wildlife habitat planning. The fact that several different tenures and forest companies can occur within the same watershed compounds this problem. As a result, short-term logging development is favored over long-term timber and wildlife habitat planning.

The “interdisciplinary team” approach is occasionally used for watersheds with high timber value and strong conflicts with other resource values. Under this system, a designated lead agency brings together a group of experts to formulate a set of joint resource objectives and develop an integrated resource plan. This approach is more conducive to development of a long-term integrated plan but it requires many specialists and it is very time consuming. These special requirements usually preclude use of the interdisciplinary team approach.

The following example illustrates the problems in planning for integrated management of deer and timber in coastal B.C. This example concerns the interdisciplinary team approach as applied to the Artlish River watershed on northern Vancouver Island. The goal was to develop a “Local Resource Use Plan” to guide multiple-use development on the 15 000-ha watershed. Involved were three licensees, two forms of tenure within two forest districts, and the MOELP.

A biophysical mapping exercise was the basis for determining capability of the land to support deer and elk. Physiographic and biogeoclimatic units (*sensu* Klinka *et al.* 1984) were used to interpret and map ungulate winter habitats and to delineate potential for high-quality spring and summer forage production sites. Forest cover and logging operability maps were compared (manual overlay method) with wildlife capability to identify conflict areas. The map comparison was also used to assess trade-offs and to plan long-term logging development given the constraints of tenure type, annual cut requirements, and wildlife habitat values. A 20-year logging plan was developed. It incorporated considerations for deferral of winter habitats, replacement of old-growth stands with managed young growth, and the spatial and temporal patterns of forage and cover on the seasonal ranges.

There were three major difficulties in the Artlish exercise. First, staff and time were too limited. The overall procedure took several years of dedicated, but often interrupted work (primarily compiling and drafting maps).

Second, it was very difficult to schedule forest management mentally over a 20-year time frame and simultaneously evaluate impact on habitat values. That difficulty arose because habitat values are partially dependent upon the spatial arrangement of specific habitat features and that arrangement is unique at each point in space and it changes with each forest harvesting operation.

Third, records of the decisions made (paper files and maps) were inadequate for purposes of recall and updating. Frequent staff changes made this situation even worse. Other problems will result from an inability to monitor the development in the Artlish and to evaluate the decisions that were made. Few records are available of changes made to the plan, including changes to forest development plans and possible changes in tenure types.

1.3 Alternatives to Current Methods

Wildlife ecologists have understood and accepted the core concept of the Habitat Assessment and Planning (HAP) approach for over 50 years; that is, the interspersion of life requisites is critical in determining the value of an area as habitat (Leopold 1933).

Interspersion reflects the distance an animal must move between any two life requisites. For example, if good winter and summer habitat are available in the same area, deer can be resident year-round. Seasonal migration, on the other hand, allows seasonal habitats to be separated in space and still be efficiently used. How deer find, and learn to use, more dispersed seasonal ranges or alter their basic movement tactics in the face of changes resulting from forestry must constrain how seasonal habitats are managed (McNay *et al.* 1988).

Within a seasonal home range, the interspersion of daily life requisites is important. In particular, the energetic costs of movement can be substantial during winter, and hence food and cover must be close together. Many stands (habitats) provide either food or cover but not both. Therefore, the stands must be suitably arranged to provide effective seasonal habitat.

Attempts have been made to incorporate habitat interspersion into wildlife habitat models and planning using ‘‘interspersion indices’’ of varying complexity (Heinen and Cross 1983). However, these indices do not adequately represent wildlife habitat because they ‘‘add up’’ interspersion over large areas and do not represent the relationship among individual habitat polygons (stands). Adequate representation of spatial interspersion is only possible by processing habitat data while retaining its spatial integrity. This was not feasible until the advent of computerized map analysis (geographic information systems [GIS]). Useable micro-computer based GIS software has only recently become available, thus the use of GIS in natural resource management is still in its infancy (Coughlan and Olliff 1988). Some results, however, show the potential use of GIS for analyzing spatial interspersion of habitats (Lyon *et al.* 1987).

GIS offers the potential to increase awareness and knowledge of the spatial and temporal interactions between deer and forest management activities. Such increase in awareness would help to ensure that deer habitat requirements entered the referral process early (Nyberg *et al.* 1989). As well, the rapid pace and large extent of forest management activities will require automated analytical tools before long-term planning can happen on a routine basis. GIS would:

1. enable the assessment of watershed-wide impacts resulting from site-specific management prescriptions;
2. help reduce the need for excessive staff inputs;
3. handle map construction tasks quickly; and
4. maintain pictorial and/or textual records of decisions for use at a later time.

