DEVELOPMENT OF ECOLOGICALLY-BASED PLANNING TOOLS FOR MANAGING CUMULATIVE EFFECTS IN JASPER NATIONAL PARK:

THE ECOSITE REPRESENTATION AND BREEDING BIRD HABITAT EFFECTIVENESS MODELS

by
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Abstract

Increasingly, National Park Managers have begun to recognize the importance of understanding, assessing and managing cumulative effects. In Jasper National Park, the rarest habitat, namely the montane, contains the greatest intensity of human use and development in the park. I developed the Ecosite Representation and Breeding Bird Habitat Effectiveness Models to contribute to an established framework for assessing and managing cumulative effects in the high use area of the park. The Breeding Bird Model integrates call-count survey results, data delineating habitat types and quantifying human use with parameters developed from the literature in an Arc/info GIS. Similarly, the Ecosite Representation Model integrates habitat and human use data with a set of parameters derived from the literature. To assess cumulative effects on breeding bird habitat, I describe a functional relationship depicting the response of breeding bird species detected in the surveys to human activity and development. The relationship for ecosite representation assumes that within a disturbance distance of a human use feature, habitat is degraded. Through these relationships, data layers are integrated to predict cumulative effects, expressed as a change in the effectiveness of habitat for the indicators. This method tracks how the area lost and degraded changes over time and in response to different land use scenarios. Prior to using the models, I conducted a sensitivity analysis identifying the sources and influence of ecological uncertainty on model results. Following this, I completed a cumulative effects analysis which indicates that failure to assess and act on cumulative effects has resulted in impacts on both indicators concentrated in a group of montane habitat types. Development in Three Valley Confluence has predominantly been concentrated in eight habitat types, some of which are rare in abundance and the most important in the park for supporting breeding bird richness. Therefore, I recommend strategic land use planning to ensure new development and expansion does not continue within these habitat types and restoration efforts be undertaken to improve conditions for both indicators. I present several realistic options including planning based on clustering development, reducing access points, restoration and continuing development of a framework for cumulative effects assessment and management.

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Chapter One Introduction

1.1 Introduction

"The one process now going on that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendants are least likely to forgive us."

E.O. Wilson 1984

Three Valley Confluence is 700 km^2 of some of the most valuable wildlife habitat in Jasper National Park. Encircling the convergence of three major river valleys, Three Valley Confluence is predominantly montane habitat; the most important habitat to a wide range of species in Jasper National Park (Holroyd and Van Tighem 1983). The montane represents only seven percent of the total park area, and is the rarest of the three ecoregion types that make up Jasper National Park. Valuable and rare, the montane of Three Valley Confluence is undergoing habitat loss as a result of having the greatest intensity of human use and development in the park.

Loss of habitat is not unique to Jasper and is certainly not unique to National Parks. At a global scale, the loss of habitat and species is happening faster than at any other time in history (Noss and Cooperrider 1994). In 1986, biologists predicted two-thirds of all tropical plant and animal species would be extinct within the next century (Shafer 1990). Currently, humans directly and indirectly expropriate 40 percent of the earth's net primary productivity (Terborgh 1999). With 100 million people added to the earth's population each year, and a doubling expected by mid-century, it will not be long before all other species on earth exist on a small portion of the net primary productivity left over by humans (Lovejoy 1997). While population growth rates are lower in countries such as Canada, the effects of habitat destruction on biodiversity are pervasive. In Canada it has been estimated there are at least 8 000 species that are vulnerable, threatened, endangered, extirpated or extinct, although the status of only about 300 has been formally determined (Mosquin 2000). Habitat loss and fragmentation in North America is having a major effect on resident biodiversity (Ibid.).

The reasons people care about biodiversity are diverse including utilitarian, recreational, esthetic and intrinsic values. Biodiversity loss has significant repercussions for people and the continued functioning of the earth's processes. Species and processes perform vital ecosystem functions

(Mosquin 2000). Among countless others, organisms and ecosystems produce oxygen, sequester carbon dioxide, control erosion, moderate climate, decompose, create food webs, cycle nutrients (Ibid.) and lastly, from solely an anthropogenic perspective; they 'lift the human spirit' (Daily 1997 in Mosquin 2000). Without them, we would likely not exist and once lost would be unable to bring them back.

Given current biodiversity declines and potential for further loss, protected areas may prove the most reliable tool to preserve biodiversity. Currently, only 3.7 percent of the earth's land area is formally designated as parkland by the World Conservation Union (Terborgh 1999). Habitat destruction bordering many existing parks is isolating them, creating habitat islands too small to support top carnivores or ecological processes (Shafer 1990). The *State of the Parks Report* indicates that while Jasper National Park is a large park, the cumulative impact of stressors from internal and external sources is major and increasing (Parks Canada 1997). All these trends point to the conclusion that protecting Jasper National Park from internal and external impacts is important nationally and internationally for global biodiversity protection.

A phenomenon, called cumulative effects, has led to the situation in Jasper where the greatest development occurs on rare and important habitat (Three Valley Confluence). No single decision created this situation. It was a series of small developments and single approvals resulting from a mismatch of scales. The scale at which land use decisions are made is different from the scale at which impacts accumulate. Habitat destruction resulting in loss in biodiversity often occurs as the result of a series of developments, extractions and activities over time and spread across a region, that is, 'destruction by insignificant increment.' (Spaling and Smit 1993). While a single land use change may result in a small, almost negligible impact, the accumulation of these individual changes over time and within a landscape may constitute a major impact (Theobald 1997). When human developments occur frequently in time or densely on the landscape, a system may not be able to absorb and respond to the impacts. The result may be a collapse, loss or flip in the system (Ibid., Holling 1986).

The need for cumulative effects management has been identified in the *1999 Draft Park Management Plan* (Parks Canada 1999), by the *Canadian Environmental Assessment Act*, and under the *National Parks Act* for the protection of ecological integrity. Failing to assess development for cumulative effects at appropriate scales and to continue to approve developments could not only compromise Parks Canada's commitment to ecological integrity, it could expose the agency to possible litigation. However, assessing the cumulative effects of a project is challenging. While park managers have begun to seek new methods for land use decision making at landscape scales, progress on cumulative effects assessment both in and outside National Parks has been slow. This may be due in part to the lack of available methods for detecting and measuring impacts, as well as the difficulty in selecting indicators and developing threshold targets for management (Cardiff 1998). The challenge facing park managers today is to understand the potential consequences of interactions among multiple developments in space and time within highly complex systems, and to take that understanding and respond. To adequately consider these interactions park managers need tools that provide a birds-eye view and often a time scale longer than a generation to create land use plans that minimize cumulative impacts.

I approach the problem of assessing and managing cumulative effects in Three Valley Confluence with a multi-disciplinary perspective, combining resource planning with conservation biology. Conservation biology has been described as a 'mission-oriented science', with its theoretical basis in the pure sciences, while using the resulting principles to address biodiversity loss (Noss and Cooperrider 1994). In a similar way, resource planners use knowledge about people and the environment to implement change, turning 'knowledge to action' (Friedman 1987). Resource planners are ideally suited to work with conservation biologists providing the link between ecological knowledge and ecologically-based decision making and action. At times, resource planners themselves may undertake technical studies to understand patterns and signals in ecosystems in response to land use impacts. Combining spatial design, community and land use planning skills they can communicate this understanding in a way that the public and decision-makers understand, and develop options to address concerns on the ground. In addition to a land use planning role, resource planners often have a second role, working toward changing decision making processes themselves to be responsive to the signals of ecosystems. While this is a fundamentally different approach, I believe resource planners must work at both levels, communicating the signals of ecosystems to influence decision making to protect biodiversity now, while sometimes working to ultimately change the processes by which decisions are made for long-term protection.

1.2 RESEARCH GOAL AND OBJECTIVES

The purpose of this thesis research is to develop tools that contribute to an existing framework for the assessment and management of the cumulative effects of land use on the ecological integrity of the high use area of Jasper National Park. My primary objectives in this research are:

a. To assess and analyze ecological concepts guiding cumulative environmental effects assessment, and in particular, the selection and use of ecological indicators.

b. To select ecological indicators that support the existing framework for cumulative effects assessment and describe a measurable relationship between human use and the response of the indicators.

c. To develop tools, namely the Ecosite Representation Model and Breeding Bird Habitat Effectiveness Model, to portray the indicator-cumulative effects relationships that: 1) are sensitive to cumulative effects at the scale of Three Valley Confluence, 2) allow for the repeated assessment of cumulative effects of current and alternative land use scenarios, 3) are scientifically defensible, 4) are operationally feasible, and 5) enable ecological validation to be carried out.

d. To assess the cumulative impact of present land use and alternative scenarios on the ecological indicators, and present recommendations for management.

1.3 METHODS

This project has three major components: (1) the development of land use planning models for assessing cumulative effects on ecological indicators; (2) a cumulative effects analysis for the study area; and (3) conclusions regarding the management of land use.

A review of cumulative effects assessment in Jasper National Park highlighted the need for additional practical planning tools that could support the Three Valley Confluence framework for ecologically-based land use planning in the high use area. I selected two new indicators, ecosite representation and breeding bird habitat effectiveness, to support the framework and I developed tools to assist in analyzing the cumulative impact of land use. The tools are spatially-based computer models. The choice of computer modeling was influenced by a review of the cumulative effects and scientific literature, the available ecological and human use data, and Parks Canada technology and expertise.

I developed a mechanism for describing the relationship between human use and the response of two selected ecological indicators. Because of the complexity of the relationships and ecological data, I hired a computer technician to write a program to depict these relationships. The result is a dynamic computer program that calculates the cumulative effect of land uses on ecological indicators. I tested the models and used them to conduct a cumulative effects analysis for the study area. These two models contribute with other tools in Jasper National Park to improve Parks Canada's understanding of how human presence in one of the most valuable areas of the park impacts ecological integrity.

1.3.1 Study Area

Jasper National Park is the largest of the four Canadian Rocky Mountain national parks (10 878 km^2). In 1984 these Rocky Mountain parks, in addition to several adjacent provincial parks, were designated as a UNESCO World Heritage Site, meaning they have outstanding universal value (Environment Canada 1991). The most northerly of the mountain parks, Jasper, is made up of three ecoregions: the alpine, subalpine and the montane. The montane ecoregion ranges in elevation from 1000 m to 1350 m, and is the most limited in extent in the park.

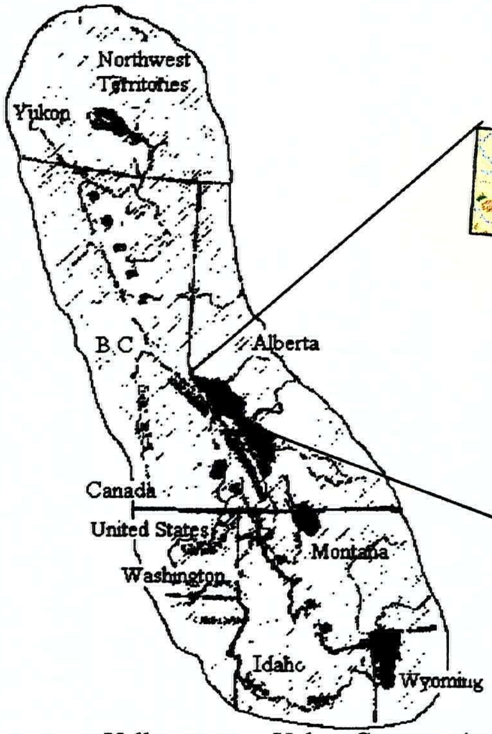
Three rivers converge in the center of the montane ecoregion: the Maligne, the Athabasca and Miette rivers. The 700 km^2 area surrounding this convergence, known as Three Valley Confluence, is of special management concern to Parks Canada for several reasons. Although it represents only 6 % of the park area it contains half of the park-wide montane habitat. The study area is characterized by ecologically productive forest dominated by Douglas fir, white spruce and aspen poplar with savannah valley arteries and wetlands (Cardiff 1998). In addition to providing valuable habitat for wildlife in the park, the confluence of the three valleys also creates a zone of convergence for wildlife movement and dispersal within and through the park (Ibid.).

Also at this convergence is the town of Jasper, the majority of the park accommodation and infrastructure to support the tourism industry, the Canadian National Railway, the intersection of two major highways, pipeline and utility corridors. Three Valley Confluence is the focus of the majority of the development proposals within the park. In 1997, 213 projects were registered under the Canadian Environmental Assessment Act. Eight-five percent of those projects occurred within Three Valley Confluence (Cardiff 1998). While there are relatively high levels of human use in other areas in the park, the concentration of various uses in this region represents a unique blend and intensity of ecological stresses.

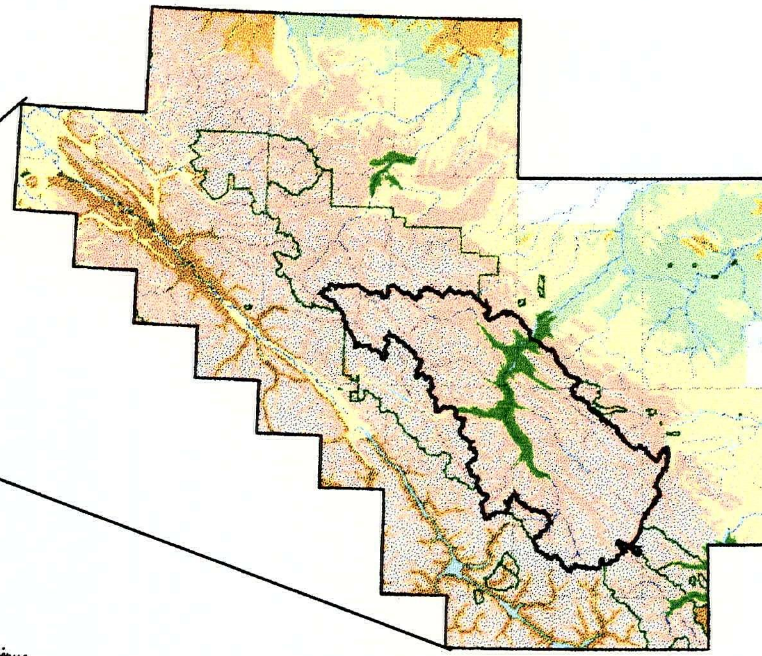
The study area is based generally on the ecological boundaries of the montane but limited to focus on cumulative effects in the high human use area. Regardless of the scale of study area chosen, it is important to recognize that processes link systems to larger and smaller systems (Peterson and Parker 1998). Three Valley Confluence nests within the park, a greater ecosystem, a world heritage site, and a continental movement corridor. It is not the intention of this thesis to suggest Three Valley Confluence is a whole system, rather it is one of the most valuable pieces of a system, and the most highly impacted by human use in the park. Figure 1 shows how the study area I have chosen for this thesis relates to the study areas chosen in other park management research programs and beyond the park.

1.3.2 The Structure of the Thesis

I begin this document with a review of the literature, local scientific understanding and data related to this thesis. An introduction to the ecological indicators selected as the basis for the cumulative effects models follows. I present the models explaining the methods by which the components were developed in a step-by-step fashion culminating in their final working form. The models were put to use in a Cumulative Effects Assessment of present land use and several alternative land use configurations. To assess the robustness of the results, a sensitivity analysis with comments on uncertainty and limitations follow. I conclude with recommendations for managing cumulative effects and improving assessment capabilities in the park.



Yellowstone to Yukon Conservation Initiative Study Area (Adapted from Stoltz 1997)



Jasper National Park (in black) in the context of the Greater Yellowhead Ecosystem. (Source: Parks Canada)

The Three Valley Confluence Study Area and the boundary of the montane ecoregion.

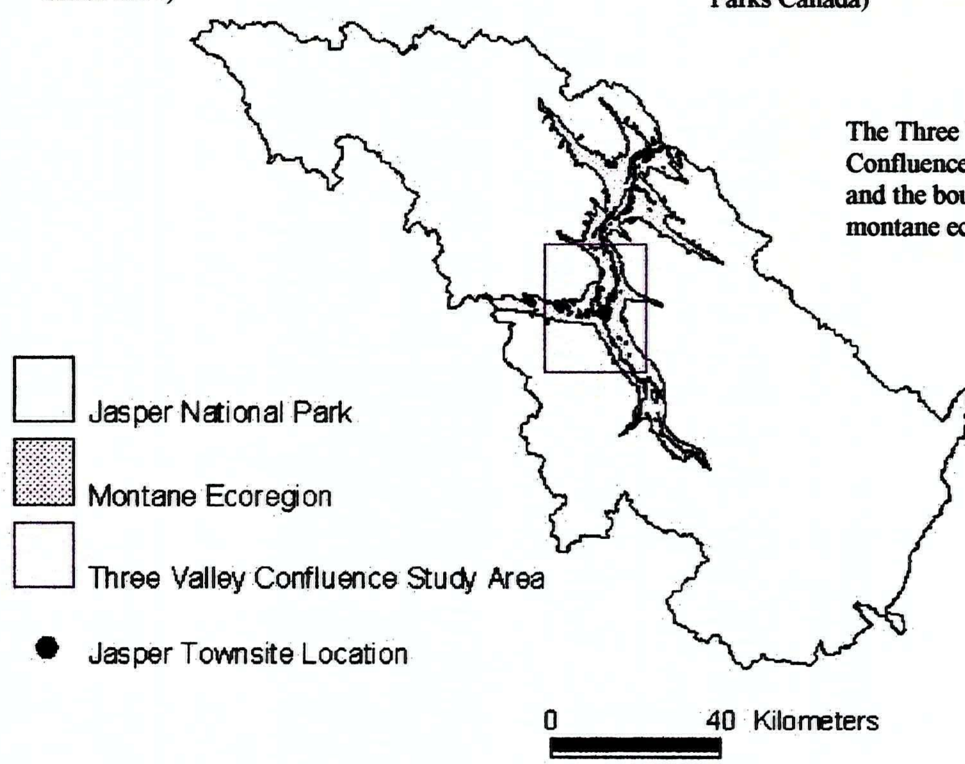


Figure 1. Forming a link for wildlife movement from Yellowstone National Park to the Yukon Territory, within a UNESCO World Heritage Site, part of the 68 000 km^2 greater ecosystem, in the heart of Jasper National Park is Three Valley Confluence.

Chapter Two Research and Ecological Concepts Guiding the Model

2.1 Introduction

The purpose of this chapter is to provide a concise account of the ecological concepts and local understanding guiding the development of the cumulative effects models used in this thesis. I begin with a brief introduction to ecological integrity as a management objective and expand on the framework adopted within the National Parks for its achievement. The use of ecological indicators is integral to Parks Canada's approach in managing for ecological integrity. The concept of indicators, the advantages and disadvantages and the criteria for selection will be articulated in the second portion of this section. Section three provides a summary of the concept of cumulative environmental effects and a review of Parks Canada's approach to cumulative effects assessment. Because assessing cumulative effects of human use on ecological integrity requires knowledge about the ecosystem and human use, section four reviews Jasper National Parks' empirical data relating to this thesis.

2.2 Monitoring Ecological Integrity

> "Maintenance of ecological integrity through the protection of natural resources shall be the first priority when considering park zoning and visitor use in a management plan"
>
> National Parks Act 1988

The ultimate management goal for Jasper National Park is to maintain, or where required restore, ecological integrity (Parks Canada 1999a). Ecological integrity is an indicator of the condition of an ecosystem in relation to a desirable state or endpoint (Woodley 1993). It is a concept upon which multiple theses could be written. For the purpose of this thesis, a simplified definition used by Parks Canada (1998) states that:

Ecological integrity is the condition of an ecosystem where:

1. *structure and function of the ecosystem are unimpaired by stresses induced by human activity and,*
2. *the ecosystem's biological diversity and supporting processes are likely to persist.*

Furthermore, a system with ecological integrity is a system with various degrees of resilience. Resilience is the ability of the system to absorb and resist impacts and respond to human-caused stresses and to continue to function (Peterson and Parker, 1998). The complexity inherent in ecosystems means monitoring and managing for ecological integrity is difficult. Therefore, when managing within a mandate of ecological integrity Parks Canada needs frameworks for understanding the structure and function of ecosystems that allow our impacts and natural phenomena to become apparent. Further, these frameworks need to encompass ecosystem components and processes merged with concepts of spatial and temporal scale (Ibid.) so impacts that accumulate at landscape scales, but are not detected at the scale of a leasehold, become distinguishable.