Projecting and evaluating habitat changes through time is repetitive and time consuming. The large volume of data makes the chore impossible for humans but suited for computers. Nevertheless, there are hardware and software limitations. The tool should function on currently available computer technology (or at least on technology that will be widely available in the near future). The aim to accommodate hardware and software limitations must be balanced with the risk of constructing a tool that is too simple and will suffer from lack of credibility.

Regardless of which type of analytical tool is developed, it might not be acceptable to all users (forest and wildlife managers as well as planners). To counter that tendency, as many users as possible should be involved with the construction of such a tool.

Lastly, there is the risk associated with accepting the *status quo* and not proceeding with the development of any new analytical tool. In that case, integrated management would likely never be well planned, largely due to incompatible planning horizons for two vastly different values: timber and deer. Also, our understanding of planning integrated management would be limited without such an analytical tool to guide research studies of animal responses to long-term, large-scale habitat changes.

2 CASE EXAMPLE: THE HABITAT ASSESSMENT AND PLANNING (HAP) TOOL

2.1 Introduction

In this section, we describe the application of a planning tool being developed by the B.C. Ministry of Environment, Lands and Parks, and Ministry of Forests. The goal of the Habitat Assessment and Planning (HAP) project is to develop a planning aid that will translate research knowledge about the habitat relationships of black-tailed deer on Vancouver Island and the south coast of B.C. into effective tools for wildlife and forestry managers. The HAP tool will be a series of micro-computer based models that will allow planners to incorporate the spatial and temporal aspects of habitat while developing harvest schedules, habitat plans, and operational forestry plans. The ideal HAP tool would allow planners to:

1. assess the quality of deer habitat (watershed-wide) and the impacts of proposed forestry plans and activities on that habitat;
2. provide information to recommend changes in plans that will minimize negative impacts or maximize the benefit of forestry on deer habitat;
3. identify the risks of pursuing uncertain management actions and, where possible, identify the data required to reduce the uncertainty;
4. assess priorities for, and the cost-effectiveness of, habitat management (enhancement) projects; and
5. provide documentation that can be used to evaluate the rationale for decisions that affect deer habitat.

The HAP tool will be a complete framework for integrating wildlife habitat planning concerns into forest planning methodology in B.C. Initially, HAP will be applicable to black-tailed deer on Vancouver Island and the south coast of B.C. This tool, however, should be viewed as a prototype of a more generally applicable tool that could be used throughout the province (or the world) for any wildlife species. An elk habitat quality model that will be incorporated into the HAP framework is currently being developed and validated by a separate research project[1].

The approach will be to develop a complete framework for the ‘‘ideal’’ HAP tool. Component parts of the framework will then be developed to the level of detail that is possible, given technological and administrative constraints (Section 3). The HAP tool delivered by this project will be functionally complete. It will, however, make use of ‘‘expert opinion’’ where policies or data are lacking, and ‘‘manual methods’’ where computer models are lacking. The tool will be developed with an ‘‘open-ended’’ architecture, allowing incorporation of new data or models.

The HAP tool will not be constrained by current methods of planning, particularly at the strategic level, within the B.C. government. Forest planning methods are in a state of flux as new planning procedures are being developed (e.g., Dellert and D.H. Williams & Associates Ltd. 1989). As well, growing public concern over integrated resource management may change forest planning. The HAP tool must be able to fit into the strategic forest planning system that eventually results, but development of the HAP tool should not be constrained by current suppositions about that planning system.

2.2 User Profile

The HAP tool will help three groups of professionals involved in forest planning:

1. Regional Habitat Protection Biologists and Technicians within the MOELP who have the primary objective of minimizing negative impacts of forestry activities on wildlife habitat;
2. Foresters in BCFS at both regional and district offices who have the primary objective of ensuring that Ministry of Forests policy is met by forestry operators; and

[1] Brunt, K. 1989. Application of a geographic information system (GIS) to test models of Vancouver Island Roosevelt Elk habitat suitability. Unpublished M.Sc. thesis proposal. Univ. Victoria, Dep. Biology, Victoria, B.C. 19 p.

3. Divisional forest planners in the timber industry who have the primary objective of minimizing the cost of timber harvesting.

As well as having different objectives, these groups have very different backgrounds, job experience, computer experience, facilities, and resources.

The user groups with the greatest immediate need for the HAP tool are the Habitat Protection Biologists and Technicians, because the referral system is the most commonly used planning method in B.C. (Section 1.2). As well, these users are the most knowledgeable about habitat requirements and forestry impacts on habitat. Therefore, these groups will be most able to identify needs for improvement in the HAP tool. For these reasons, HAP will be initially designed for these users. During development, consideration will be given to the needs and capabilities of the other potential user groups.

2.3 Task Profile

The HAP tool will support a variety of tasks performed by all three user groups. These tasks include the development of, or response to, 5- and 20-year plans for Timber Supply Areas (TSA's) and Tree Farm Licences (TFL's) and the development of Local Resource Use Plans and small business plans. We expect forest planning to progress eventually to the point where rotation-age plans are created using a planning method that is spatially explicit. Initial development of the HAP tool will concentrate on aiding MOELP staff in responding to 5-year ‘‘operational’’ plans submitted by forestry companies or the BCFS. This task represents a major portion of the work load for the ‘‘prototype’’ user groups (Habitat Protection Biologists and Technicians). The task is complex and requires an understanding of species' habitat requirements, forest successional patterns, and local conditions. Recommendations that frequently result from such a task include:

- long-term deferral of logging of old-growth stands that represent high-quality winter range for black-tailed deer;
- short-term deferral of old-growth stands that represent future foraging areas and potential visual cover;
- changes in cutblock location, size and shape to minimize impacts on sensitive habitats;
- changes in the harvesting mosaic to obtain favorable ‘‘green-up’’ patterns;
- changes in scheduling of spacing and thinning operations to enhance desired cover or forage attributes; and
- changes to road layouts or logging methods to minimize harassment of wildlife.

Five-year plans are normally submitted early in the calendar year and Habitat Protection staff are expected to respond to them before the end of March. Technicians may have up to 10 plans to respond to at any one time. The response to each plan can take from 20 to 120 hours to prepare, depending on the complexity of the plan, the size of the planning area, and the sensitivity of wildlife issues involved.

Habitat Protection Technicians' satisfaction with the current method of processing referrals is low because:

- much of the task involves menial and repetitive comparison of new and old plans to detect changes from year to year, and the processing and filing of responses to plans;
- there is a heavy reliance on site-specific knowledge but very little time is available to obtain site-specific information;
- the extreme complexity of the spatial and temporal interactions of habitat quality are very difficult to assess manually, resulting in possible errors and overly conservative recommendations; and
- the task is so time consuming that adequate time to respond to other kinds of referrals (municipal, industrial, etc.) is not available.

Use of the HAP tool will help alleviate these problems by:

- automating many of the menial aspects;
- identifying areas where site-specific knowledge is critical;
- reducing the apparent spatial and temporal complexity by modeling those aspects of habitat quality; and
- reducing the total time required to prepare a response.

2.4 HAP Development Concepts

2.4.1 The planning unit

The HAP tool must be applied within some circumscribed planning unit. Regional forestry plans are prepared for entire TFL's or TSA's (10^5–10^6 ha). This is too large an area to be an effective planning unit for wildlife habitat because of variability in conditions throughout the area. As well, TFL boundaries are based on administrative considerations and habitat planning units should be based on environmental considerations. Operational forestry plans, on the other hand, are designed on a stand-by-stand basis and hence are too small to incorporate the habitat requirements of even a single large animal. Ideally, the habitat planning unit should relate to population characteristics. For deer the best planning unit is most likely to be the "watershed." Biological evidence for the planning unit definition is a subject of research on related projects (McNay *et al.* 1988; McNay and Morgan 1989). For black-tailed deer it is likely that an effective planning unit could be defined using some combination of watershed boundaries and snowpack zone boundaries (Nyberg and Janz 1990).

2.4.2 Scale and resolution

Time scale is dictated mainly by forest planning procedures. Operational forestry plans are developed for 5-year periods and significant changes in wildlife habitat probably cannot be detected over a shorter time than this. The modeling process would ideally include 5-year steps through a full rotation for the managed forest.

The level of detail of the data required to model deer habitat adequately is still unclear. Our current modeling efforts are based on current vegetation cover maps prepared using the ecosystematic association (and successional stage) classification at a scale of 1:20 000. Our elevation and aspect polygons are based on visual interpretation of 1:50 000 topographic maps. These sources appear to be adequate for modeling exercises. It is necessary to assess the impact of lower quality information (e.g., forest cover data compared to ecosystematic classification data) on the model output. Conversely, we will determine whether or not higher-quality information (e.g., digital terrain models compared to topographic maps) improve the model output.