Monitoring Using Indicators

The method adopted by Parks Canada for understanding and monitoring ecological integrity relies on indicators. Indicators are measures of environmental change. They are components of the environment (e.g. species and processes) that are sensitive to stresses, characterize the system, and quantify a relationship between the degree of stress and an ecological response (Innis 1998). We cannot measure the response of a system in its totality to changes in the environment. As Cairns et al. (1993) conclude "everything indicates something but nothing indicates everything". Therefore, we monitor a set of components to detect the extent of impacts on the system. In the context of this thesis, selecting appropriate indicators for detecting stresses on ecological integrity is essential.

Indicator selection may be the most critical step in a monitoring program for cumulative effects assessment (McGeoch and Chown 1998, Noss and Cooperrider 1994). For example, if indicators are selected and later are found not to be sensitive or representative enough, the entire monitoring process may fail (Noss and Cooperrider 1994). Parks Canada has adopted a hierarchical approach for selecting indicators. Since the effects of environmental stresses are expressed differently at different levels of biological organization (Noss 1990), changes due to land uses that effect a species may not be detectable at higher levels of organization in the system. Therefore, a set of indicators must be selected with representative indicators at each level to improve the detection of impacts. The levels of organization most commonly considered are the genetic, population/species, community/ecosystem and landscape levels (Ibid.). This hierarchical characterization of biodiversity provides a conceptual framework for monitoring the overall status of biodiversity at different spatial and temporal scales. Combining this approach with the identification of major stressors in the ecosystem is the foundation for Parks Canada's approach for monitoring cumulative effects on ecological integrity.

It is important to note that this framework is not sufficient for selecting indictors. According to Lambeck (1997) indicators ought to be chosen based on their sensitivity to impacts at the spatial and temporal scale of interest. Specifically for cumulative effects, they must be sufficiently sensitive to detect incremental impacts of land use occurring over long time periods within the landscape. Additional criteria for selecting indicators include ease of monitoring, sensitivity to human disturbance, and knowledge of their biology (Caro and O'Doherty 1999).

In Jasper National Park several biodiversity indicators and ecosystem functions have been identified for monitoring. Two examples are grizzly bear habitat quality and disturbance processes. The primary threats creating stresses on ecological integrity in Jasper National Park have been identified in the *1999 Draft Park Management Plan*. They include the following: habitat fragmentation and loss of connectivity, resource extraction outside the park, wildlife-human conflicts, altered vegetation succession, loss of montane habitat due to development and fire suppression, and altered predator-prey relationships (Parks Canada 1999). This thesis addresses the threats of habitat loss at two levels of biological diversity: community and landscape levels.

This discussion on ecological integrity ultimately brings us back to cumulative effects assessment. Cumulative effects assessment in a national park context is really an evaluation of how the effects of a proposed project interact with effects of existing or future projects as a collective stress on the processes, structure and function of an ecosystem. In this sense cumulative effects assessment is essentially an operational framework for monitoring human-caused stresses on the ecological integrity of a system . The challenge is how to operationally measure accumulated and diverse stresses within a system.

2.3 The Concept of Cumulative Effects

"The tyranny of small decisions."

W.E. Odum 1982

"Under what circumstances do actions that are beneficial at the individual level become destructive at the ecosystem level?"

Edward Rykiel 1998

Cumulative environmental effects have only been widely recognized in the last twenty-five years (Spaling and Smit 1993). This section introduces the concept of cumulative effects and provides background on the status of assessment methods and tools relevant to national park management. My objective is to provide a context for the cumulative effects assessment Framework in Jasper National Park and for the development of the cumulative effects models in this thesis. This section will address the following three questions:

What are cumulative effects and how do they differ from environmental effects?
What methods are used to assess cumulative effects?
What approach has been adopted by Parks Canada?

Cumulative effects are changes in the environment caused by a human action in combination with the effects of other past, present and future human actions (Hegmann et al. 1997). Cumulative effects result when individual impacts accumulate over time and space and intensify in such a way that the whole effect is greater than the sum of the individual impacts. Each decision to approve a development or activity may cause an incrementally insignificant change. However, when repeated through time and within a region these impacts can accumulate to a significant impact (Spaling and Smit 1993). Pathways of change describe how impacts accumulate. Impacts from multiple sources may accumulate additively with each project adding incremental impacts. Or the impacts may accumulate synergistically, producing an impact greater than the sum of the effects of the individual sources (Kalff 1995). Cumulative effects assessment is the evaluation of these effects.

Cumulative effects assessment is really "environmental assessment as it always should have been." (Hegmann et al. 1999). Generally, cumulative effects assessment improves on past environmental impact assessment practices which previously did not 1) account for the additive effects of repeated developments in the same ecosystem, 2) adequately deal with growth-inducing developments, or 3) deal with nonlinear cause-effect relationships (Kansas et. al. 1994). Figure 2 clearly shows the difference between environmental impact assessment and cumulative effects assessment.

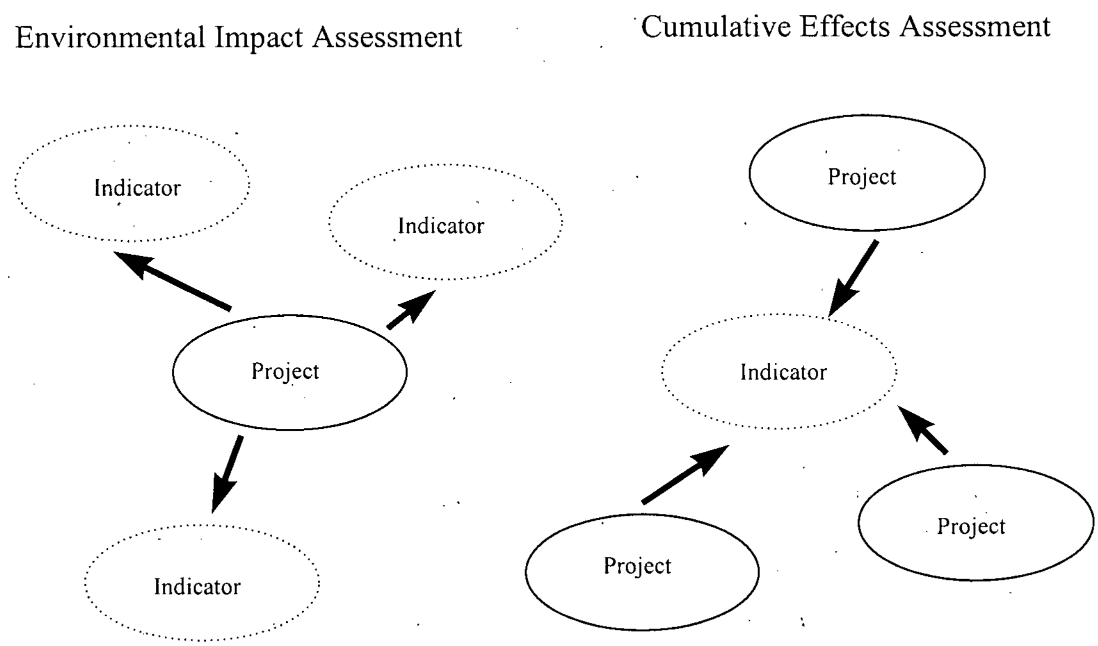


Figure 2. This diagram compares the relationships between projects and indicators in environmental impact assessment (EIA) to those in cumulative effects assessment (CEA). In EIA, a project's impact on indicators was assessed in isolation. CEA considers a project's impact on an indicator in combination with all other existing and proposed projects.

Two non-mutually exclusive purposes for cumulative effects assessment have been recognized. Cumulative effects assessment is a reactive tool used to evaluate land use proposals and it is also a proactive tool for future land-use planning. In the second instance, cumulative effects assessment may be used as a method for assembling information and applying principles of research design and scientific analysis. The results of the analyses may guide decision-makers in their management strategies (Spaling and Smit 1993). In addition, cumulative effects assessment may use planning principles and procedures to determine options from a set of resource allocation choices (Kansas 1993, Smit and Spaling 1995). This thesis acknowledges that at times proactive and reactive approaches are appropriate for incorporating knowledge of cumulative environmental effects into the land use decision making process. A principal role of a land use planner is to take advantage of ecological insights so decisions are based on the best available understanding of the interactions within human and ecological systems. While the planning approach is more strategic for minimizing impacts on ecosystems, we still rely on cumulative effects assessment in the reactive form when we have not developed comprehensive land use plans and thus need proposals to be assessed on an iterative and ad hoc basis.

While the literature provides a range of definitions and descriptions of cumulative effects, there is limited guidance on methods for evaluating cumulative effects (Damman et al 1995). Cocklin et al (1992) reviewed a selection of conventional methods for evaluating cumulative effects. Methods range from environmental checklists, which are simply lists of environmental effects and impact indicators, to a more progressive approach using a matrix incorporating cause and effect relationships. Rather than a specific method applicable broadly, most authors view cumulative effects assessment as a process or framework for collecting and analyzing information (Kalff 1995) and potentially for managing impacts.

Parks Canada established a process for cumulative effects assessment for Canadian National Parks (Kalff 1995). The process includes three components: identifying the source(s) of cumulative environmental change, assessing cumulative effects, and managing cumulative effects. The steps in this process include: describing the ecosystem, selecting indicators, describing their status, setting goals for indicators, describing past, present and future land use, establishing cause-effects linkages, assessing the significance of cumulative effects and finally undertaking cumulative effects monitoring (Ibid.). In 1997, Jasper National Park initiated the Three Valley Confluence Framework to support this process.

The Three Valley Confluence Cumulative Effects Framework

Parks Canada developed this cumulative effects framework to support land use planning and decision making within the Three Valley Confluence area of Jasper National Park. The framework was initiated in 1998 to respond to key challenges of identifying pathways of change, selecting and monitoring indicators and prescribing management thresholds against which landscape conditions could be measured (Cardiff 1998). The method adopted to address these challenges was a framework of ecological and social indicators and scientific methods to predict the consequences of existing and proposed projects and activities. The tool was designed to enable consideration of environmental effects among projects as they interact and accumulate at the scale of Three Valley Confluence and compare these to measurable thresholds (Ibid.).

The framework identifies a set of indicators for tracking changes in the ecosystem caused by human impacts. Indicators complement one another so that changes can be detected at different levels, from a small patch of rare plants to the pattern of old growth in the park. It is clear that this approach has been influenced by recommendations in the scientific literature (Noss 1990, Woodley 1993) to select indicators for cumulative effects assessment at multiple levels of biodiversity. As section 2.4 outlined, one indicator cannot detect impacts occurring for all habitats and species. To date, a study area has been defined, some of the indicators have been selected, and tools to assist in assessing cumulative effects have been developed for a some of these indicators (Cardiff 1998). Parks Canada specialists, in consultation with experts proposed the eight indicators shown in Figure 3 be investigated for their appropriateness within the framework. The selection was based on the specialists' perceptions of the key issues and stressors in Three Valley Confluence (Ibid.). Additionally, indicators were selected based on their ability to support analysis by the existence of site-specific data.

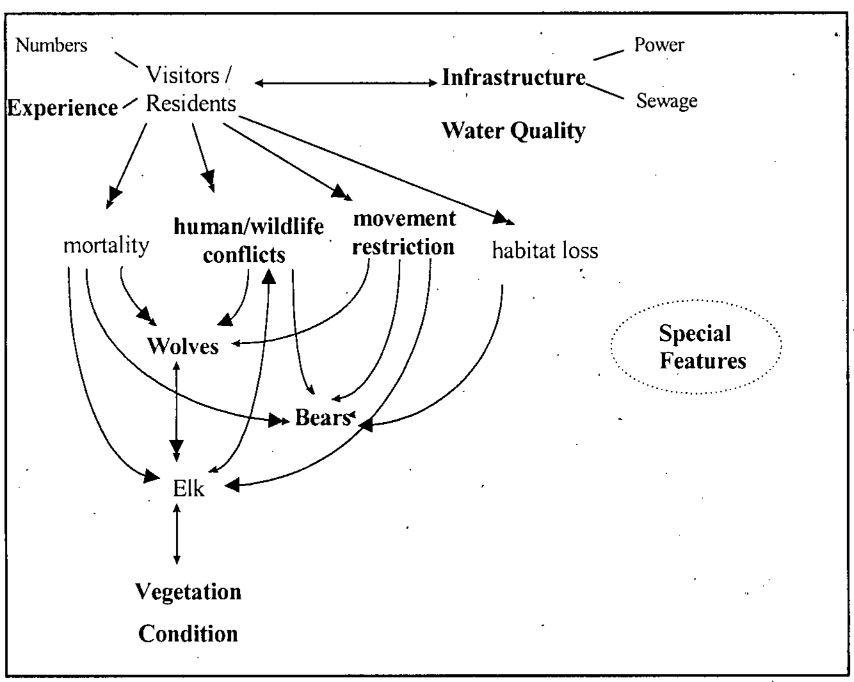


Figure 3 The interaction among indicators (in bold) selected in the Three Valley Confluence Framework (Adapted from Cardiff 1998).

Several models have been developed to facilitate the assessment of cumulative effects on a some of the indicators including a wolf movement model and grizzly bear habitat effectiveness model. The grizzly bear model provided the conceptual basis upon which I based the two models developed in this thesis.

The Grizzly Bear Habitat Effectiveness Model

The grizzly bear habitat effectiveness model was developed as a cumulative effects tool by the USDA Forest Service in 1985. The model includes past and present human impacts on bears and their habitat. Jasper National Park has adapted the model for use in the park as a cumulative effects assessment tool.

Habitat effectiveness expresses the effect of human actions on grizzly bears and their habitat. It compares the potential of an area to support grizzly bears to the actual or realized value of the area as bear habitat after human disturbance has been accounted for. It then reflects this ratio as a percentage of the potential (Gibeau et al. 1996). The spatial scale of analysis is the park, broken down into smaller units called Bear Management Units (BMUs). A BMU is equivalent to the area capable of supporting one reproductive female grizzly. This scaling of effects ensures analysis is conducted at a biologically meaningful scale for grizzly bears. Of the 33 BMUs in the park, the BMU containing the Three Valley Confluence Study area has the lowest habitat effectiveness value (61 %) even though it has the highest rating for habitat value. The threshold habitat effectiveness by BMU commonly used for protected areas is 80 % (Hood 1998).

While it is useful for assessing land use configurations at the scale of the BMU, the grizzly bear habitat effectiveness model has inherent limitations in assessing land use options at fine scales, such as at the scale of Three Valley Confluence (Cardiff 1998). These limitations result from the mapping scales and the set of rules that govern the model's application (Ibid.). For example, a ski lodge may degrade conditions for a female grizzly bear in the area surrounding the lodge. The cumulative effect of an additional two to ten more developments clustered close to the lodge, each resulting in habitat loss, may not be detected in the model. The model predicts bears may avoid suitable habitat surrounding the ski lodge because of human activity and sensory disturbance. The impacts of the added developments that actually alter habitat are not detected in the model because the grizzly bears already avoided the habitat due to sensory disturbance.

Thus, the model may not be sensitive to substantial changes in human use at fine spatial scales and may not be sufficient for understanding and exploring the implications of land use changes at fine spatial scales.

Parks Canada identified the need to develop tools to assess cumulative effects of land use at a finer resolution (Cardiff 1998). The mechanism for assessing cumulative effects of development on habitat for a particular indicator has been adapted for two new indicators: ecosite representation and breeding bird habitat effectiveness. The two models developed in this thesis complement the grizzly bear habitat effectiveness model within the cumulative effects framework for Three Valley Confluence by broadening the focus to three levels of organization for biodiversity operating at different scales of resolution.

Modeling and GIS as tools for Cumulative Effects Assessment

Why use ecological modeling for land use decision making? There are significant obstacles in environmental monitoring including the extrapolation of short-term results to longer periods of time, the inability to change perspective and view problems from a landscape scale, and the establishment of cause and effect relationships (Innis 1998). This is where models are helpful. Models are simply tools that help us understand processes or trends by integrating complex information from disparate sources. They simplify ecological systems so that we can either (1) focus on relationships or specific concerns, or (2) view the landscape at a scale beyond which we normally focus. Models can incorporate complex data at large spatial scales and long time periods into assessments (Ibid.).

This thesis uses GIS modeling to bring related data from different sources together to accumulate land use impacts over space and time, to look at spatial relationships and to describe a complex functional relationship between human-caused stresses and the response of indicators.

2.4 A Review of the Jasper National Park Empirical Data

Assessing cumulative effects of human use on ecological integrity requires knowledge about the ecosystem and human use in the park. Making management decisions within a mandate of ecological integrity requires an understanding of how ecological components interrelate and how they relate to human use. In response to the need for ecological understanding, Parks Canada developed a natural resource management process requiring an ecological land classification, description and analysis. Jasper National Park completed the project in 1982. While some analysis has been completed using this data, there are opportunities to build on current understanding through further analysis of existing data.

2.4.1 The Banff and Jasper National Parks Ecological Land Classification

Parks Canada initiated the Banff and Jasper Biophysical Land Classification in May 1974 (Holland and Coen 1982). This inventory classified similar land units within the parks by integrating landform, soil, vegetation data and a wildlife inventory of the two parks at a scale of 1:50 000. The resulting geo-referenced biophysical database classified the park into 3 ecoregions, 55 ecosections and 124 ecosites. Initial stratification established the ecoregion boundaries (alpine, subalpine and montane). At a more detailed level, ecosections were based on broad differences in genetic materials and drainage classes reflected by landform features. Once soil and vegetation information was superimposed on ecosection boundaries, ecosites could be identified based on vegetation differences as well as soil parameters. Field checking the accuracy of mapping on the black and white aerial photographs was conducted by a team consisting of a soil scientist and a vegetation scientist. The wildlife component of the survey included all known animal species in the park and relied on a variety of survey techniques for data collection. The objective of the wildlife survey was to assess the importance of the 124 ecosite types (listed in Appendix I) to each of 300 wildlife species found in the park (Ibid.). The field work was completed in 1980 with the data presented in map and report form. Several years later the data were digitized.

As part of the wildlife survey, field biologists studied breeding birds from 1975 to 1980 throughout both parks using call-count transects. Breeding bird populations were sampled by counting birds along 500 m transects. Each transect was located within a single ecosite type. The number of individual birds seen and heard and the estimated perpendicular distance of these birds from the transect line were recorded. Every 50 m the surveyor paused for 0.5 to 2 minutes. To reduce variability in data due to changes in singing frequency, all transects were surveyed between one half hour before dawn and 9:00 a.m. between June 1 and July 15 over the five year period (Holroyd and Van Tighem 1982). This method (point counts along a transect) is generally used to sample birds populations to estimate densities in local areas to determine trends in populations over regional areas, to assess habitat preferences and for other population monitoring purposes (USDA 1995a).

An analysis of the wildlife and ecosite data allowed researchers to associate species occurrences with habitat types using 'ecosite' as the habitat descriptor. Ecosites were subsequently rated for their importance to breeding birds. This rating was based on the species associations determined from a total of 1700 call-count transects. The 'importance' ratings were relational with ecosites classified as very high, high, medium and low importance to breeding birds. Prior to this thesis, the raw data had not been analyzed further than these broad ratings. It was not in a digitized form usable within a GIS and had not, to my knowledge, been used in any further studies. This data is the basis for the breeding bird model developed in this thesis.

Table 1 A selection of the raw data showing 9 of the 10 522 species records from the original bird call-count survey database. UTMstart and end refer to the start and end points for each 500-m transect. Below are data from two transects with the division in records indicated by the double-line.

date	observer	ecosite	watershed	utmstart	utmend	species
290676	GLH	HD4	Athabas-L	MJ256790	MJ259795	Brown Cowbird
290676	GLH	HD4	Athabas-L	MJ256790	MJ259795	Common Flicker
290676	GLH	HD4	Athabas-L	MJ256790	MJ259795	Chipping Sparrow
290676	GLH	HD4	Athabas-L	MJ259795	MJ262799	Warbling Vireo
290676	GLH	HD4	Athabas-L	MJ259795	MJ262799	Swainson's Thrush
290676	GLH	HD4	Athabas-L	MJ259795	MJ262799	Western Tanager
290676	GLH	HD4	Athabas-L	MJ259795	MJ262799	Vesper Sparrow
290676	GLH	HD4	Athabas-L	MJ262799	MJ265804	Gray Jay
290676	GLH	HD4	Athabas-L	MJ262799	MJ265804	Yellow-rumped Warbler

2.4.2 Human Use Database

In 1997 human use data was collected and estimated for the park (Parks Canada 1999b). The data, shown in Table 2 , has been mapped in digital form and includes all infrastructure, as well as trails and transportation lines, with their approximate user numbers. Line, point and polygon data are categorized into 7 classes on an exponential scale based on park visitation records and personal observation (e.g. 1-100, 100-1000, 1000 – 10 000 visitors/month). In this thesis, I assume the human activity data accurately reflects actual human use at the scale of Three Valley Confluence. Disturbance buffers will be added to human uses in relation to the category of use (trail, highway, and building) and the particular indicator. Presently, the human use data is being validated through a number of studies in the park including through a trail counter study in Three Valley Confluence.