These questions and many like them can only be answered through data analysis and model creation and validation. There will probably be more than one answer to many of the questions involving data resolution. Data requirements will vary with the specific nature of management questions and the geographical area of interest. For black-tailed deer we currently accept that 200 m elevation classes are sufficiently precise and that forest cover maps provide insufficient indication of understory forage production.

We may be able to infer understory from other relationships (such as among forest cover, soil type, aspect, and site history). A more promising approach is to use the habitat modeling to direct sampling effort at the relatively few stands where such data are needed. Rather than mapping the entire area for a precise attribute like forage, the information can be collected and entered only when needed. The elapsed time for an evaluation will obviously be lengthened, but this is an extremely efficient way of collecting data. We anticipate that the use of the HAP tool will frequently involve an iterative approach in which managers try to answer the questions with available data. The HAP tool will then generate a list of data requirements to answer the question adequately.

2.4.3 Uncertainty and risk

There is a strong tendency for computer-generated output to be treated with unacceptably high regard for precision (Hilborn 1987). Imprecise initial data sources can propagate and compound errors dramatically, particularly with projections into the distant future. The usual solution is to attempt to increase the precision of the original data sources. However, this may be difficult and the increase in precision may still be insufficient to affect the quality of the model output. There are much better ways of dealing with uncertainty than accepting on faith that we have the ‘‘best’’ data possible.

One method of dealing with uncertainty is to conduct sensitivity analyses in which the scenario being assessed is intentionally biased in one direction and the effect on the management outcome is observed. For example, assume a 20% increase in rate of harvest knowing that 10% is the maximum permissible. How much difference will it make? What if an area that has experienced fairly mild winters suddenly encounters a series of winters with much greater snowfall. What impact would drier summers have on summer forage production?

Another method of dealing with uncertainty is to provide managers with the opportunity to practice adaptive management in their decision-making processes. Walters (1986: 159) advocates ‘‘adaptive management’’ because ‘‘many key management decisions are essentially gambles, no matter how nicely we may try to package the justification.’’ Walters (1986: 257) suggests that we embrace, rather than ignore, the element of uncertainty in our decision making and use it to develop ‘‘actively adaptive policies.’’ Actively adaptive or ‘‘dual control’’ policies seek to establish some optimum, or at least a reasonable, balance between learning and short-term performance.

2.4.4 Optimization versus decision aid

It is neither possible nor desirable to develop a HAP tool that would generate an ‘‘optimum’’ operational forestry plan for a planning unit. ‘‘Optimum’’ plans would require ‘‘rules’’ about biology and forestry that we cannot presently develop. As well, input from managers about the types of management actions will allow for adaptive management procedures (Walters 1986) to be developed and incorporated. By trying various scenarios in the real world and on the computer, documenting the assumptions and reasons behind the decision, and evaluating success or failure, we can gain knowledge most rapidly. This is expected to eventually improve forest management. The HAP tool should be viewed as providing information to managers for use in decision making rather than as providing a prescriptive tool.

2.4.5 Reductionism versus holism and Occam’s razor

The biological system we are attempting to model is extremely complex. It might therefore be assumed that an adequate model must also be complex. This assumption generally leads to a ‘‘reductionistic’’ modeling philosophy. That is, ‘‘a whole can be understood completely if you understand its parts and the nature of their sum’’ (Hofstadter 1979). This approach has been successful for modeling simple systems not influenced by prior history, particularly in the field of physics. However, very little success has been attained in the field of ‘‘ecosystem’’ modeling. This lack of success stems not only from the extreme complexity of ecological systems but also because, for complex systems, ‘‘the whole is greater than the sum of its parts’’ (Hofstadter 1979). This alternate world view, known as holism, requires a ‘‘top down’’ approach to modeling in which the desired output is identified and the model includes only the necessary components of the system required to obtain that output.

The debate over the correctness or validity of the reductionist versus the holist world views will probably never be resolved because, to some extent, the question is flawed. That is, neither view is wrong or right (Hofstadter 1979). From a pragmatic point of view, however, modeling should be done on the basis of Occam’s razor, that is, ‘‘it is vain to do with more what can be done with fewer’’ (Dunbar 1980). This approach is to build the simplest model that appears to ‘‘work.’’ It is ‘‘holistic’’ in nature and requires an expert system model in which the expert specifies those aspects of the system believed to be most important for arriving at the desired model output.
The ‘‘Occam’s razor’’ approach is advantageous for four reasons:

1. the resulting models are simple and can be clearly understood and ‘‘believed’’ by managers with expertise similar to that of the model developers;
2. model inputs are simple to obtain because they are frequently the opinions of experts;

3. models can be developed quickly and inexpensively; and
4. models live or die based on their management success ("the proof is in the pudding").

2.5 General Description of Components

The complete framework for the HAP tool currently has three parts:

1. a regional priorities model;
2. a watershed assessment model; and
3. a management options model.

Each model will have separate inputs and outputs. The outputs of each model will be linked as inputs to the other models so that the framework will be integrated and iterative (Figure 1). The regional priorities model will rank planning units (watersheds) in terms of the need for habitat management. For each high-priority planning unit, the watershed assessment model will evaluate the proposed forestry scenarios and specify the habitat management requirements. If no management requirements are identified, the process will return to the regional priorities model to obtain a new planning unit for assessment. If management requirements are identified, the management options model will be used to determine the cost/benefit ratio for the proposed management action. If a poor cost/benefit ratio results, the process will return to the regional priorities model to obtain a new planning unit for assessment.

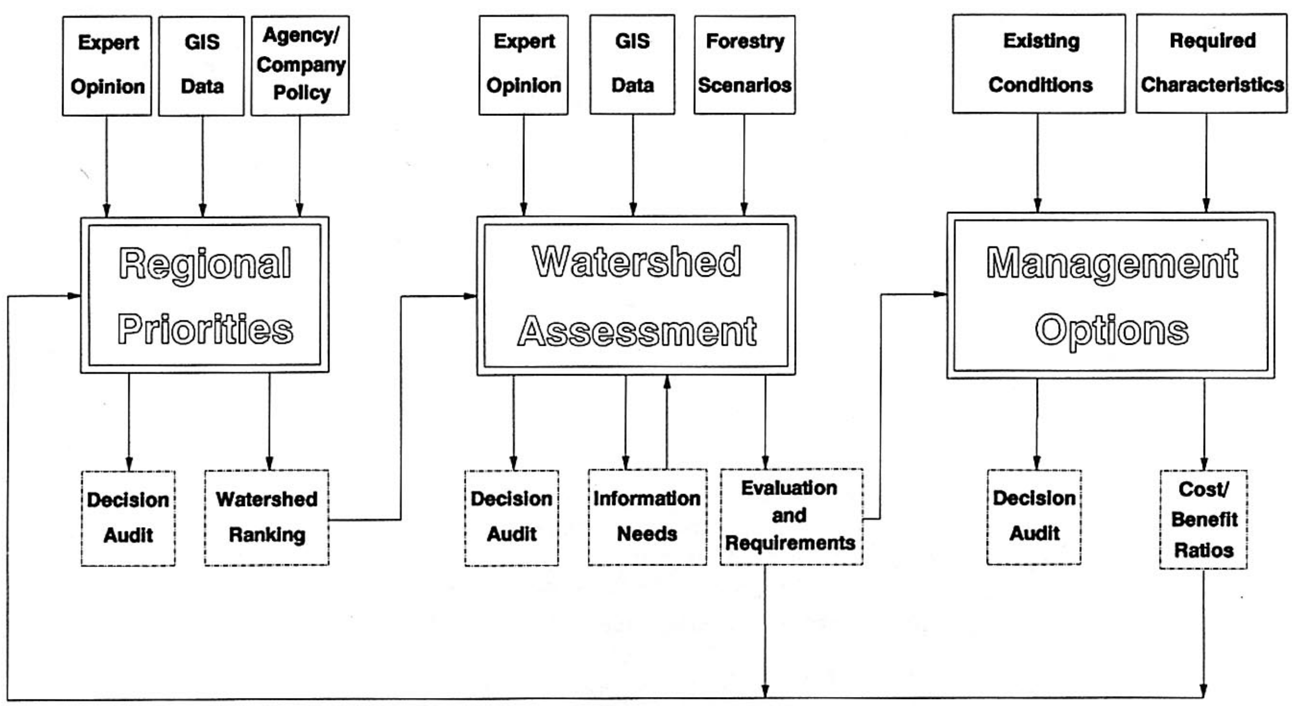

FIGURE 1. Conceptual framework for the habitat assessment and planning tool.

2.5.1 Regional priorities model

The regional priorities model answers questions about where, in a regional context, management efforts should be directed. An example question is: Where are deer management priorities so low that little or no effort is required for spacing/thinning to provide forage production, thermal cover, or winter range?[2] The model will be primarily an expert system that would require substantial knowledge about the geographical area and species of interest to operate effectively. The model would require user input to questions and it may obtain input from, or assist the user in providing input through, small-scale GIS data and government or industry policy information. Outputs would include a ranking of planning units (watersheds) in terms of the need for a detailed assessment of habitat quality and a decision audit that would record the reasons why the ranking occurred.