Table 2. A simplified section of the human use database for the area including Three Valley Confluence. Features are classified by their physical class and major use.

Feature Name	data	date	paved	unpaved	air	railway	lake	river	trail
rodeo pit	Polygon	3/1/96							
wapiti campground	Polygon	3/1/96							
sleepy hollow area	Polygon	3/1/96							
jasper park lodge	Polygon	3/1/96							
jasper park lodge road	Line	3/1/96	✓						
pine bungalows	Polygon	3/1/96							
sand pit	Polygon	3/1/96							
palisades commerical area	Polygon	3/1/96							
palisades trail	Line	3/1/96							✓
snaring road	Line	3/1/96	✓						
celestine road	Line	3/1/96		✓					
highway 16 east	Line	3/1/96	✓						
railway east	Line	3/1/96				✓			
Powerline	Line	3/1/96							✓
Airstrip	Polygon	3/1/96			✓				
warden office	Polygon	3/1/96							

Each human use feature in the database has been categorized within one of twenty feature categories. Each category is either a line (e.g. trail), point (e.g. campsite) or polygon (e.g. accommodation) feature.

Chapter Three Selecting Ecological Indicators

3.1 Selecting the Indicators

Four factors influenced my selection of ecological indicators for this thesis. First, as Chapter 2 outlined, the indicators fill gaps in the Three Valley Confluence Cumulative Effects Assessment Framework to support monitoring at multiple levels of biodiversity. Second, empirical data existed on the biology of the two chosen indicators providing an understanding of the status of the indictor within the study area. Third, the relationship between the chosen indicators and the concept of ecological integrity has been well documented. Lastly, the chosen indicators are measurable, cost effective and tractable thereby allowing the models to be verified through future field research.

Both indicators selected in this thesis support the Three Valley Confluence Cumulative Effects Assessment Framework. Figure 4 shows the relationship of the two new indicators, breeding bird habitat effectiveness and ecosite representation, to the existing ecological indicators presented in section 2.3 for the Three Valley Confluence Framework. I selected these indicators to detect cumulative effects at two additional levels of organization for biodiversity. Ecosite representation is an indicator for the regional landscape level while breeding bird habitat effectiveness indicates impacts at the community level. These characteristics will be discussed for each indicator in the following two sections.

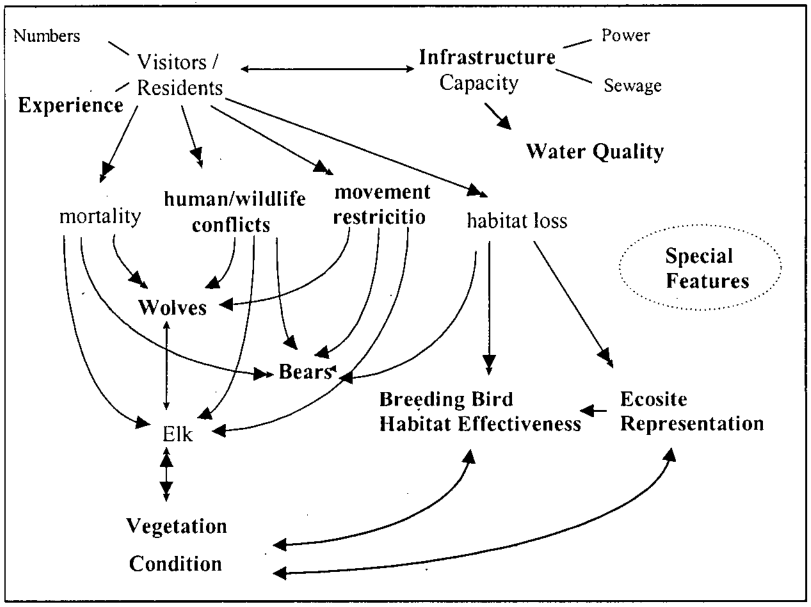


Figure 4 The relationship between the indicators selected in this thesis and the existing indicators selected in the Three Valley Confluence Framework (indicators in bold).

3.2 Ecosite Representation

3.2.1 Ecosite Representation as an Ecological Indicator

"National parks protect representative examples of the Canadian landscape."

Canadian Heritage 1994

Jasper National Park is a mosaic of habitat types that repeat in small and large patches throughout the park. Some habitat types are abundant, such as rock and ice, which make up 40% of the park area (see Figure 5). For other habitat types, ecosites occur in small patches. For example, many montane ecosite types occur in less than 0.5 % of the park. Figure 6 and Table 3 list and map rare montane ecosite types in Three Valley Confluence.

A fundamental purpose of the national parks is to represent landscape types at a variety of scales at the biome, ecoregion, and ecosite levels (Canadian Heritage 1994). The montane ecoregion occupies a small fraction of Jasper's land area. However, it is of very high importance to a wide range of species (Holroyd and Van Tighem 1983), and therefore critical for the maintenance of ecological integrity (Cardiff 1998). Many montane ecosites are rare in abundance and distribution. Therefore there is a high risk that modification or loss of ecosite representation due to human activity may result in the elimination of some ecosite types in the park. The purpose of this model is to measure and predict the cumulative impacts of human activity on the representation of montane ecosites.

Representation is an ecosystem approach to conservation because it focuses on habitats and species assemblages rather than on single species (Noss and Cooperrider 1994). "The best way to represent all ecosystems is to maintain the full array of physical habitats and environmental gradients in reserves, from the highest to the lowest elevations, the driest to the wettest sites and across all types of soils, substrates, and topoclimates" (Noss 1993). Therefore, an assessment of representation of ecosystems or communities in Jasper National Park across varying degrees of human use in comparison to the undisturbed representation indicates a change in ecosystem diversity. Terrestrial communities and ecosystems are often defined and delineated by their dominant plants, and sometimes by their functional groups of animals (Usher 1986, Noss and Cooperrider 1994). Parks Canada delineated ecosites according to landform and soil taxonomies and an associated vegetation community (Holland and Coen 1982).

I selected ecosite representation as a surrogate indicator for the maintenance of ecosystem or community diversity. Ecosite diversity may be lost inadvertently when development occurs in an ecosite type rare in abundance or limited in extent. Benefits of this indicator are that: it provides for assessment across stressed and non-stressed conditions; it supports the multi-indicator approach; data is available to measure ecosite representation; and it accommodates a wide range of spatial and temporal scales given different resolutions of mapping.

3.2.2 Available Data

As outlined in section 3.2.1, the Jasper National Park Ecological Land Classification (Holland and Coen 1983) delineates habitat types in the park (Holland and Coen 1983).

3.2.3 Limitation of Ecosite Representation as a Measure

Interpreting ecosite representation as a goal rather than an indicator may lead some to conclude Parks Canada's objective is to manage the landscape to maintain it in the snapshot condition surveyed in the 1980s. In contrast, all components of ecosystems including landform, soil, and vegetation are dynamic. Monitoring ecosite representation in the context of ecological integrity means ensuring protection is provided to the full array of ecosite types so that ecological processes, not land use, continue to shape their evolution.

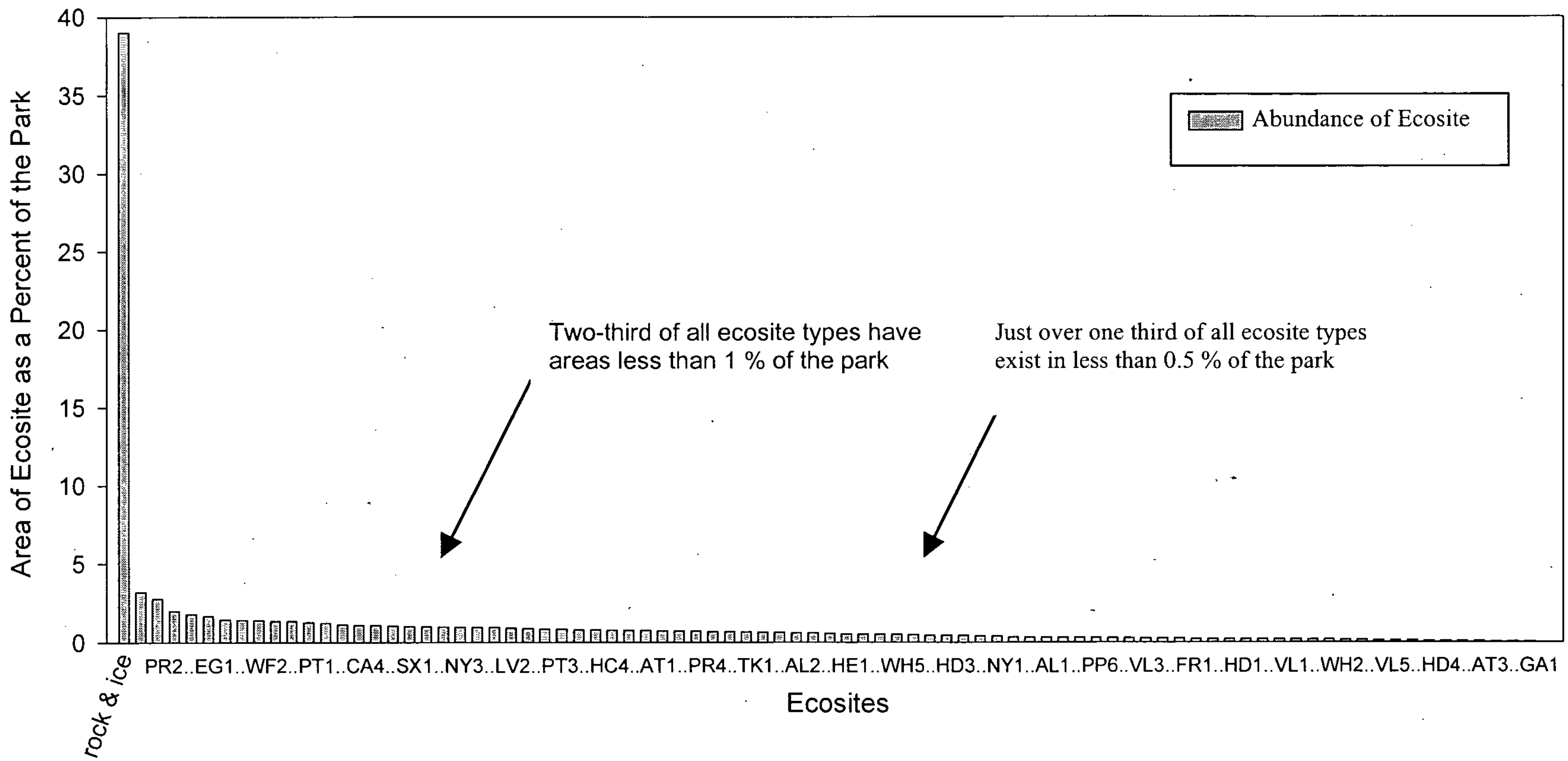


Figure 5. Abundance of ecosite types in Jasper National Park.

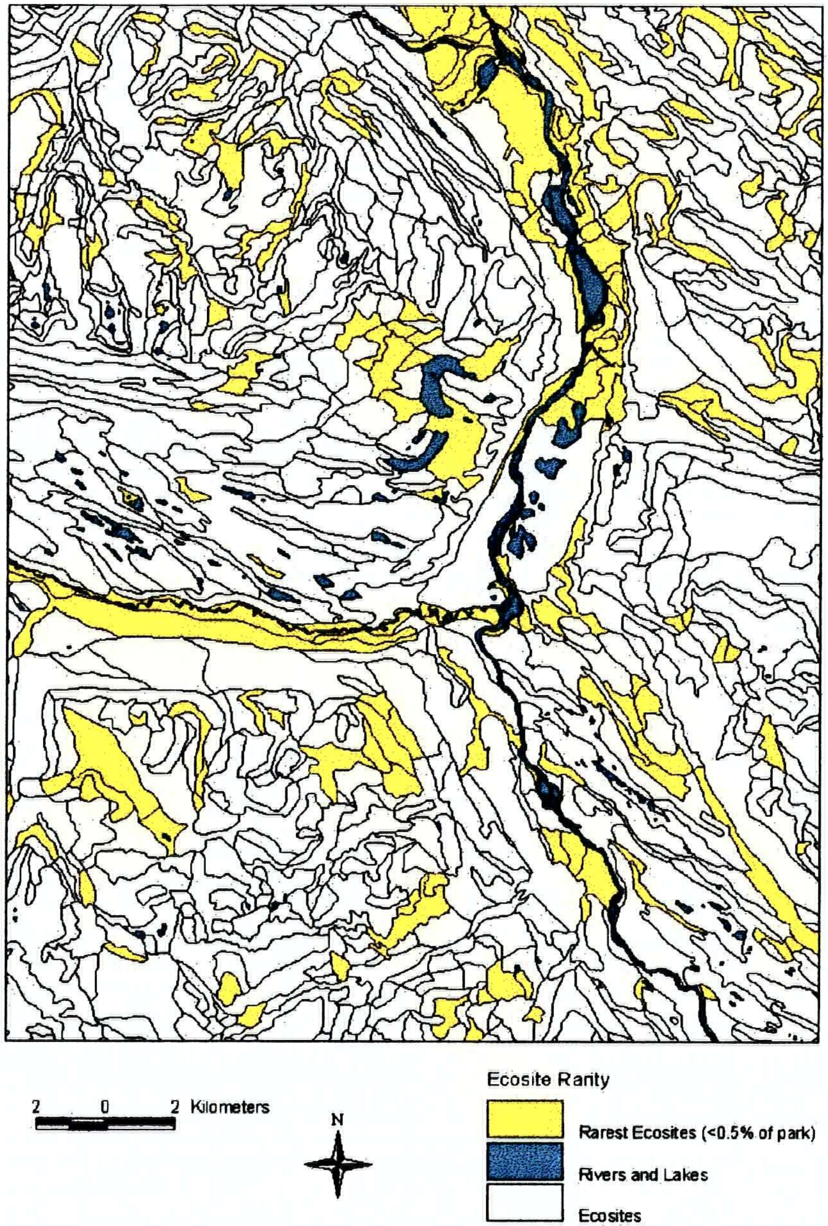


Figure 6 and Table 3. Ecosites whose representation in Jasper National Park is below 0.5 %. Many of these ecosites occur in Three Valley Confluence (3VC), and are montane ecosite types. It is important to note this cumulative effects analysis gives an indication of the condition of ecosites in Three Valley Confluence. The condition of ecosites in Jasper, yet outside Three Valley Confluence, are unknown, with some affected by land uses.

Ecosite	% of Park	# Patches 3VC & JNP
GA1	0.01	2 : 2
AT3	0.05	3 : 5
ML3	0.05	1 : 5
KA1	0.06	1 : 27
NT3	0.08	2 : 28
SX3	0.08	1 : 16
HD4	0.08	6 : 17
VL5	0.09	10 : 23
PT4	0.11	7 : 14
WF4	0.12	1 : 30
HD2	0.13	3 : 20
WH2	0.16	2 : 28
NT2	0.17	1 : 64
VL1	0.18	15 : 38
VD2	0.19	2 : 28
GT1	0.20	2 : 34
IB3	0.20	1 : 46
TA2	0.21	1 : 23
HD1	0.22	16 : 52

Ecosite	% : Park	# Patches 3VC & JNP
FR1	0.22	13 : 56
VL3	0.23	26 : 55
WF1	0.23	12 : 60
IB2	0.25	3 : 47
BY4	0.26	1 : 27
PP6	0.27	2 : 75
TZ1	0.28	1 : 36
CN1	0.28	5 : 91
AL1	0.30	3 : 72
PL5	0.31	3 : 65
NY1	0.31	6 : 29
WH5	0.32	11 : 72
HD3	0.32	9 : 49
BP1	0.34	8 : 81
FV2	0.39	2 : 66
HE1	0.42	13 : 89
SB3	0.43	6 : 88
AL2	0.46	2 : 98
PP3	0.46	5 : 50
PR3	0.50	12 : 50

3.3 Bird Species Richness by Habitat

Long-term trends in Canadian songbirds show 37 percent of resident species and 54 percent of short-distance migrants are decreasing (Environment Canada 1999). These species breed and over-winter in North America, leading to concern about habitat loss and fragmentation (i.e. declining trends not likely due to habitat loss in the tropics). An objective for managing for ecological integrity is ensuring species diversity is likely to persist.

Breeding bird species richness is a simple count of the number of species. It is the most common approach used by ecologists for measuring species diversity (Humpheries et al. 1995, Krebs 1989). The approach adopted in this model is not a direct approach for managing populations of breeding birds (Block et al. 1995). I use breeding bird species data to establish the importance of different habitat types. Then the model measures and accounts for the loss and modification of habitat types important in supporting breeding bird species.

Table 4. Breeding bird richness for the top ten richest ecosites in Three Valley Confluence.

Ecosite Type	Breeding Bird Species Richness
VL1	71
HD1	60
HC4	60
NY3	56
VL3	53
PR2	49
PT5	44
BY1	42
SB1	38
BK4	37

3.3.1 Birds As Ecological Indicators

The value of birds as indicators of ecosystem integrity has been widely discussed (e.g., Morrison 1986, Temple and Wiens 1989). Specific factors, in addition to their ability to represent the community level of organization, make birds attractive as indicators.

- Ease of monitoring because identification is simple.
- Availability of established survey protocols (USDA 1995a).

- Longer life span than many other indicators; this may make them more sensitive to some cumulative impacts.
- Availability of a relatively extensive nationwide databases on trends, habitat needs, distribution (Breeding Bird Surveys and Bird Atlas Locations).
- In general, bird community structure is highly controlled by physical habitat and predation making them sensitive to changes in land use (Temple and Weins 1989).

3.3.2 Available Data

Data collected during the ecological land classification enabled researchers to associate species richness for breeding songbirds to habitat types. Breeding bird richness by ecosite forms the basis for the indicator (habitat effectiveness for breeding birds) used in the cumulative effects model.

3.3.3 Limitation of Species Richness as a Measure

There are several limitations in species richness as a measure for community diversity and in using breeding birds as an indicator. First, species richness is simply a count of the number of species found in an area. Species richness interprets area A with 10 American Robins as equal to area B with a count of 2 American Robins. Clearly area A supports a greater abundance of robins and may provide better habitat. Although this measure has been criticized as being crude (Rodda 1993, Conroy and Noon 1996), species richness is one of the most widely used indicators for diversity measurement (White et al. 1997, Humpheries et al., 1995, Kiester et al. 1993, Prendergast 1993, Margules and Nicholls 1988). While both abundance and richness would be ideal, in the context of this study, a coarse grain approach of measuring the effect of accumulated land uses on habitats that support a diversity of breeding bird species is sufficient.

Secondly, there are disadvantages in using birds as indicators of cumulative effects. Many breeding birds are migrants. They may be affected by changes on breeding grounds in the park as well as on wintering grounds outside the park. However, the model assesses the capacity of habitat in the park to continue to support breeding birds in response to land use, not changes in species richness due to land use. The model uses species richness data to establish the importance of different habitat types in supporting breeding birds in Jasper National Park. Next, the model assesses the effectiveness of habitats to continue to support breeding birds once accumulated land uses and related disturbance effects have been considered.

In summary, measuring trends in the effectiveness of ecosites in supporting breeding bird species can indicate cumulative effects. While limitations are recognized, given the current availability of high quality data using tested protocols, this measure is capable of detecting the impacts of accumulated land use on availability of habitat for breeding birds.

Summary

These indicators support the established framework for cumulative effects assessment and have been selected based on principles outlined in the scientific literature. My next task was to describe the relationship between the response of the indicators and accumulated land use. The following section explains how I developed the models to quantify the response of these two indicators to accumulated land use.