A prototype regional priorities model has been constructed (McNay *et al.* 1987; McNay and Page 1988). This model incorporates a decision hierarchy that attempts to mimic the thought processes of habitat biologists. The model attempts to find the limiting factor among three major questions:

1. Are deer a sensitive management issue from the point of view of predation, societal demand, etc.?
2. Is the topography potentially highly capable of supporting deer?
3. Is the current habitat quality comparable to the topographic capability?

These three questions are addressed by a series of specific sub-questions. The manager has the option of ignoring some of the specific factors in the model (such as predation) if he or she sees fit, but the basic logical structure of the decision-making process is fixed.

2.5.2 Watershed assessment model

The watershed assessment model is the core of the HAP tool. It should ''help in resolving habitat management decisions over a watershed-sized area and through pre-determined time steps'' (Harcombe and Baker 1987). The watershed assessment model will be GIS-based and will allow assessment of habitat quality of watersheds at a specific time. Temporal changes will be included by projecting the succession of forested land and repeating the watershed assessment at pre-determined time intervals. Model inputs will include large-scale GIS-based data on the present conditions of the watershed landscape (including descriptions of seasonal habitats and their interspersion), proposed operational forestry plans, and long-term forestry and wildlife objectives. Model outputs will be of three types:

1. **Decision Audit:** mechanisms that would record the results of the watershed assessment and the resulting management decisions so that future managers could evaluate those decisions. The decision audit mechanism would also assist in the day-to-day duties of the Habitat Protection staff (i.e., processing and filing of plan referrals).
2. **Information Needs:** an identification of locations (stands) in the watershed where the available data are not sufficient to allow a reliable assessment of the present or future habitat conditions.
3. **Evaluation and Requirements:** map-based, graphic, and tabular reports on the changes in habitat quality within the watershed through time, that would help managers assess the impact of proposed forestry plans and make recommendations to minimize the negative impacts. Additionally, there would be an identification of locations (stands) in the watershed where small changes in stand characteristics would result in large changes in habitat quality.

2.5.3 Management options model

The management options model will determine the most appropriate methods of achieving the habitat requirements identified by the watershed assessment model. Model inputs will be the required

[2] MacDougall,I. 1987. Phase II - problem analysis for second growth habitat: an overview for HAP (Habitat Analysis Procedure). B.C. Min. Environ. Unpubl. Memo. 5 p.

habitats and the existing habitat conditions. Model outputs would be cost/benefit ratios of site-specific habitat management actions. If it is determined that poor cost/benefit ratios result for all management options, then the regional priorities model would be re-applied to select a new watershed for evaluation.

Application of the management options model will involve an evaluation of the efficiency of different habitat management options rather than trade-offs between timber values and deer habitat values. Not all possible options can be evaluated. For many, we lack both information on likely costs and, in most cases, information on likely benefits to wildlife. A potential surrogate is to define break-even points. A hypothetical example would be: spring forage plantings must cost less than $233/ha and benefit 51 deer. More likely, the model outputs would be relative benefits; for example, a specified amount of money will benefit more deer if Option A is applied in Area 1 than if Option B is applied in Area 2.

It is difficult to model "optimal" options because of the large number of interactions between site-specific needs and seasons. It may be that a lack of winter range in Area 1 can be alleviated by provision of better summer range in Area 2, so that migrators arrive in better condition. The number of such possible interactions exceeds current computing capabilities, but is manageable within the human mind. Once the manager decides that a possible management intervention is worth considering, the power of GIS and the management options model can be used to evaluate the possible habitat benefits.

This model may be relatively weak in the version of HAP that will be delivered (Section 3). The utility of many habitat enhancement options will only be demonstrated after many years and trials. The focus of this model will be a demonstration of how to evaluate options, with less focus on definitive recommendations to managers. We do not know at this point if the knowledge exists to make this model work. An adaptive management scheme to continuously evaluate the utility of this model is clearly required.

2.6 Example Application of HAP

Although the HAP tool is far from being complete, we felt that it was important to apply the tool to "sample" areas and to evaluate the results to guide overall direction as we proceed with tool development. An initial attempt to evaluate the regional model was achieved by having one of the model builders and two managers not familiar with the model assess the deer habitat in two small areas on Vancouver Island. The watershed assessment model was evaluated by applying the model to the study area used to collect the data for model development. The results of the model application were "visually" evaluated by the model-building team and a group of resource managers familiar with the area.

2.6.1 Regional priorities model

An attempt was made to evaluate the regional priorities model developed by McNay *et al.* (1987). This model uses the Deciding Factor (Channelmark Corp., San Mateo, Cal.) as the expert system software shell. Users are asked to provide information sensitivity of the deer management issue by answering specific questions about predators, demand for deer, density of deer, accessibility, and winter severity patterns. The sensitivity of the management issue is then weighed against the capability of the area to provide habitat (based on questions about biophysical parameters) and the current quality of the habitat (based on questions about the managed state of the habitat). The result is a relative rating of priority of the need for habitat management.

In the structure of the model (Figure 2) the first two hypotheses — (1) deer are a sensitive management issue and (2) topography is capable of supporting deer — both provide positive weight to the main hypothesis (habitat quality should be a concern). If deer are a more important issue in one area than another, then it follows that deer habitat would be of more concern there as well. Conversely, the third supporting hypothesis — (3) quality is comparable to capability — provides negative weight to the main hypothesis. If deer habitat is already high quality, then habitat management will be marginally effective in increasing the habitat quality. Only when habitat quality is low relative to capability would habitat management achieve any significant benefits.

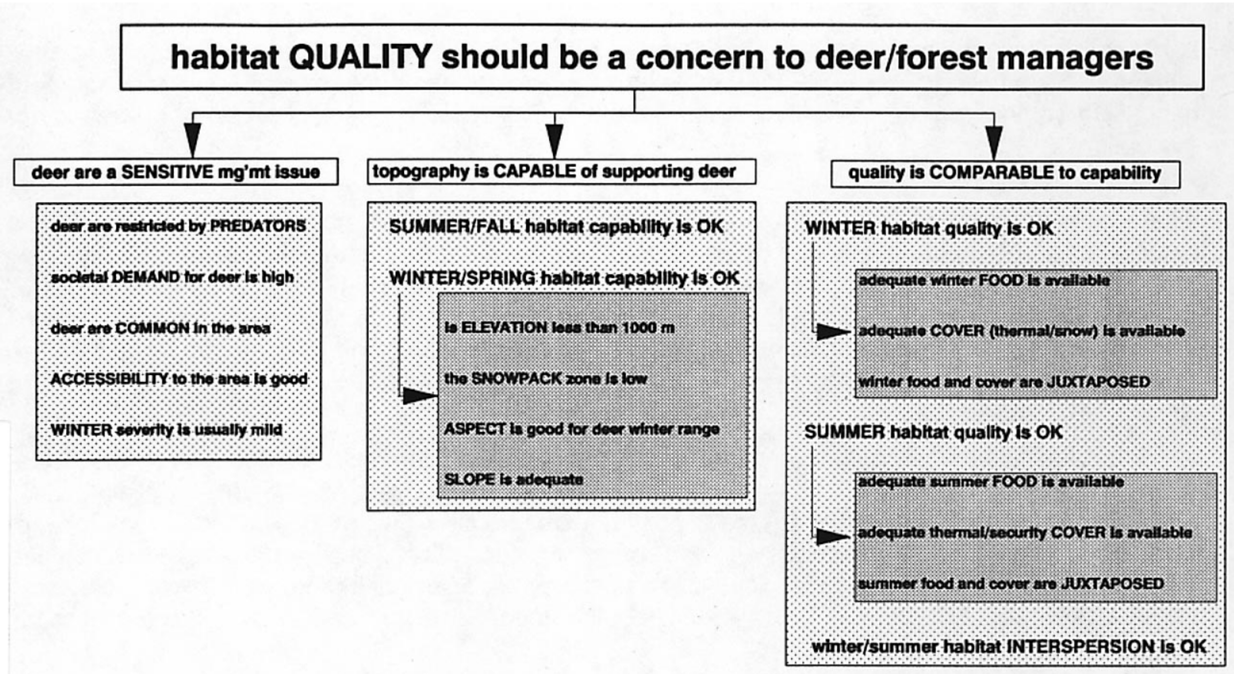

FIGURE 2. Regional priorities model structure.

The final priority rating is determined according to the limiting factor. If any of the three supporting hypotheses provide negative weight, then habitat management is not a concern. For instance, even though habitat quality is not comparable to capability, habitat management does not have high priority as an undertaking if the sensitivity of the deer management issue is very low.