Chapter Four Methods: Building the Models

4.1 Introduction

This section describes the construction of the ecosite representation and breeding bird cumulative effects models. Each model predicts cumulative effects by integrating information from disparate sources through an indicator-disturbance relationship. I begin with a profile of the ecosite representation model describing broadly how it expresses cumulative effects. I continue with a step-by-step explanation of how the components of the model were constructed and then integrated in the GIS and conclude with a visual presentation of the working model. A profile and description of the methods for construction of the breeding bird model follows. A GIS was integral to the development of both models. Thus, I will begin with a brief description of GIS.

4.2 Geographic Information System Application

Geographic information systems are analytical tools that integrate complex spatial data into a unifying computer platform (Parks Canada 1995). A GIS overlays, links and integrates diverse sorts of spatially explicit information. The major advantage for cumulative effects analysis is that it allows the user to combine land uses and natural features into one model representing the landscape. An analysis can include information about the disturbance resulting from land uses and then relate the disturbance to a response in an ecological indicator. The result is a model representing cause-effect relationships at potentially large landscape scales. The key requirement is that adequate descriptive data be available in a spatial form (CEAA 1999). The GIS does not store maps, rather it stores the data from which the user can draw a view of the map for a particular purpose (Environmental Systems Research Institute 1997). Therefore, while the information is stored digitally it may be displayed visually.

The Cumulative Effects Assessment models in this thesis were built in a GIS on an Arc/Info platform with Info and Borland DBASE and Microsoft Access as the database programs. UNIX is the GIS operating system. The application was written in Arc/Info Advanced Macro Language (AML) using Arc/Info Rev. 7.2.1.

4.3 The Ecosite Representation Cumulative Effects Model

The objective of this model is to track ecological conditions in Three Valley Confluence using ecosite representation as an indicator. Tracking the abundance and rarity of ecosites helps ensure that habitat diversity is not lost at a landscape scale when development inadvertently occurs on rare habitat types. The model provides a quantitative and qualitative assessment of habitat types in relation to land use impacts. To quantify the cumulative effect of human use on the representation of ecosites, data delineating ecosite types and data quantifying human use in the park must be integrated through a cause-effect relationship. I developed a functional ecological relationship predicting how human uses modify ecosites. This relationship integrates land use and habitat data layers in a GIS model to calculate cumulative effects.

4.3.1 Expressing Cumulative Effects on Ecosite Representation

The model determines the cumulative effect of land use on ecosite representation by comparing the potential ability of an area to represent an ecosite type to the realized ability of the area once human use is accounted for. Habitat potential is a measure of the extent and location of habitat patches while habitat effectiveness is a measure of an area's potential ability to reflect the inherent habitat type after factoring in the negative influences of human development and disturbance. The ratio between the potential and realized is the *ecosite habitat effectiveness*. I adapted this method of accounting for accumulated land uses from the Grizzly Bear Cumulative Effects Model (USDA 1990). Figure 7 shows how the GIS integrates information about ecosites in the habitat component with information about land use in the disturbance component to calculated habitat effectiveness.

The model also expresses cumulative effects in a second format called *ecosite representation.* By calculating the abundance (e.g. 0.5 % of the park) of each ecosite type in the park, and comparing the abundance to the effective habitat lost, the significance of the loss is put into context. For example, if there are only twenty hectares of HD4 in the park and half occurs in Three Valley Confluence, and a land use that removes 50 % of that HD4 habitat, this represents a 25 % loss of a rare ecosite at the scale of the park. By using both formats, habitat effectiveness and ecosite representation, the model highlights the ecosite area lost to accumulated land use in Three Valley confluence and the significance of the loss at the scale of the park.

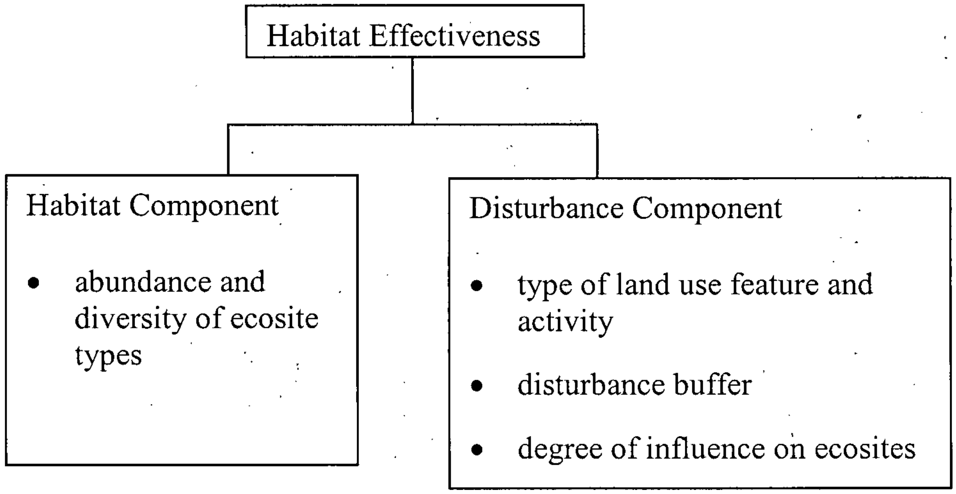


Figure 7. Framework for the model to calculate the cumulative effect of land use on the effectiveness of habitat for ecosite representation (adapted from USDA 1990).

4.3.2 Habitat Component

The model uses the Ecological Land Classification (ELC) data delineating ecosite types as the basis for the habitat component. I define potential ecosite representation as the baseline abundance of ecosites from which to measure incremental change over time due to land use. Hegmann et al. (1999) define an environmental baseline as the condition of an indicator before the effects of most major actions were present on the landscape. I justify using the 1982 ELC as a baseline because the ELC study design included methods (based on landform and soil) for predicting the ecosite type that *would have existed* prior to development. Consequently, the entire study area was classified according to ecosite type regardless of whether it had already been developed. An additional problem with using 1982 data as a baseline results from the difficulty in distinguishing the combined effects of natural disturbance and long-term human presence in this landscape. This issue requires some clarification before I continue describing the model.

Humans have been living in and changing vegetation patterns and processes in Jasper National Park for centuries. While the model assumes the ecosite classifications in 1982 are the environmental baseline or potential representation of ecosites, clearly this is not the case. Both natural disturbance and land use change ecosite conditions over time. Developing an ecological baseline for assessing cumulative effects begs the question, what is 'natural'? However, the importance of 'what is natural ?' to the model is mediated by the fact that the model does not assign a greater value to one ecosite type over another. Rather it is ecosite variety that has value. Consequently, the model focuses strictly on the relationship between land use and the degree of variation in ecosites. This approach addresses the practical issue of accounting for accumulated human use with an open acknowledgement of the limitations imposed by our incomplete understanding of ecological baselines and interactions between human-induced and internal changes in ecosystems. While the ELC is not an ideal baseline, it does provide a measure of comparison for assessing the effects of recent high levels of human use.

The digital ecosite map shown in Figure 8 was derived from the results of the ELC. It classifies the park into a mosaic of 128 habitat types and forms the habitat component of the Ecosite Representation Model.

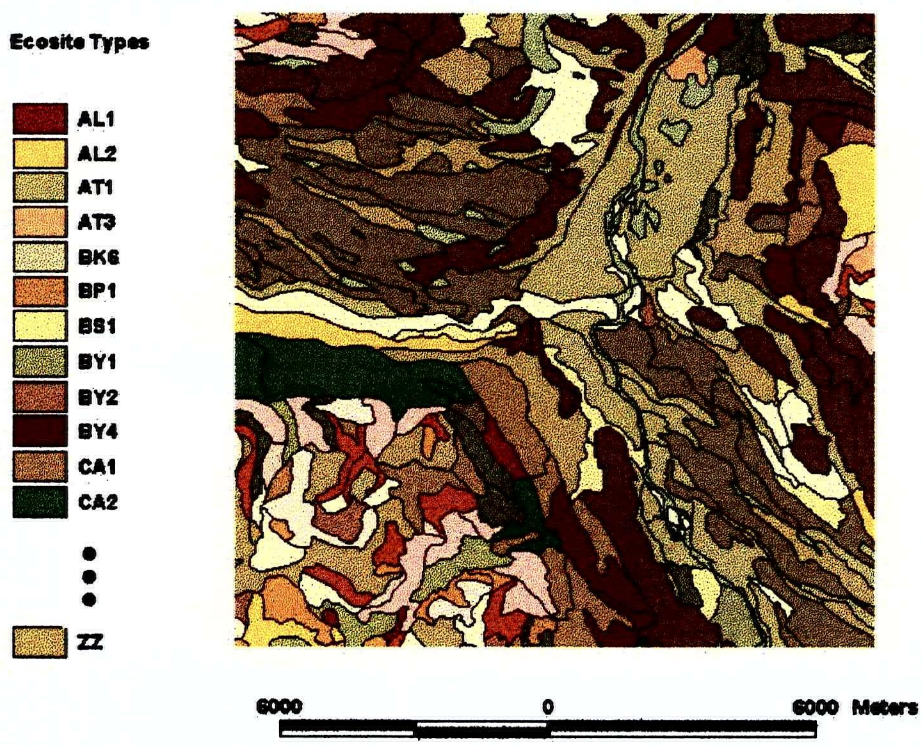


Figure 8. A portion of the Three Valley Confluence computer-based digital ecosite map. It is the habitat component of the model and the potential ecosite representation in TVC. This map is the first layer of information in the GIS. The legend shows 12 of the 100 ecosite types found in the study area.

4.3.3 Disturbance Component

For the model to calculate cumulative effects I developed a functional relationship describing how human use affects ecosite representation. This relationship is based on the premise that effective habitat is lost when land uses remove or alter habitat. This relationship can be partially quantified by overlaying the map of ecosites with a map showing human use. Accordingly, any ecosite area overlaid by a land use would be considered 'lost habitat'. However, human activity and habitat alteration can also change the landform, soils, vegetation and security of surrounding habitat. While it is unlikely that this surrounding habitat will be completely lost, it is likely to change and no longer be representative. The result is lost representation. Following the Grizzly Bear Cumulative Effects Model, I call this area surrounding a land use feature, within which ecosites are no longer representative, the disturbance buffer[1]. There are three aspects to the disturbance component: type and location of land use features; disturbance buffer distances; and the degree that disturbance influences the indicator.

Land Use Features

The human use database (Chapter 2, Table 2) and associated spatial information includes hundreds of different land use features, from golf courses to campgrounds to hiking trails. Several modifications were required to use the existing digital human use maps as the basis for the disturbance component in these models. When I conducted a review of the scientific literature to assign disturbance buffers to land uses, the literature indicated that different types of land use features (road vs. building vs. highway vs. suburban backyard) influence surrounding habitat to different extents. While several studies focus specifically on the distance that land use impacts extend beyond development footprints in general, many studies focus on specific land use types. My review suggested that if land uses could be classified into a set of feature types based on physical structure, then the literature could provide an ecological basis for assigning disturbance buffers to land use features in Three Valley Confluence.

The human use database includes descriptive information about each land use feature in the park. The linked human use map displays this information spatially (see Figure 9). However, the

[1] The Grizzly Bear Habitat Effectiveness model uses 'disturbance buffer' to similarly describe the area surrounding human uses within which grizzly bears are displaced (USDA 1990).

database does not classify features based on physical structure. For example, Trail 2 and Marjorie Lake Trail are both considered trails in the database under 'type of use'. However, Trail 2 is a 6 m wide fire road while Marjorie Lake trail is a 2 meters wide trail. To establish disturbance buffers based on the literature review, I needed to distinguish features based on their physical structure. To this end, I completed a brief survey of land use features. This involved measuring trail widths and powerline right-of-ways in several areas of Three Valley Confluence. The Parks Canada Highways Manager provided the average right of way distance (Table 5) for each of the road types in the study area.

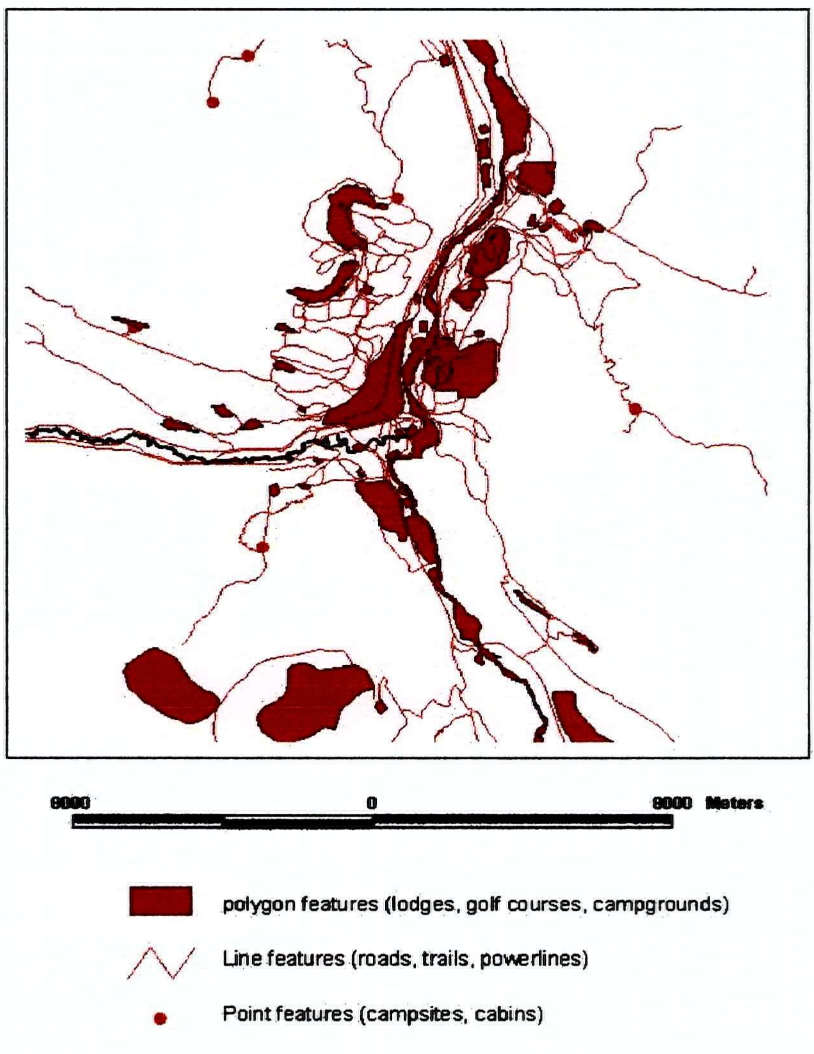


Figure 9. Human use data layer showing a portion of the human use features in Three Valley Confluence including line, point and polygon feature types.

Table 5. Right-of-way (ROW) distances for a selection of roads in the study area.

Specific Line Features	ROW distance (distance on either side of feature)
highway – 16	60 m
highway – 93	60 m
major road - 93A	45 m
major road – Maligne	45 m
road – Pyramid lake	30 m
road – JPL	30 m
road – Edith Cavell	30 m
road – Marmot	30 m
road – Snaring	30 m
road – Old fort point	30 m
gravel road – Celestine	10 m
gravel road – Moab lake	10 m
railway road – railway access	7 m
Powerlines	4 m
CNR	30 m

I defined twenty feature categories shown in table 6. I used the information from my brief survey to review the human use database and finally group features with common physical structure and land use type (trails, roads, buildings). I assigned every human use feature in the study area to one of the twenty feature categories. For example, Highway 93A and Maligne Road are both designated as 'road' features according to their physical structure, and are predicted to have a similar disturbance buffer for ecosite representation. I used this reclassified land use feature data for the ecosite model and the breeding bird model.

Table 6. Human use feature re-classifications according to physical structure.

Feature Category
Trail
Fire road
Highway
Major road
Road
Gravel road
Railway road
CNR
Powerline (include. Pipeline, telus, etc.)
Day use
Campsite
Utility (include sewage lagoon, power stations)
Cabin (include portal, acc huts, warden cabins)
Campground
Accommodation
Townsite
Horse corral
Golf course
Pits
Ski area

Applying Disturbance Buffers to Land Use Features

Once the land use features in 3VC were stratified according to their physical structure, I assigned each feature category group a disturbance buffer. I established buffer distances based on a review of scientific literature which identified edge effects[2] and specifically microclimatic effects as the primary disturbance mechanism acting on ecosites (Matlack 1993, Yahner 1988, Murcia 1995, Reese and Ratti 1988, Laurence and Yensen 1991). In the context of this thesis, only human-created edge is considered a disturbance mechanism. Edge effects include direct alteration of habitat due to trampling, human activity extending into adjacent habitat, and microclimatic impacts. Temperature, evaporation rates and wind-shear forces next to openings may affect habitat characteristics such as litter moisture, humidity, shrub cover and habitat structure (Matlack 1993, Laurance and Yensen 1991). Several studies cited in this thesis have attempted to quantify the distance microclimatic effects extend into adjacent habitats. Disturbance buffer distances, based on the literature, are summarized in Table 7. Figure 10 shows how the GIS applies buffer zones to human use features based on feature category.

Once an ecosite is disturbed directly or indirectly through microclimatic effects and edge effects, it has changed resulting in perhaps dryer, more open, or more eroded conditions. I assume once changed by these factors, the area within the buffer is no longer "representative" of the potential ecosite. Although still habitat, the disturbed area represents another ecosystem type, resulting in a loss to ecosite representation. Thus, within disturbance buffers, representation is entirely lost. The GIS integrates the ecosite layer, human use layer and applies disturbance buffers to each land use in Three Valley Confluence to account for the direct and indirect accumulated loss of representative habitat. This result is expressed both as habitat effectiveness and, in the context of the larger spatial scales of Jasper National Park, as ecosite representation. The following section shows how the model integrates the information to calculate cumulative effects.

[2] Edge effects are characteristics of the junction between two dis-similar habitat types that positively or negatively effect the species living in the habitat (Faaborge 1995).

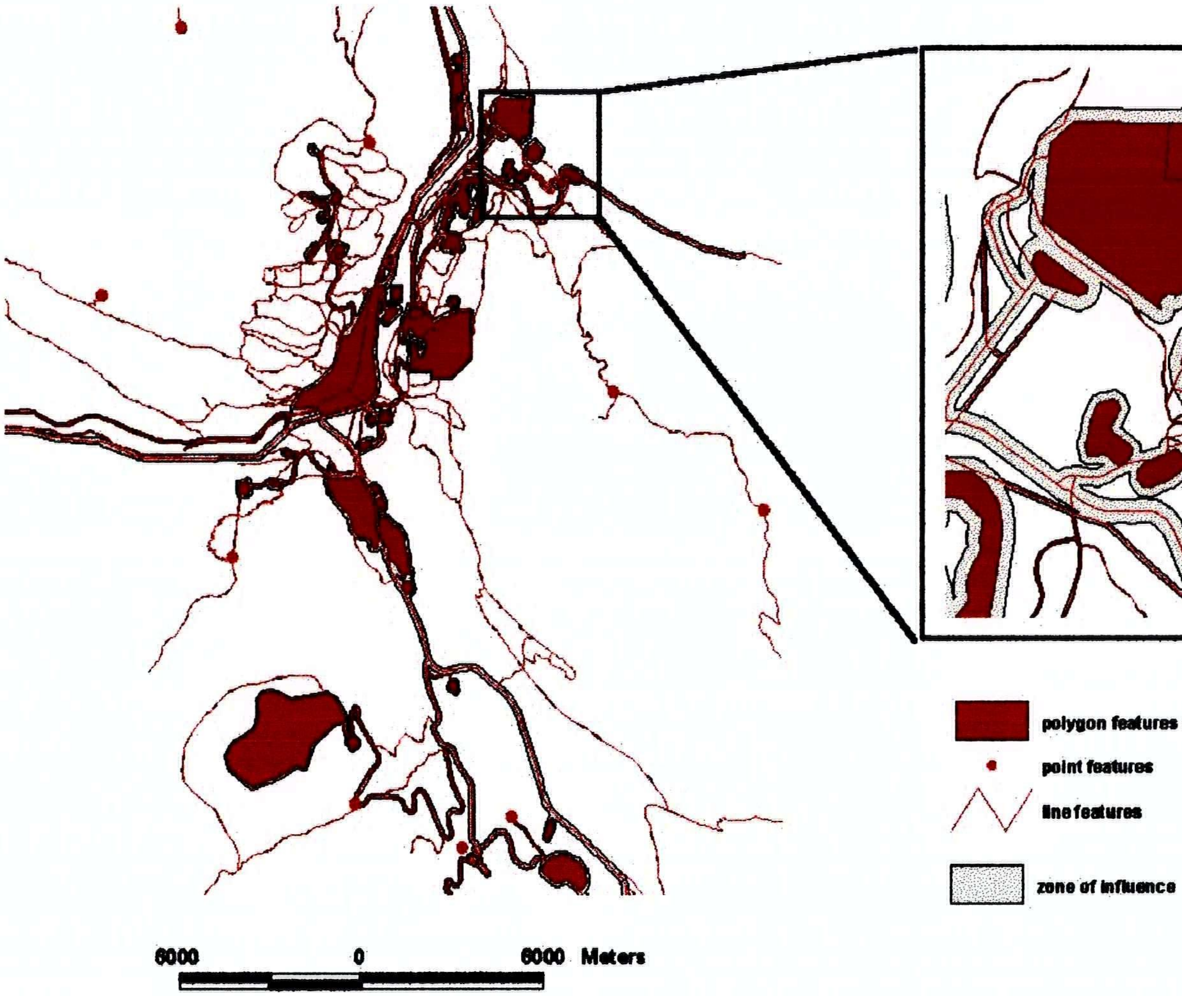
Table 7 Disturbance buffers for each feature category for the ecosite representation indicator.