To evaluate the regional priorities model, a test group (two managers and one research biologist) applied the model to two areas of approximately 1500 ha each. One area was familiar to all three users and one area was somewhat unfamiliar. All users were trained biologists and well aware of the concepts described in the model. Presumably, if the results varied dramatically among the users, it would indicate a problem with the model rather than simply a misinterpretation or a lack of understanding. The level of disagreement among the users was determined by adding the difference between the scores of all combinations of the three biologists (Figure 3).

In general, there was a high level of agreement. However, strong disagreement arose over the questions about predation and winter severity. This indicates that either the questions were poorly worded or that the users' world views differ on those topics. There was also disagreement about the value of cover and habitat juxtaposition as they relate to current habitat quality in the area that was relatively unfamiliar. This indicates that a more ''data-driven'' model may be required to assist users with little experience in the location being assessed.

We note the following conclusions about the regional model:

1. Frequently, the consultation with the regional model was difficult because of poor wording of the questions.
2. The question format was not sufficiently flexible to express adequately all of the questions.
3. The logic structure available with the Deciding Factor software was not sufficiently flexible to express realistically the relationships among the variables.
4. It would be advantageous to assist the user by providing him or her with the ability to query databases while within the consulting session.

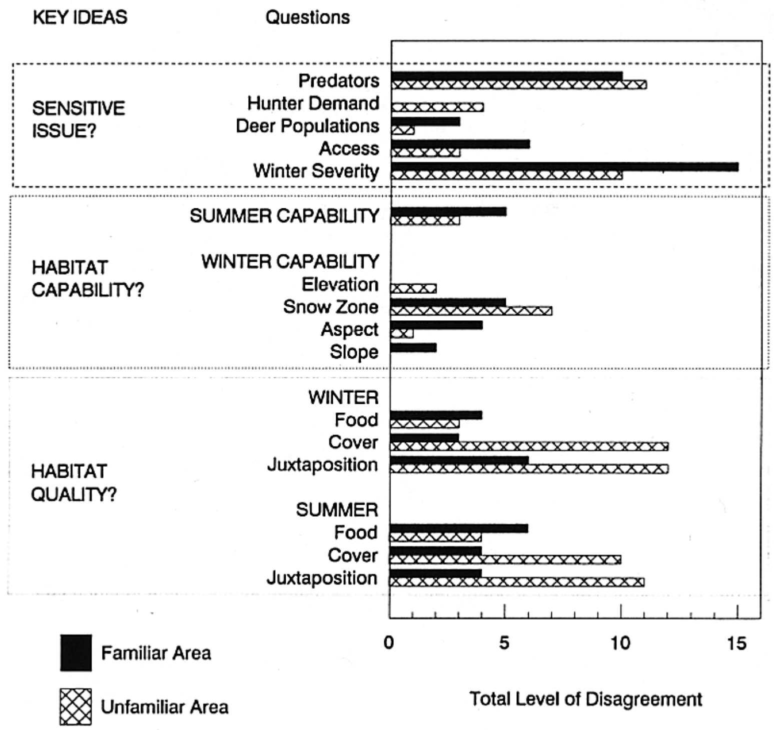

FIGURE 3. Level of disagreement among users who applied the regional priorities model to two small areas on Vancouver Island.

2.6.2 Watershed assessment model

The process of watershed assessment involves five steps:

1. evaluation of current habitat quality;
2. modification of land attributes (primarily forest age) based on one or more forest harvesting scenarios and forest succession;
3. re-evaluation of habitat quality at pre-determined time steps;
4. comparison of future habitat quality with objectives for habitat; and
5. modification of harvesting scenarios or recommendation of habitat enhancement procedures if future habitat quality does not meet objectives.

For the purposes of this example we describe the process and results associated with the first three steps for black-tailed deer winter habitat on an 11 000 ha study area on southern Vancouver Island. The study area has been the focus of deer habitat research and model development and is described by McNay and Doyle (1987).

Evaluation of current habitat quality requires a species habitat relationship model. Current development efforts are focused on modeling habitat quality during the winter season for black-tailed deer. That submodel (Figure 4) is based on the following premises.

Snowfall on Vancouver Island exhibits a highly variable pattern, with severe winters (persistent deep snowpack) recurring infrequently (at approximately 20-year intervals). Severe winter conditions (defined as a snowpack of 45 cm or greater, persisting for more than 30 days [Nyberg and Janz 1990]) occur with varying frequency throughout the island, depending on elevation. Therefore, for long-term population viability, black-tailed deer require access to habitats that will enable them to survive both mild and severe winter conditions. McNay and Doyle (1987) have found that accessibility of severe winter habitat is influenced by the migratory behavior of individual deer.