Feature Category	Disturbance Buffer[3]
Trail	3 m
Fire road	9 m
Highway	80 m
Major road	65 m
Road	50 m
Gravel road	30 m
Railway road	27 m
CNR	40 m
Powerline (includes pipelines, telus, etc.)	14 m
Day use	80 m
Campsite	90 m
Utility (includes sewage lagoon, power stations)	50 m
Cabin (includes portal, acc huts, warden cabins)	80 m
Campground	80 m
Accommodation	80 m
Townsite	80 m
Horse corral	80 m
Golf course	50 m
Pits	50 m
Ski area	50 m

4.3.4 Integrating the Information

The GIS uses an overlay technique to integrate 1) the ecosite map with 2) the human use layer with 3) the disturbance coefficients, and calculates the effective habitat which has been alienated or disturbed. The following shows how the model uses the overlays to make a final calculation of effectiveness and representation.

[3] Values derived from the following studies: Matlack 1993, Yahner 1988, Murcia 1995, Reese and Ratti 1988, Laurence and Yensen 1991.



Feature Category	Buffer Zones
trail	3 m
fire road	9 m
highway	80 m
major road	65 m
road	50 m
gravel road	30 m

Figure 10 The GIS applies buffer zones to each human use feature based of feature category

Expressing Cumulative Effects as Habitat Effectiveness

Habitat Potential (area)	Realized Habitat (area)	Habitat Effectiveness
Undisturbed ecosite area, no human use applied	Human use features applied with disturbance buffer	remaining area for each ecosite/ undisturbed area of each ecosite

Human Use & Disturbance →

$$\frac{\text{Realized Habitat}}{\text{Habitat Potential}} = \text{Habitat Effectiveness}$$

Sample calculation for the Athabasca 1 Ecosite Type:

$$\frac{18.67\ \text{km}^2}{33.11\ \text{km}^2} = 0.56 = 56\ \%\ \text{effective habitat}$$

Almost half (44%) of the Athabasca 1 habitat in Three Valley Confluence is no longer effective due to accumulated land uses.

Expressing Cumulative Effects as Ecosite Representation

1) Ecosite Representation

Potential contribution of 3VC ecosites to the ecosite representation in JNP (%)	Realized contribution of 3VC* ecosites to representation in JNP (%)
Undisturbed, no human use applied to the ecosites	human use features applied with disturbance buffers

*3VC is Three Valley Confluence.

Human Use & Disturbance

Potential contribution to total representation (%) : Realized contribution to total representation (%)

2) Ecosite Rarity = Sum of AT1 in the park / Total area of the park

Sample calculation for Athabasca 1 (AT1) Ecosite Type

AT1 Representation =

$$\frac{\text{potential area of AT1 in 3VC}}{\text{area of AT1 in park}} : \frac{\text{realized area of AT1 in 3VC}}{\text{area of AT1 in park}} =$$

$$\frac{33.11\ \text{km}^2}{68.80\ \text{km}^2} : \frac{18.67\ \text{km}^2}{68.80\ \text{km}^2} =$$

56 % : 27 % = potential representation : realized representation

Rarity of AT1 in the Park = sum of AT1 in park / total area of park

= 68.80 km^2 / 10 878 km^2 = 0.0063

= AT1 makes up 0.63 % of the park.

The AT1 found in Three Valley Confluence represents over half (56%)of the existing AT1 in the park. Already a relatively rare ecosite, this means 27 % of the effective AT1 has been lost in the park due to a single land use in Three Valley Confluence.

4.4 THE BREEDING BIRD HABITAT EFFECTIVENESS MODEL

The objective of the breeding bird model is to track the abundance and value of breeding bird habitat in Three Valley Confluence. To be expressed in measurable terms, the model integrates data delineating and rating ecosite types for their value as breeding bird habitat with data quantifying human use in the park. To calculate the cumulative effect of human use, I describe a functional ecological relationship predicting how human use affects breeding birds. The model uses this relationship to integrate data layers in a GIS and calculate cumulative effects.

It is beyond the capacity of this thesis, the available data, and present scientific theory to use habitat fragmentation theory to attempt to predict which species would be lost from Three Valley Confluence as a result of development. While habitat fragmentation theory for songbirds has been developed extensively in the literature and through field research (Andrén 1994, Desrochers and Hannon 1997, Fahrig and Merriam 1994, Hagan et al. 1996, Nudds 1993, Robinson 1992, Saunders et al. 1991, Weins 1994, White et al. 1996, Wilcox and Murphy 1985) the focus has generally been on patches of habitat surrounded by agriculture, forestry or urbanization. The patches (ecosites) of habitat in Three Valley Confluence are patches within contiguous habitat with minimal fragmentation and little alienation of patches. Therefore, models developed using species-area relationships (Dial 1995, Nudds 1993) which are designed for isolated patches do not hold for ecosites in Three Valley Confluence. Therefore, the model developed in this thesis focuses on measuring the loss of species rich habitat, not the loss of specific species as a result of cumulative effects.

4.4.1 Expressing Cumulative Effects for Breeding Bird Habitat

Similar to the Ecosite Representation Model, the Breeding Bird Habitat Effectiveness Model represents the cumulative impact of all the human uses, past and present, on the capacity of ecosites to support breeding bird richness. Comparing the potential ability of habitat to support birds to the realized habitat ability results in the effectiveness of the habitat to support bird richness. The potential habitat is a measure of the inherent suitability of an area to support breeding bird richness. Habitat effectiveness is a measure of an area's potential usefulness to support bird species, after factoring in the negative influences of human development and disturbance. To track the cumulative effect of land uses on breeding bird habitat, several types of data were integrated. The framework, adapted from the Grizzly Bear Habitat Effectiveness Model and used in the ecosite representation model, was adapted for use with breeding birds. The two major components of the model, shown in Figure 11 are the habitat and disturbance.

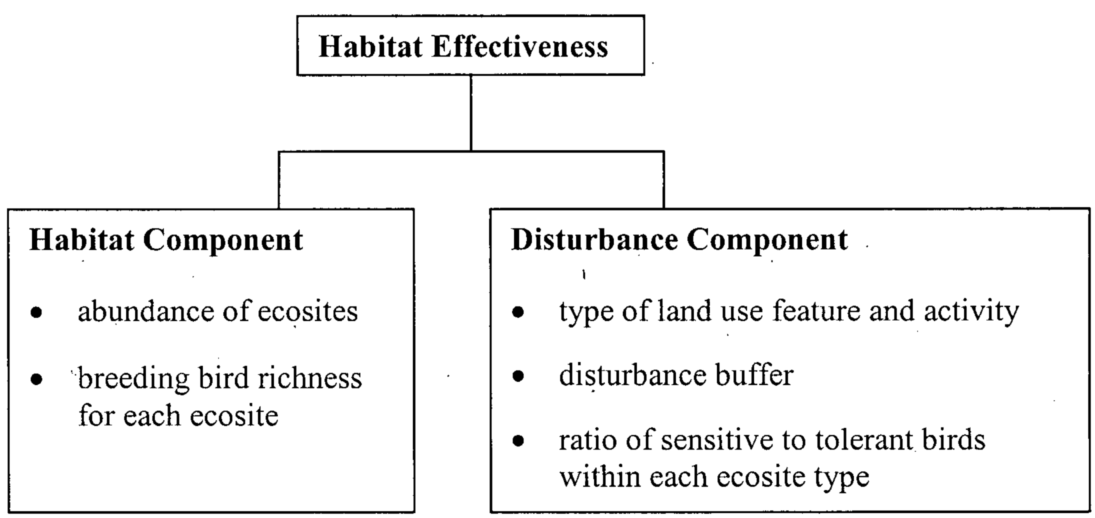


Figure 11. Cumulative Effects Framework for breeding bird habitat effectiveness (adapted from USDA 1990).

4.4.2 Habitat component

The Breeding Bird Model is based on the Ecological Land Classification data delineating ecosite types and the data collected in the 1982 call-count survey results. The potential value of habitat is a function of the richness of birds supported by an ecosite type and the abundance of that ecosite type. The problems associated with using a fixed ecological baseline exist for this model as with the Ecosite Representation Model. Breeding bird richness by ecosite is assumed to be the baseline for the model. While the data was collected in 1982, the ecosystem components affecting bird richness (e.g. succession and weather) are constantly evolving. Because of fire suppression, many ecosites historically in early seral stages are now in later stages of succession. These changes consequently effect the community of birds using the area of habitat. Maintaining the effectiveness of breeding bird habitat means identifying and protecting those habitat types affected by accumulated human uses and disturbance. Teasing out the effects of human land use from activities such as active fire suppression on breeding bird habitat is beyond the scope of this thesis. However, it is important to acknowledge factors such as fire suppression and habitat loss in wintering-grounds for neotropical migrants increases uncertainty in the model. This model does not include all impacts on breeding birds in the park, rather it focuses on measuring the accumulated effects of land use on bird habitat. Examples of potential impacts not included in the model are: land use outside the park (e.g. mining and forestry); increasing scavenger populations; and grazing pressure from increasing ungulate populations. Given these limitations, the model can identify habitats most at risk due to the cumulative effects of land use. Several studies in the mountain national parks has begun to identify specific relationships between land uses and disturbance. Studies of the response of Harlequin Ducks to recreational river use (Hunt 1998) and a current study conducted at the University of Alberta on the effects of a twinned highway on forest bird movement are attempting to determine the effect of disturbance over fixed time periods. While the studies focus on specific species, the approaches may help tease out the effects of land use in the park from other impacts outside the park and internal ecosystem changes.

Breeding Bird Transect Data

Chapter 2 outlined the collection of breeding bird data in the ELC. I adapted this data to be useful in the model. The 10 229 bird records surveyed through Banff and Jasper Parks in the

1970s and '80s were stored in a Microsoft Access database. I georeferenced the data, error-checked it, and converted it into a spatial coverage in Arc/Info to be used in the model.

As discussed in chapter 3, each transect was located within a single ecosite type. Figure 12 shows the call-count transect locations surveyed in Three Valley Confluence during the Ecological Land Classification surveys in the early 1980s. As each transect was located within a single ecosite type, I was able to group the bird transects by ecosite. This allowed me to calculate the total number (species richness) and composition of bird species surveyed in each ecosite type. For example, in Athabasca 1 ecosite types species richness was 36 while Vermillion 4 had a species richness of 62. Figure 13 illustrates the habitat component for the model showing a portion of the Three Valley Confluence ecosites rated for species richness.

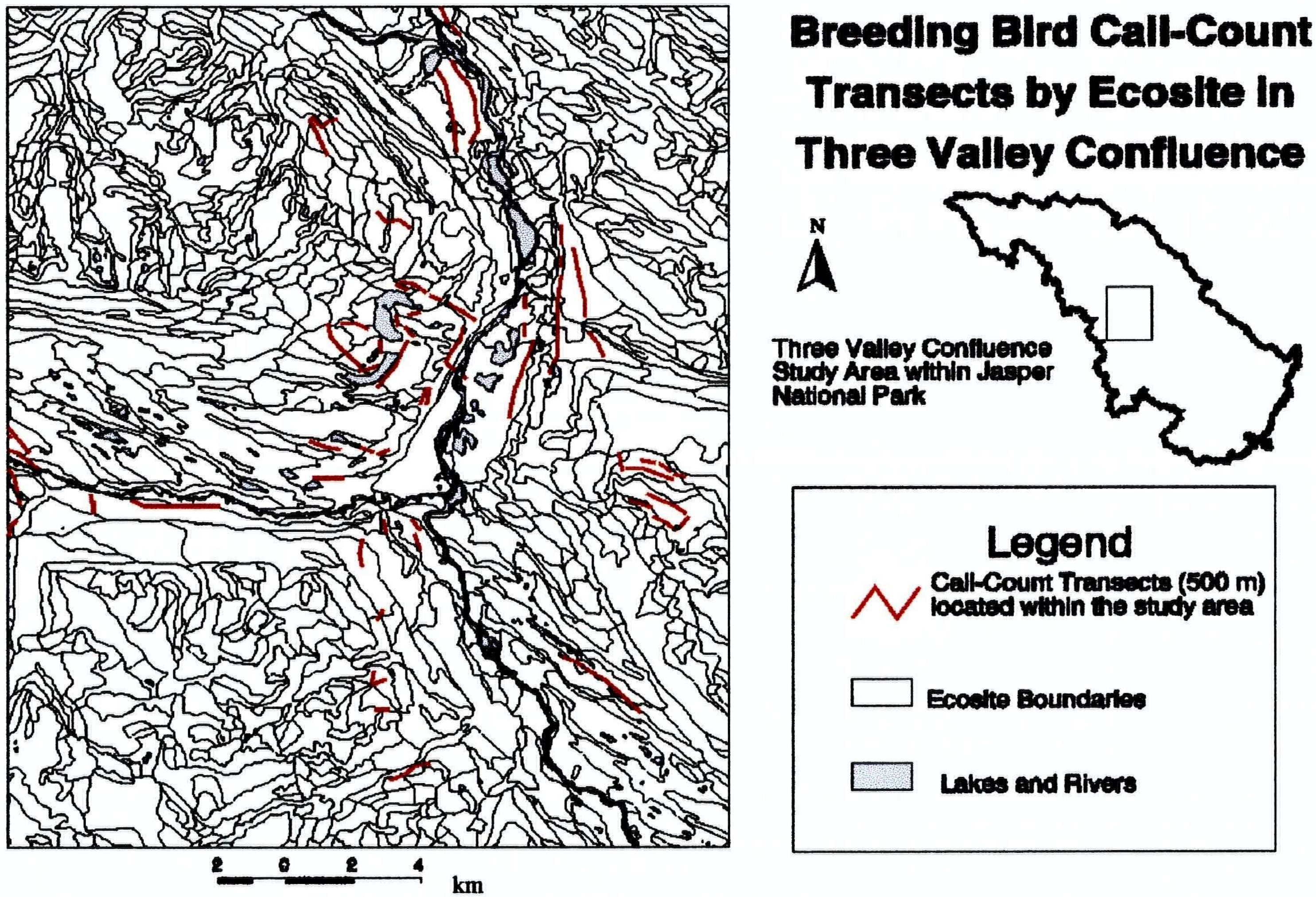


Figure 12 Transect locations in 3VC for the ELC. In combination with the ecosite delineations, this data forms the basis of the habitat component in the model.

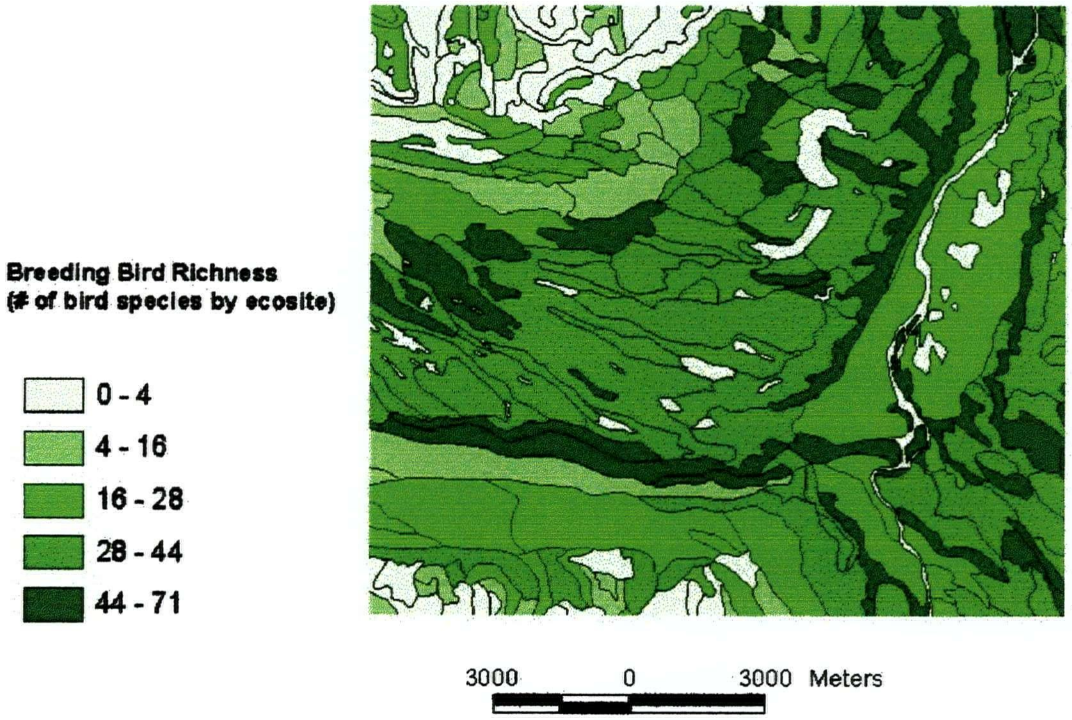


Figure 13 Breeding bird richness for ecosites in a portion of Three Valley Confluence.

4.4.3 Disturbance Component

For the model to predict relationships between past, present and future land uses and breeding bird habitat, an ecologically defensible relationship needed to be established. A simple overlay of the human use and breeding bird habitat maps shows habitats directly lost to development. However, development affects habitat directly and wildlife indirectly (Theobald 1997). Impacts on birds and bird habitat can extend beyond the footprint of a development and can be caused by the mere presence of people.

A review of the habitat fragmentation, edge effects and wildlife disturbance literature provided the basis for the breeding bird/human disturbance relationship for this model. Research indicates some species of breeding bird may be displaced where human use is highly concentrated or where habitat has been completely alienated (Sloan *et al.* 1998, Desrochers and Hannon 1997, Sawyer et. al. 1997, Evinck et. al. 1996, Friesen et. al. 1995, Reignen et. al. 1995, Murcia 1995, Rudnicky and Hunter 1993, Small and Hunter 1989, Brittingham and Temple 1983, Ferris 1979). I used results from the scientific literature to assign disturbance buffers to each category of human use. The ecosite representation model predicts representation is entirely lost within the disturbance buffer. However, this is not the case for the bird model where only a subset of breeding birds are predicted to be displaced. The problem with assigning all-inclusive disturbance buffers is that development does not affect all bird species equally. The type of human use and the behavioural response of the species determines whether habitat loss is complete or partial (Bromley 1985). Species with a long history of coexistence with humans or species that take advantage of artificial feeding or nesting opportunities can thrive within disturbance buffers while habitat alteration or human activity displaces other species (Theobald 1997). To better represent the relationship between breeding birds and development, I incorporated a classification of all the breeding bird species in Jasper according to their sensitivity to human use. I predicted the sensitivity of every breeding bird species detected in the breeding bird surveys through a literature review according to a set of ecological criteria (defined in 4.4.4). To summarize, while all species in an ecosite type become displaced within the footprint of a development, only sensitive species become displaced within the disturbance buffer surrounding a human use. The model incorporates the ratio of sensitive to tolerant species in an ecosite using a coefficient of displacement (%) within the disturbance buffers for each ecosite type. The following three sections describe how I developed the disturbance component.

Land Use Features

This model uses the human use map and database with the new field for physical feature structure (see table 6) created for the Ecosite Representation Model. I developed disturbance buffers for each feature category and applied coefficients of disturbance specific to the suite of breeding birds in each ecosite type.

Breeding Bird Disturbance Buffers

The disturbance buffer for breeding birds is the area surrounding a land use within which breeding birds may be displaced. The literature identified edge effects, habitat fragmentation and sensory disturbance as the primary mechanisms affecting breeding birds in relation to development and human activity. Table 8 presents disturbance buffers for this model based on the literature.

Table 8. Disturbance buffers for feature categories used in the Breeding Bird Habitat Effectiveness Model.

Feature Category	Zones of Influence[4] (m)
Trail	0
Fire road	17
Highway	260
Major road	145
Road	130
Gravel road	110
Railway road	19
Railway	130
Powerline (includes Pipeline)	34
Day use	100
Campsite[5]	110
Utility (includes sewage lagoon, power station)	100
Cabin (includes portal, alpine hut, warden cabin)	100
Campground	100
Accommodation	100
Townsite	100 m
Horse corral	100 m
Golf course	100 m
Pit	100 m
Ski area	100 m

Because these disturbance buffers values are predictions based on a literature review I have incorporated options into the model for updating and changing these values as they are tested and as new information becomes available. The coefficients of disturbance are applied within these buffer areas. The coefficients only vary with ecosite type and not with feature category.

4.4.4 Coefficients of Disturbance for the Breeding Bird Model

Within each disturbance buffer an ecosite-specific coefficient of displacement, rated on a scale between 0 and 1, reflects the ratio of birds sensitive to disturbance, and thus displaced, in the ecosite type. A disturbance coefficient of 0 implies all of the species within an ecosite type are sensitive. A coefficient of 0.5 indicates, for an ecosite with a richness of 18 species, 9 are

[4] Values derived from the following studies: Murcia 1995, Brittingham and Temple 1983, Rudnicky and Hunter 1993, Sloan et. al. 1998, Small and Hunter 1989, Evinck et. al. 1996, Reignen et. al. 1995, Ferris 1979, Desrochers and Hannon 1997, and Sawyer et. al. 1997

[5] Campsites are point features in the human use layer and have no associated area. The average campsite area is 20 m in radius. Therefore, I added 10 m to the disturbance buffer of 100 m to include the campsite area.

sensitive and will be displaced. I developed the coefficients of disturbance through the following three step process.

I found no consolidated listing of the responses of breeding bird species to development or human activity. However, individual species accounts, descriptions and research studies on a species-by-species basis included conservation and disturbance results. To establish a consistent method for classifying every species, I established a set of criteria by which to rate each species recorded in every ecosite in Three Valley Confluence. I followed up by classifying every species and then concluded with a peer review.

Step One: Criteria for Breeding Bird Sensitivity Classifications

I focused mainly on the habitat fragmentation and edge effects literature for songbirds in selecting the criteria by which to classify species (Alberta 1997, Brittingham and Temple 1983, Rudnicky and Hunter 1993, Small and Hunter 1989, Laurence and Yensen 1991, Murcia 1995, Hagan et al. 1996, Sawyer et al. 1997, Desrochers and Hannon 1997). I also reviewed the literature on the relationship between breeding birds and recreation (Riffel et al. 1996, Klein et al. 1995, Gutzwiller et al. 1998, Hill et al. 1997). The following criteria were investigated and then selected from the literature review to continue to the next stage of categorizing breeding birds as tolerant or sensitive to human use within disturbance buffers.

Sensitivity to Human-caused Edge: The following effects on breeding birds are associated with human-caused edge: habitat alteration as a result of microclimate change; high rates of nest predation; high rates of brood parasitism; high rates of inter-specific competition; reduced pairing success; and reduced nesting success (Faaborg et al. 1995). There is no universal threshold distance that edge effects extend. The effects depend on the habitat type and the bird species.

Designation as a Forest Interior Species: Neotropical migrants are more abundant on large fragments than on small fragments ((Martin 1988, Faaborg et. al. 1995) and selected species have been categorized as requiring forest interior habitat. The pattern that has been detected is that neotropical migrants 1) are more abundant in large fragments than short-distance migrants or residents, 2) tend to be open nesters rather than cavity nesters and 3) have single broods rather than multiple broods.

Disturbed by Human Use: Some species are displaced during foraging or nesting by the mere presence of human activity.

Habitat Generalist or Habitat Specialist: A habitat specialist is a species dependent on specific microhabitat characteristics. The loss of critical microhabitat due to land use may result in a displacement of the species. Habitat generalists include those species noted for their ability to adapt or even thrive when habitat is altered by human use (e.g. access to unnatural food sources or nesting areas).

Provincially Listed in Alberta as a Yellow B (Population in Significant Decline and Vulnerable): These are sensitive species that are not currently at risk but may require special management because of low population sizes, limited provincial distributions or life history features that make them vulnerable to human-related changes (Alberta 1997).

Step Two: Classification of Breeding Birds

I rated each breeding bird species in Jasper National Park against each of the five criteria. My methods included an extensive literature review, consultation with scientists and local naturalists, and a peer review of my final results. The literature review included species profiles, field guides, articles in the scientific literature, and serials. The American Ornithological Union publishes a species profile called "The Birds of North America" that includes conservation management issues and the effects of human activity. This publication was used to classify at least half of the breeding birds. However, for some species, few research results are available. In these cases, I have included a notation 'unknown' where there was not enough information available to classify the species for the criteria. If the species was found to meet one of the five criteria, it was classified as sensitive to human use. If not enough information was available, I classified the species as not sensitive. The model has been designed to accept updates to this classification as new research results on species become available. Each result includes the reference(s) consulted to classify the species (Table 9).

Table 9. An excerpt from my classification results table indicating how each of 125 species was rated for the five criteria. For each species, the source(s) supporting the classification are listed in the results column. The entire table including each footnote is located in Appendix II. I used 'unk' where there was not enough information available to classify the species for the criteria, 'y' where the species is sensitive for the criteria and 'n' where the species is not sensitive for the criteria. Footnotes two through to six refer to footnotes in Appendix II.

Species	edge sensitive	forest interior	habitat specialist (not edge/interior)	habitat generalist	disturbed by human activity	listed in Alberta	result
alder flycatcher	unk	unk	unk	unk	unk	n	not sensitive[6]
American kestrel	n	n	n	n	n	n	not sensitive[7]
American redstart	y	n	n	n	y	n	sensitive[8]
American robin	n	n	n	y	n	n	not sensitive[2, 9]
American wigeon	n	n	n	n	n	n	not sensitive[2, 4]
Bald eagle	n	n	n	n	y	yellow B	sensitive[2, 10 11]
Barrow's goldeneye	n	n	n	n		n	not sensitive[2, 4]
Belted kingfisher	n	n	unk	n	y	n	sensitive[12]
Black capped chickadee	n	n	n	n	n	n	not sensitive[13]
Blue grouse	n	n	n	n	n	n	not sensitive[2]
Black-billed magpie	n	n	n	y	n	n	not sensitive[2, 4]
Black swift	n	n	y (canyons)	n	unk	yellow B	sensitive[14, 6]
Blue-winged teal	n	n	n	n	y	n	sensitive[2]
Barn swallow	n	n	n	n	n	n	not sensitive[2, 4]
Boreal chickadee	unk	y	unk	n	unk	n	not sensitive[2, 4]
Boreal owl	unk	y	us forest service	n	unk	yellow B	sensitive[5, 6, 15]
Bohemian waxwing	n	n	n	n	n	n	not sensitive[2, 4]
Blackpoll warbler	unk	y	unk	n	unk	n	sensitive[2, 4]
Brewer's blackbird	n	n	n	y	n	n	not sensitive[2, 4]
Brown cowbird	n	n	n	y	n	n	not sensitive[5, 16]
Brown creeper	y	y	n	n	unk	yellow B	sensitive[2, 6, 5]

[6] no reliable sources yet to provide any indication of habitat specialization or sensitivity to human disturbance.
[7] Holroyd, G.L. and K.J. Van Tighem. 1983. Ecological Land Classification of Banff and Jasper National Parks, Vol. III: The Wildlife Inventory. Bird Species Accounts. Parks Canada, Western Region Publication.
[8] Sherry, T.W. and T. Holmes. 1997. The Birds of North America. A. Poole and F. Gill (eds.). No. 277. The Academy of Natural Sciences of Philadelphia.
[9] National Geographic Society. 1991. Field Guide to the Birds of North America. Second Edition. National Geographic Society, Washington, D.C.
[10] Sawyer, M., D. Mayhood, P. Pacquet, R. Thomas and W. Haskins. 1997. Southern East Slopes Cumulative Effects Assessment. Hayduke and Associates Ltd. Calgary, Alberta.
[11] Alberta Fish and Wildlife Division. 1997. The Status of Alberta Wildlife. Government of Alberta.
[12] Hamas, M.J. 1994. The Birds of North America. A. Poole and F. Gill (eds.). No. 84. The Academy of Natural Sciences of Philadelphia.
[13] Smith, S.M. 1993. The Birds of North America. A. Poole and F. Gill (eds.). No. 39. The Academy of Natural Sciences of Philadelphia.
[14] Gadd, B. 1995. Handbook of the Canadian Rockies. Second Edition. Corax Press: Jasper, Alberta.
[15] Hayward, G.D. and P.H. Hayward. 1993. The Birds of North America. A. Poole and F. Gill (eds.). No. 63. The Academy of Natural Sciences of Philadelphia.
[16] Lowther, P.E. 1993. The Birds of North America. A. Poole and F. Gill (eds.). No. 47. The Academy of Natural Sciences of Philadelphia.

Step Three: Scientific Review

I provided a number of academics, working biologists and local birders with a copy of the criteria for classification and the classification results. Input has been received from a selection of these scientific reviewers. Where they provided input that influenced a rating, their name with a personal communication notation is included as a footnote reference in Table 9.

Summary of Coefficient of Disturbance Development

The model calculates the realized ability of habitat in a disturbance buffer to support bird richness by multiplying the coefficient of disturbance by the potential habitat within the buffer. See Table 22, Appendix IV for the list of coefficients of disturbance for the model. Figure 14 displays spatially how the GIS integrates the land use information, disturbance buffer distances and coefficient of disturbance to establish the disturbance component for the model.

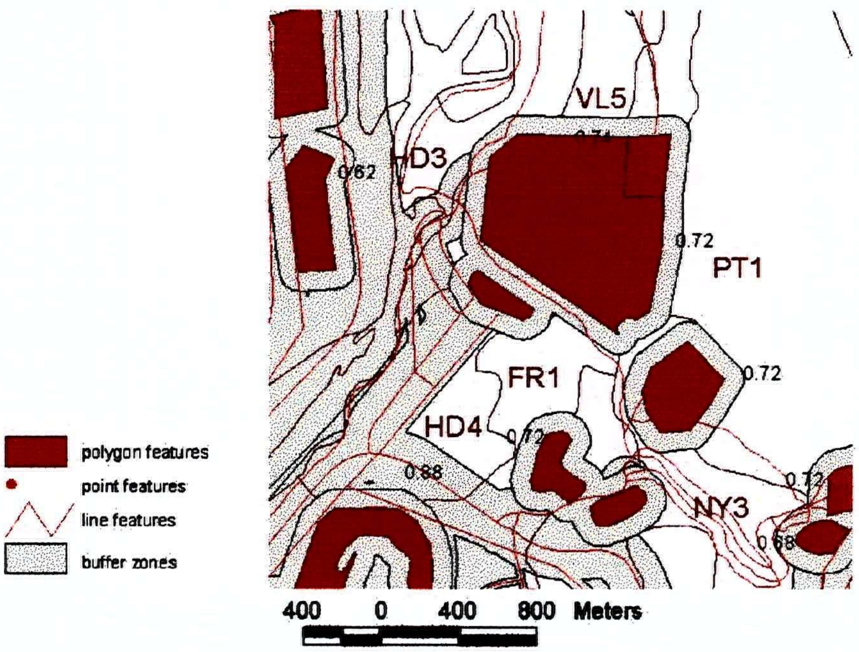


Figure 14 Visual display of how the GIS integrates land use information, disturbance buffer distances, and coefficients of disturbance to establish the disturbance component of the model. For example, all buffers in PT1 have a coefficient of 0.72 while buffers in HD4 have a coefficient of 0.88.

4.4.5 Integrating the Information and Calculating Cumulative Effects

Figure 13 describes how the GIS model integrates data to calculate breeding bird habitat effectiveness.

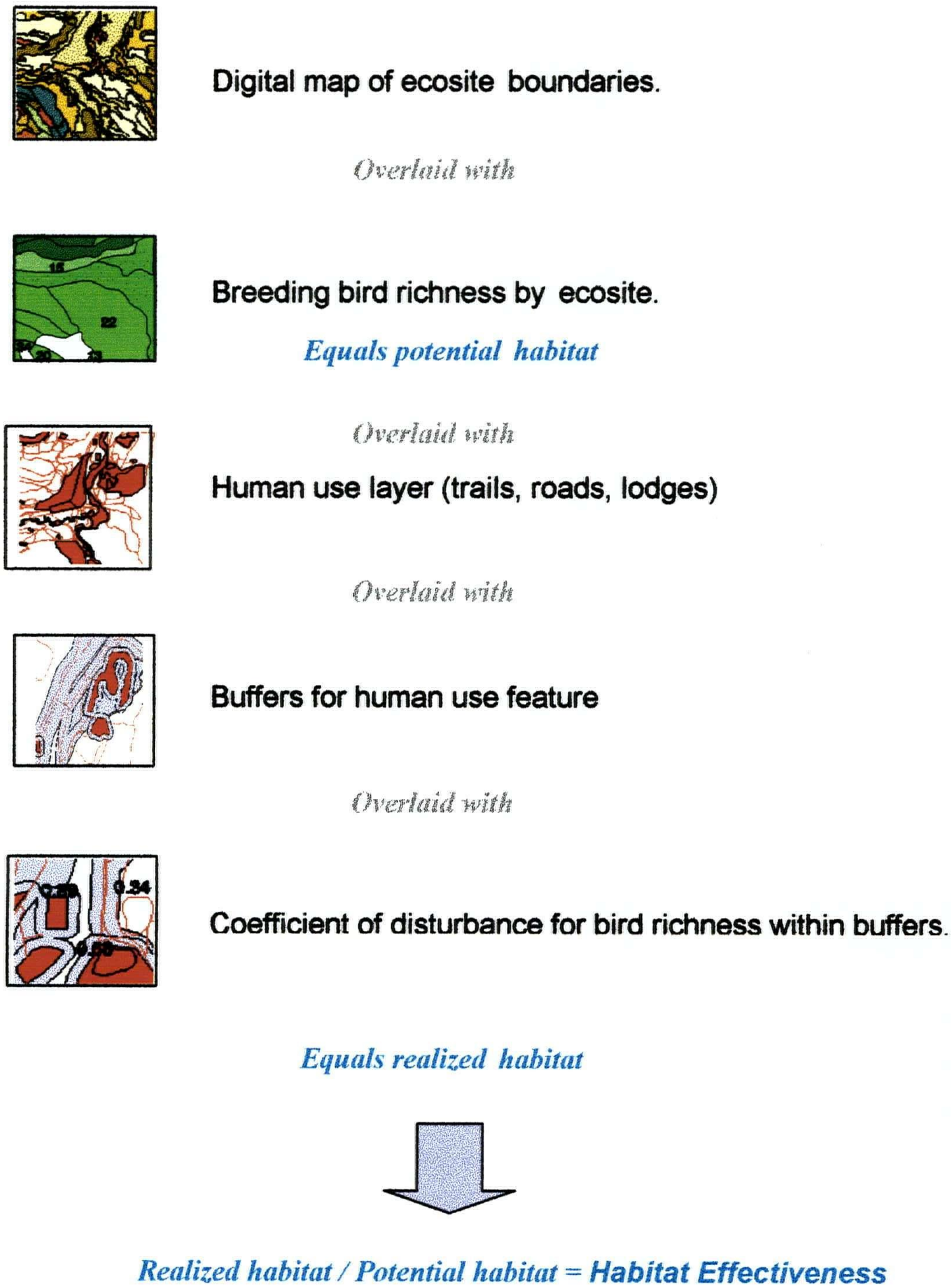


Figure 15. Spatial overview of the working breeding bird model showing how the layers of data are integrated to calculate breeding bird habitat effectiveness.

Habitat Effectiveness

The habitat and disturbance components are used in several different ways in the model to assess cumulative effects at two scales of resolution. (1) The summary habitat effectiveness statistic (by ecosite type) considers habitat loss in the context of Three Valley Confluence. (2) Habitat effectiveness by patch identifies individual ecosite patches which receive the greatest concentration of land use and degree of cumulative effects.

At the scale of Three Valley Confluence, summary habitat effectiveness calculates habitat loss collectively by ecosite type. If there is a land use in each of three patches of HD4 habitat in the study area, the model calculates the total loss in effectiveness to HD4 due to the three land uses. If HD4 is rare, very little effective HD4 habitat may be left in the study area. Had the same land uses occurred in VL3, a more abundant habitat type, loss in habitat effectiveness overall would not be as high. HD4 provides a different habitat type than VL3 and therefore supports a unique suite of breeding birds. The diversity of habitat types, and suite of breeding birds provides for increased diversity of species at the scale of the study area. Ensuring cumulative effects do not severely impact rare breeding bird habitat is the purpose for the summary habitat effectiveness statistic. While VL3 has higher breeding bird species richness, interpreting the results at a broader spatial scale acknowledges site richness is not the only factor to manage for. The composition of breeding birds and diversity of bird habitats is also important.

Habitat effectiveness at the scale of the patch identifies individual ecosite patches that receive a large proportion of the impacts from accumulated land uses. Analyzing the results of accumulated land use at the ecosite patch level identifies areas in Three Valley Confluence where land uses most impact breeding bird habitat.

1) Summary Habitat Effectiveness

The potential and realized habitat effectiveness values are summed for each ecosite type for Three Valley Confluence. The sum values are then compared to calculate the effectiveness for the ecosite.

Habitat Effectiveness by Ecosite Type =

$$\frac{\text{Summed Realized Habitat by Ecosite Type}}{\text{Summed Potential Habitat by Ecosite Type}} =$$

$$\frac{\sum \text{patch areas x richness} - [(\text{land use areas} + \text{buffer areas x disturbance coefficient}) \text{ x richness}]}{\sum \text{patch areas x richness}}$$

Sample Calculation for Athabasca 1 Ecosite Type

$$\frac{2000 \times 30 - [(500 + 100 \times 0.68) \times 30]}{2000 \times 30} =$$

$$\frac{32\,760}{60\,000} = 54.6\ \%\ \text{habitat effectiveness}$$

If there are 140 patches of AT1 ecosite habitat in 3VC, then land uses within these patches account for a 45.4% loss in effective AT1, previously available as breeding bird habitat.

Summary habitat effectiveness (by ecosite type) is useful in coarse-scale planning and comparing the state of different ecosite types (PT1 vs. PT3) within Three Valley Confluence. However, for finer scale management of cumulative effects, habitat effectiveness at the ecosite patch highlights the most sensitive and threatened patches of habitat.

2) By Ecosite Patch

The potential and realized habitat values are calculated for each individual ecosite polygon.

Habitat Effectiveness by Ecosite Patch =

$$\frac{\text{Realized Habitat for the Ecosite Patch}}{\text{Potential Habitat for the Ecosite Patch}} =$$

$$\frac{\text{patch area x richness} - (\text{land use areas} + \text{buffer areas x disturbance coefficient})}{\text{patch areas x richness}}$$

Sample calculation for a patch of Athabsca 1 ecosite located south of Jasper Townsite

$$\frac{20 \times 30 - [(6 + 3 \times 0.68) \times 30]}{20 \times 30} = 59.8\ \%\ \text{habitat effectiveness for the patch}$$

Almost half of the effective habitat in this patch of AT1 has been lost due to a portion of a highway and campground that occur in an area of the patch.

4.4.5 Assumptions and Limitations

The model assumes that responses of breeding bird species to human use and disturbance described in the literature apply within Jasper National Park. This assumption can be validated by future research in the park. The model coefficients of disturbance only account for those species displaced due to sensitivity to human use and do not include additional tolerant species that would move into disturbed habitats. In this way, the species sensitive to human land use are subtracted from the suite of species counted by ecosite type in the surveys. In reality, other exotics or generalist species may increase in disturbed areas, actually causing the richness to increase or remain the same while the composition of species drastically changes. While this relationship between exotics and sensitive species is important in that sensitive species may be further impacted by increasing number of exotics, it was not addressed within this model, and may result in underestimates of cumulative effects. This concern is mediated somewhat because the species of concern from a cumulative effects management perspective are those most sensitive to land use. Providing conditions suitable for species most sensitive to land use can help ensure, at a very coarse level, conditions for other native species are also protected and conditions for exotics are not promoted. The exception is where a species may have very specific habitat needs requiring special management, or where the presence of an exotic species is related to an aspect of human use not necessarily represented through spatial modeling (e.g. presence of a horse coral and habitat conditions for Brown Cowbirds). These issues may require problem-specific and site-specific management.

4.4.6 Summary

While the capacity of habitat to support species richness is the indicator in this model, this method incorporates species specific behaviour to account for the effects of human use. This relationship accounts for the displacement of sensitive species acknowledging it is the species that make up richness in an ecosite that is important, not only the number. The two scales of analysis allow the model to track the loss of rare ecosite types and to identify patches with concentrated impacts and the overall pattern of cumulative effects.

4.5 Development of the User Interface for both models

I developed these cumulative effects models to be planning tools. Therefore, it was important to make them accessible to users with limited technical ability. While the programming to run the models is quite complex, developing land use scenarios and running the models to assess potential cumulative effects is user-friendly through the user interface. The user interface is a pop-up menu that guides the user upon opening the model through to presentation of the results. The user selects the inputs required to run the model from a pick-list. A help menu guides them through the selection of menus.

Carol Doering created this interface, and completed the model programming. The interface builds on work done on the Grizzly Bear Cumulative Effects Model. Carol and I discussed the intended audience (park warden, park manager or planner, biologist or GIS technician) for the model and objectives for its use. This is reflected in the design of the interface. The interface prompts the user to include documentation on objectives and interpretation of 'run' results. The model also flags when changes are made to default parameters to ensure that results are not misinterpreted. The following series of figures shows a selected set of progressive menus the user would see and interact with to complete a run of the model.

4.6 User Guide and System Guide

Two guides were developed to accompany the model to ensure that they would be accessible to the intended audience. The first is the User Guide (The Forestry Corp 1999). This document guides the user through the steps in running the model and in the data layers required to run alternate land use scenarios (Appendix IV). The second guide is a Systems Guide (The Forestry Corp 1999). It provides enough information to install, maintain and trouble shoot programming problems with the models. This guide assumes that the reader has a working knowledge of Unix system administration, Arc/Info GIS and Arc/Info programming language (AML).

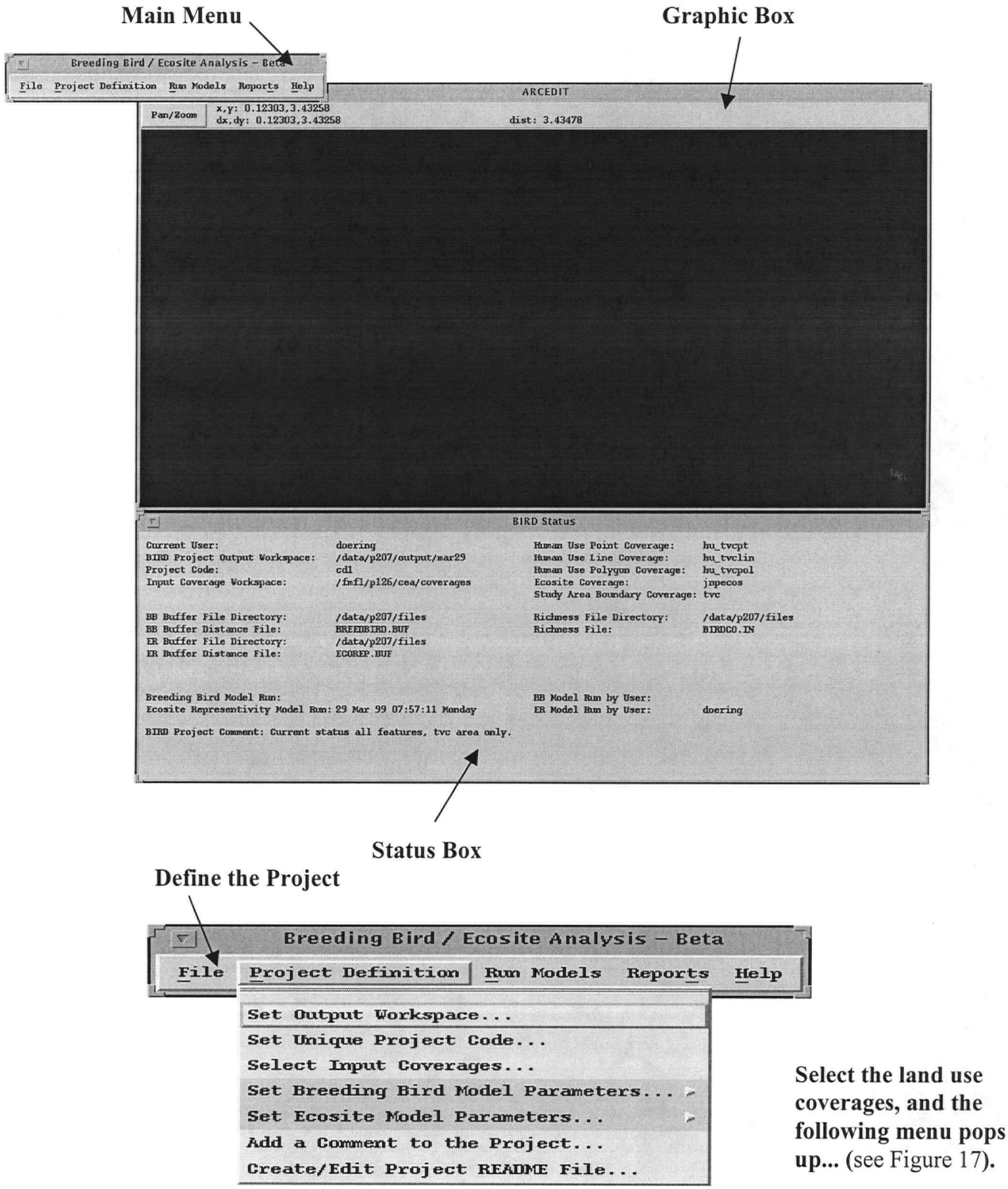


Figure 16. The user opens the main menu at an Arc/Info workstation. From the main menu the user proceeds with a project definition and selects the input coverages described in the methods section of this thesis.

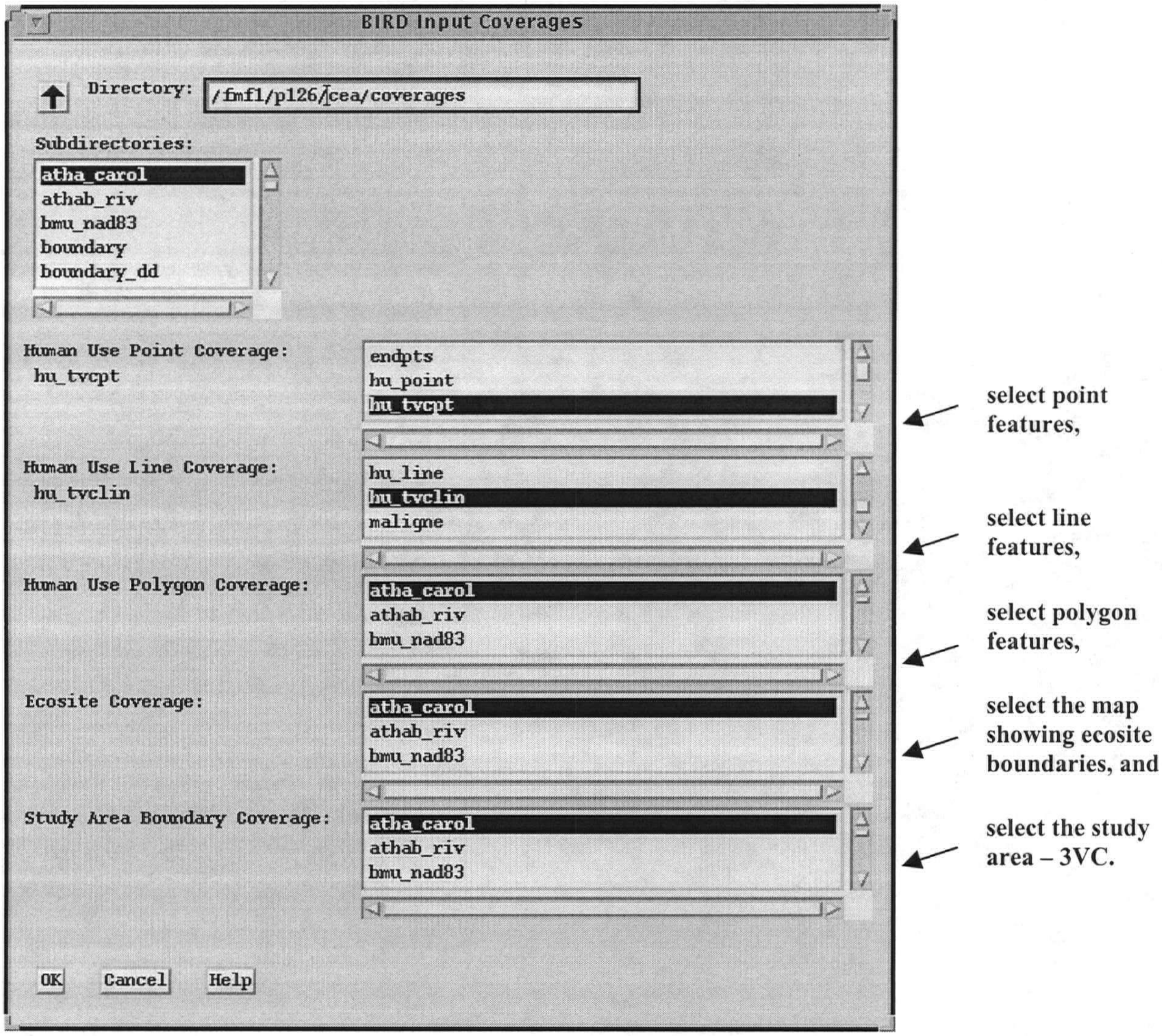
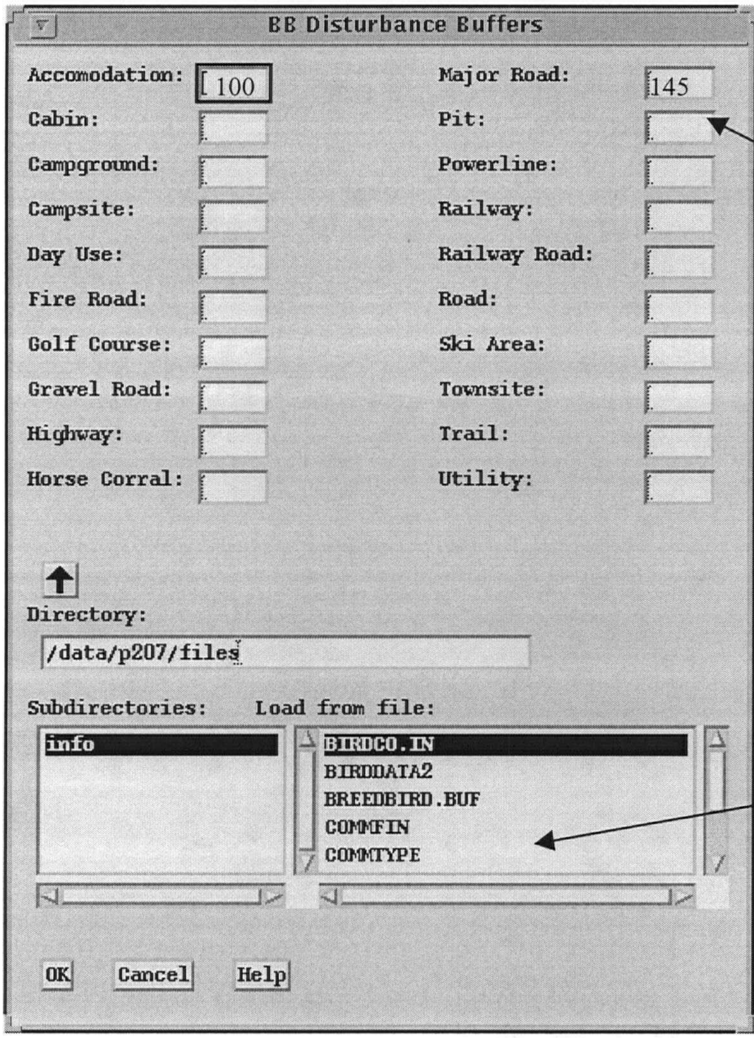


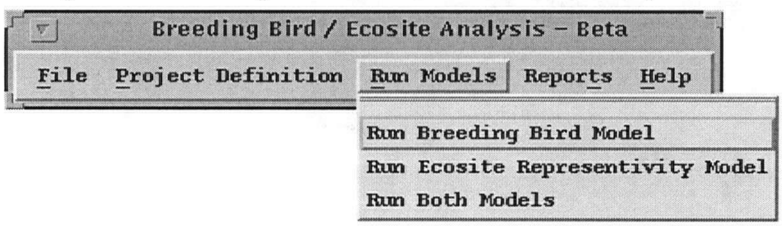
Figure 17. The user interface prompts for the land use coverages of the study area. If a user is interested in developing and testing 'what if' land use scenarios by adding or deleting specific land use features, it is at this stage where an alternative land use scenario would be selected.



The buffer distances can be keyed in manually or loaded from a file containing the default parameters

Available Files listing default buffers. The following menu prompts for the file of bird sensitivities 'birdco.in'

Once the input values and parameters have been selected, the models are run...



The runs are complete, and the habitat effectiveness reports are prepared.

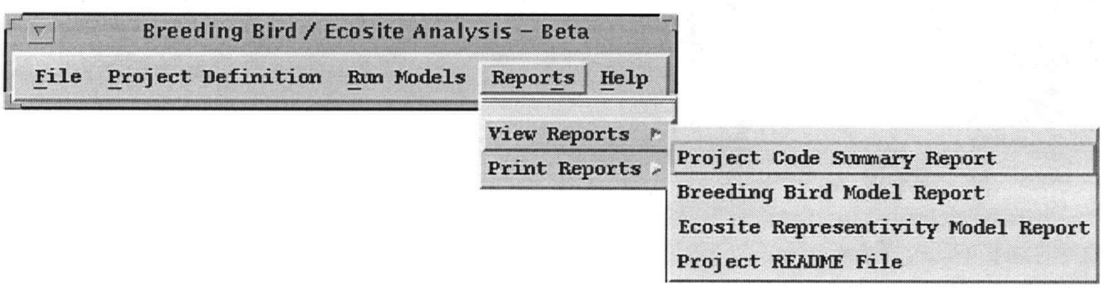


Figure 18. The user can input new disturbance buffers or coefficients at this stage of the model, or choose files containing default parameters and select which of the two models will be run. The models produce a set of reports detailing the parameters used and results.

Chapter Five Cumulative Effects Analysis

5.1 Introduction

Using the new models I completed a cumulative effects analysis of the impact of accumulated land uses presently on the landscape in Three Valley Confluence. I summarized the model results for ecosite types at the scale of Three Valley Confluence. In addition, I determined habitat effectiveness at the scale of the ecosite patch and the study area for breeding birds. I first outline the methods for this cumulative effects analysis, followed with a presentation and discussion of the results.

5.2 Methods

I used the ecosite representation and breeding bird models described in Chapter 5 to complete this cumulative effects analysis. Default parameters for buffers and coefficients were selected for the initial run of the models. The human use data layer (point, line and polygon features) developed by Parks Canada included all human use features in Three Valley Confluence.

I also ran the models to determine which features contribute most to decreased habitat effectiveness values. I edited the human use data within the GIS to create land use scenarios based on the overall feasibility of reconfiguring human use. Scenarios included (1) twinning of highway 16, (2) the removal of plausible Parks Canada polygon features and (3) the removal of plausible Parks Canada land use features (Table 10).

Table 10. Features edited in the GIS to produce land use scenarios for Three Valley Confluence.

Scenario	Features Changed
(1) Highway Twinning	Buffer increased by 30 m on either side of highway 16
(2) Plausible Polygons	Removed the following polygons: old warden office, trade waste pit, Snaring Overflow Campground, Whistler Hostel, horse pasture, airstrip, 9 gravel pits.
(3) Plausible Land Use Features	In addition to the polygons removed in the plausible polygon scenario: Trail 7, Old Fort Point Trail, Bike Toss, Marjorie Lake trail, Saturday Night Loop, wood pit access, 93a Highway south of Wabasso Lake, 93a Highway north between Alpine Bungalows and the Miette River.

5.3 Results

Effects of Accumulated Land Uses on Ecosite Representation (Model 1)

All results for ecosite representation at the present level of land use are included in Appendix V. Of the 100 ecosite types in Three Valley Confluence, cumulative effects have resulted in 9 ecosite types with a habitat effectiveness of less than 90 % (see Table 11). Three of these ecosite types (AT1, AT3 and HD4) have habitat effectiveness values of less than 60 %. Figure 19 illustrates the most impacted ecosites are located along the Athabasca and Miette river corridors. Two major highways, several lodges and Jasper townsite occur in the most impacted ecosites.

Figure 20 presents the potential and realized representation values for ecosites that contribute more than 10 % of the park-wide representation for an ecosite type. These are the ecosite types found in Three Valley Confluence that are important to park-wide representation because they form a considerable portion of the representation. The potential contribution of AT1, AT3, and PT4 to park-wide representation is between 50 % and 85 %. This means while Three Valley Confluence makes up only 6 % of the Park, it contains more than 50 % of these ecosite types.

Table 11 Ecosite types for which cumulative effects reduced the effectiveness to below 90%.

Ecosite Type	# Patches in 3VC:JNP[17]	Potential Contribution to Representation in JNP (%)	Realized Contribution to Representation in JNP (%)	Habitat Effectiveness (%)	Ecosite Rarity (% of Park)
AT1	21 : 56	48	27	56	0.63
AT3	3 : 5	85	47	55	0.05
FR1	13 : 56	27	20	75	0.22
HD1	16 : 52	37	30	82	0.22
HD3	9 : 49	10	9	89	0.32
HD4	6 : 17	34	15	46	0.08
PT4	7 : 14	59	53	89	0.11
VL3	26 : 55	35	28	79	0.23
WH2	2 : 28	3	2	62	0.16

Cumulative effects have impacted ecosite representation for several ecosite types. The following summaries present a profile of the most impacted ecosite types in relation to the pattern of land use and the importance of the ecosite to park-wide representation.

[17] This compares the number of patches of each ecosite in 3VC of the total number of patches of this ecosite that exist in Jasper National Park (JNP).

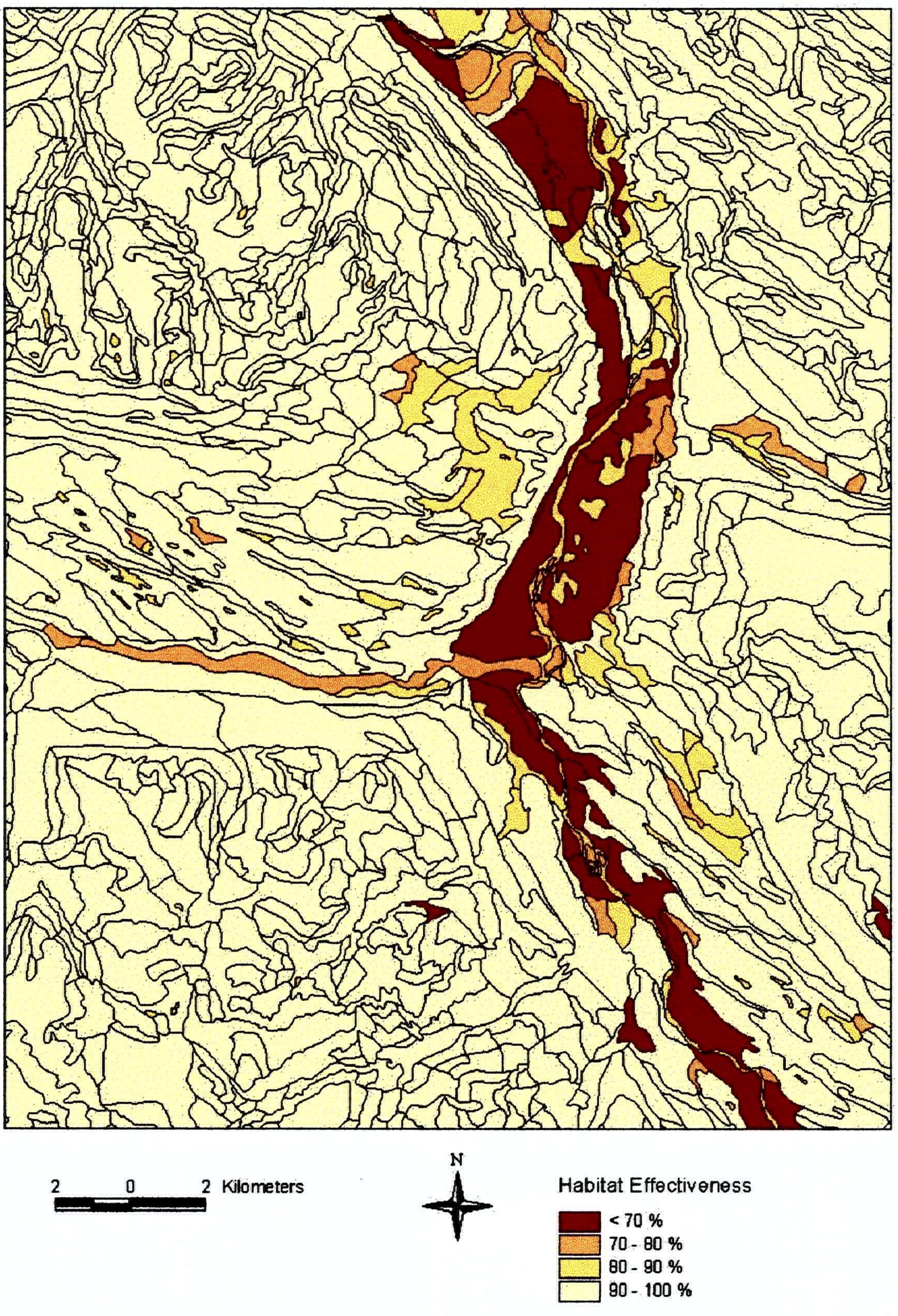


Figure 19. Habitat effectiveness results for ecosite representation at the present level of human use in three Valley Confluence.

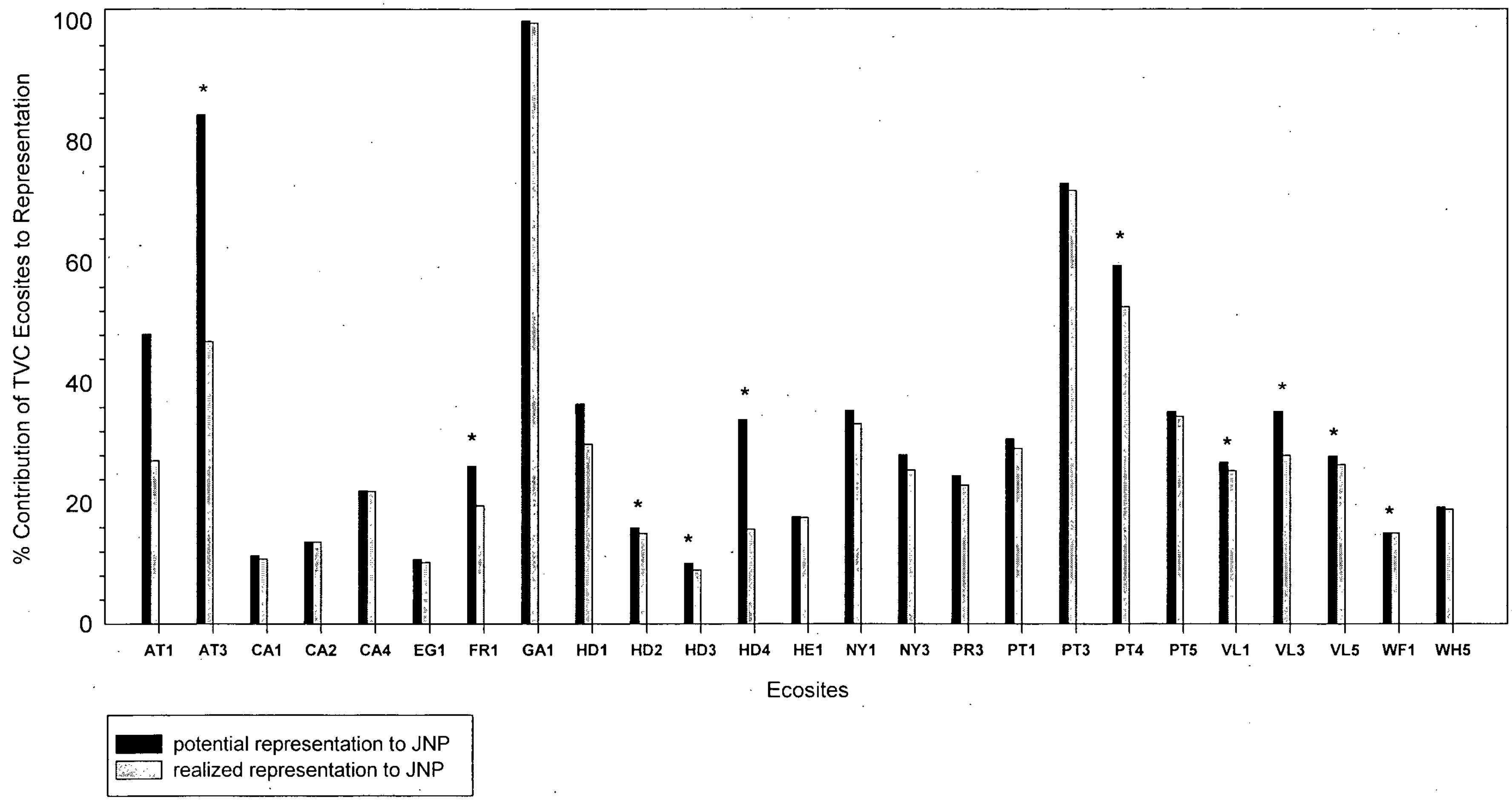


Figure 20. A comparison of the potential to realized percent contribution of Three Valley Confluence (TVC) ecosites to representation at the present level of land use. The ratio of the realized to the potential ecosite representation is the habitat effectiveness. Only ecosite types that contribute more than 10 % of the park-wide ecosite representation are included in this figure. The asterix highlights rare ecosites occurring in less than 0.5 % of the park. Ecosites that are rare and that have high levels of cumulative effects, reflected in low habitat effectiveness values are a management concern (AT3, HD4, FR1, VL3).

Athabasca 3 - AT3

Three Valley Confluence contains 85 % of the existing AT3 in Jasper National Park. This ecosite is the third rarest in park and occurs in only five patches, with three located in the study area. The present level of land use has resulted in a habitat effectiveness value of 55 %. This means that 46 % of all the AT3 may be alienated or disturbed due to land uses in Three Valley Confluence (55 % effectiveness in 85 % of the AT3). Cumulative effects in AT3 mark the greatest loss to ecosite representation due to the rarity and limited aerial extent.

Hillsdale 4 - HD4

HD4 is the most impacted ecosite type in Three Valley Confluence with a habitat effectiveness of 46 %. The model predicts only half of the original HD4 in 3VC is now effectively representative. The study area contains 34 % of the HD4 in the park in six patches. HD4 is the fifth rarest ecosite in the park occurring in a total of only 17 patches.

Athabasca 1 - AT1

While Three Valley Confluence contains almost 50 % of the park-wide AT1, it is spread throughout the study area in 21 patches. AT1 is a relatively abundant montane ecosite type within the study area (occurring in 0.6% of the park area). However, dispersed land uses have occurred in this ecosite type resulting in a loss of almost half of the effective habitat area. That translates to a loss of one-quarter of the AT1 in the park due to land use in Three Valley Confluence alone.

Patricia 4 – PT4

Land use in PT4 has been relatively limited in comparison with the above 3 ecosites. However, the context for cumulative effects in PT4 deserves some mention due to the ecosite's limited extent. Habitat effectiveness in PT4 is 89 %. It occurs in 0.11 % of the park and is among the 10 rarest ecosites. Of greater significance, the representation is quite limited in extent to 14 patches in the park. Three Valley Confluence contains 60 % of the ecosite type within seven patches, with the majority of these concentrated on the 'bench' area north of the townsite.

Whitehorn 2 - WH2

The previous ecosites are montane and occur in the area with the highest concentration of land uses. WH2 is not a subalpine ecosite yet has a habitat effectiveness of only 62 %. At the scale of the study area, WH2 appears to be impacted by accumulated land uses. However, Three Valley Confluence contributes only 3 % to the total representation within the park making it less important to park-wide representation. The loss in effectiveness is due to a ski development and access road.

Effects of Accumulated Land Uses on Breeding Bird Habitat Effectiveness (Model 2)

The cumulative effects analysis for breeding birds provides results at two scales. At the level of Three Valley Confluence a summary statistic expresses habitat effectiveness by ecosite type (see Appendix V for results). I also dissolve the ecosite boundaries and display the results at the scale of Three Valley Confluence providing a coarse scale view of potential habitat fragmentation. Second, I calculate habitat effectiveness at the level of the individual ecosite patch. This analysis determines cumulative effects at a finer scale, providing more information about how specific land uses in particular areas contribute to cumulative effects in the study area. Factors that should be considered in interpreting the cumulative effects results for breeding bird habitat include: the breeding bird richness by ecosite type, the ratio of sensitive to tolerant birds reflected in the disturbance coefficient and the area of the ecosite patch and aerial extent in Three Valley Confluence.

Accumulated land uses across Three Valley Confluence have resulted in habitat effectiveness values below 90 % for seven ecosite types (Table 12). Figure 21 compares the potential and realized habitat values for all ecosite types in the study area. While the summary statistic provides an indication of which ecosite types are most impacted by cumulative effects, the result is summed across all patches in each ecosite type. Therefore, the summary statistic fails to communicate there is a range of effectiveness results for the individual patches that make up an ecosite type, and that some areas receive high levels of concentrated land use.

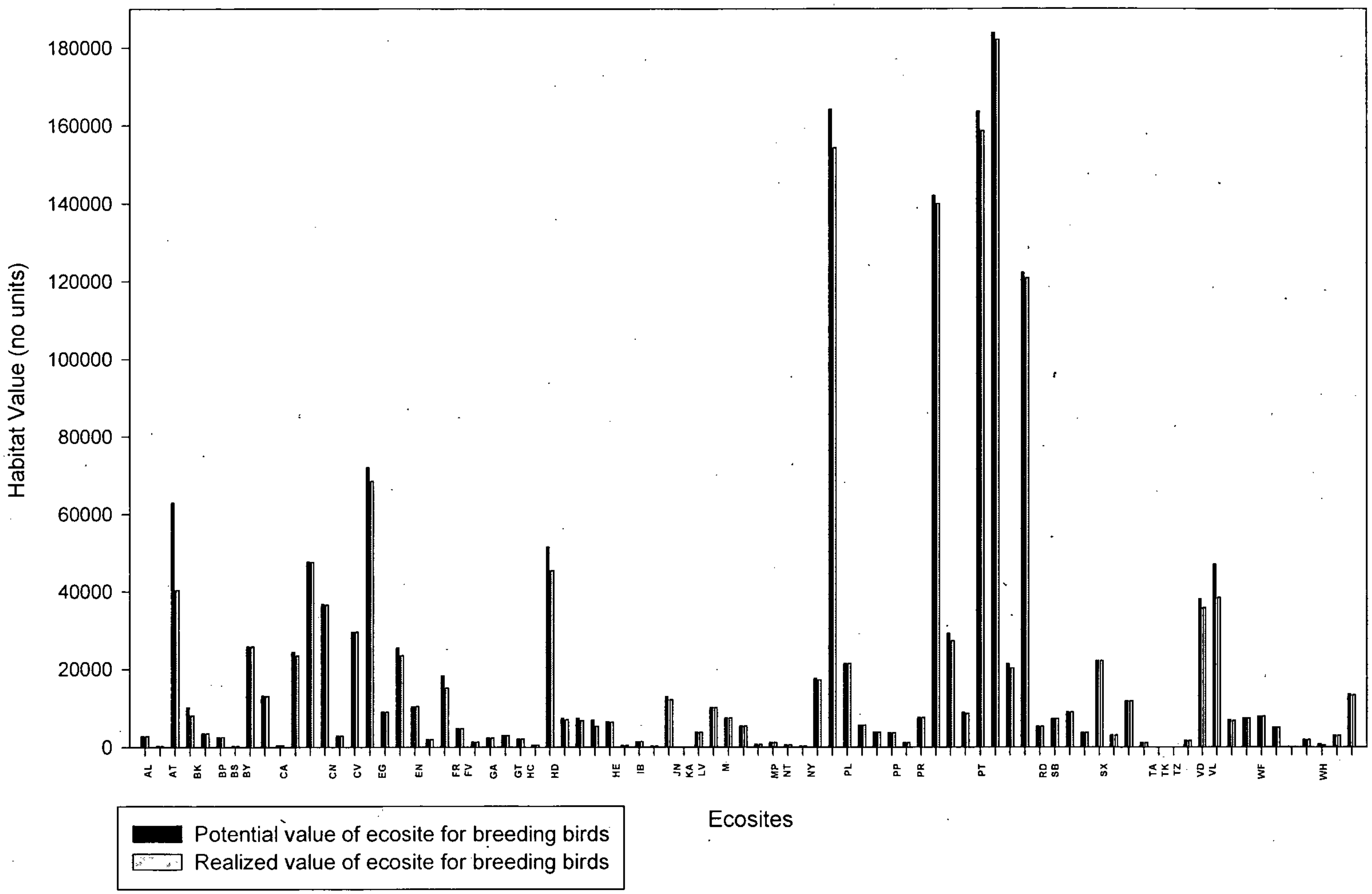


Figure 21. Habitat value is a function of the value of the habitat type for breeding birds and the area of the habitat available. This figure highlights ecosite type having a high potential for supporting breeding bird richness, as a function of both their area and richness. Several ecosite types have lost a considerable proportion of their effectiveness. These include Hillsdale ecosites (HD4) and Athabasca ecosites (AT1, AT3).

Table 12 Ecosite types that have habitat effectiveness values below 90 % at the present level of land use summed across all patches in each ecosite type in Three Valley Confluence.

Ecosite Type	Potential Habitat	Realized Habitat	Disturbance Coefficient	Habitat Effectiveness summed over study area (%)
AT1	62915	40362	0.68	64
AT3	10187	8185	0.79	80
FR1	18316	15159	0.72	83
HD1	51565	45446	0.75	88
HD4	6997	5406	0.88	77
VL3	46993	38426	0.70	82
WH2	860	544	0.69	63

Looking at a finer scale, land uses have impacted many individual ecosite patches resulting in effectiveness values well below 70 %. Cumulative effects by ecosite patch displays the feature-by-feature impact of land uses on ecosite patches. Figure 22 highlights the location and degree of impact for ecosite patches most affected by accumulated land use. To identify the ecosite type impacted in each location, refer to Figure 23 for the names of affected ecosite patches. Habitat effectiveness ranges for ecosite patches from 0 % to 100 % (see Table 13). Zero values result when a small ecosite patch falls completely within the footprint of a development, thereby causing a total loss in habitat effectiveness.

At an even finer resolution, Figure 24 displays habitat effectiveness values within the disturbance buffer surrounding a land use. This approach identifies land uses occurring on ecosites with a high proportion of sensitive species. The variation in impact within disturbance buffers reflects that different ecosite types have different coefficients of disturbance. The major East-West highway and North-South highway have been developed on ecosites with a high proportion of sensitive species. The highways displace these species within the buffer, and the result is reduced habitat effectiveness for adjacent habitat.

Back to a coarse scale, Figure 25 provides insight on the cumulative effect of land use on habitat fragmentation for breeding birds. This figure displays the model's interpretation of Three Valley Confluence for a highly sensitive breeding songbird. Ecosite boundaries have been dissolved and grouped collectively as habitat. Habitat is fragmented by natural features such a rivers and lakes, and by land use features and their associated buffers. Fragmentation of habitat occurs to a limited extent in the area directly around the townsite suggesting that several patches may have insufficient interior habitat to support sensitive species of breeding birds.

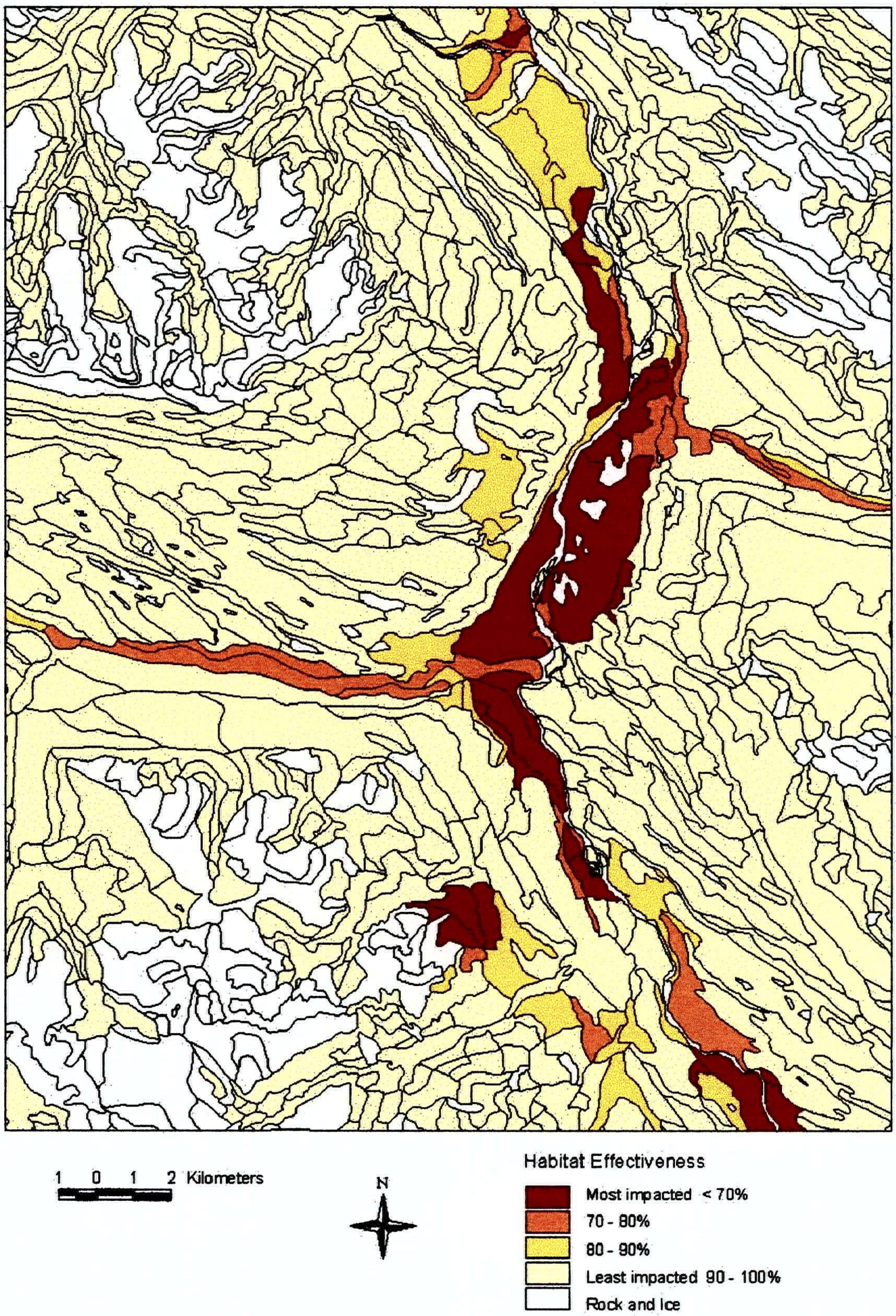


Figure 22. Habitat effectiveness results for breeding birds by individual ecosite. While the summary statistic reports habitat effectiveness values summed by ecosite type, this map shows the impact on habitat effectiveness for individual ecosites. It illustrates where land uses reduce the effectiveness of ecosites for breeding birds. Refer to Figure 23 for ecosite patch names.

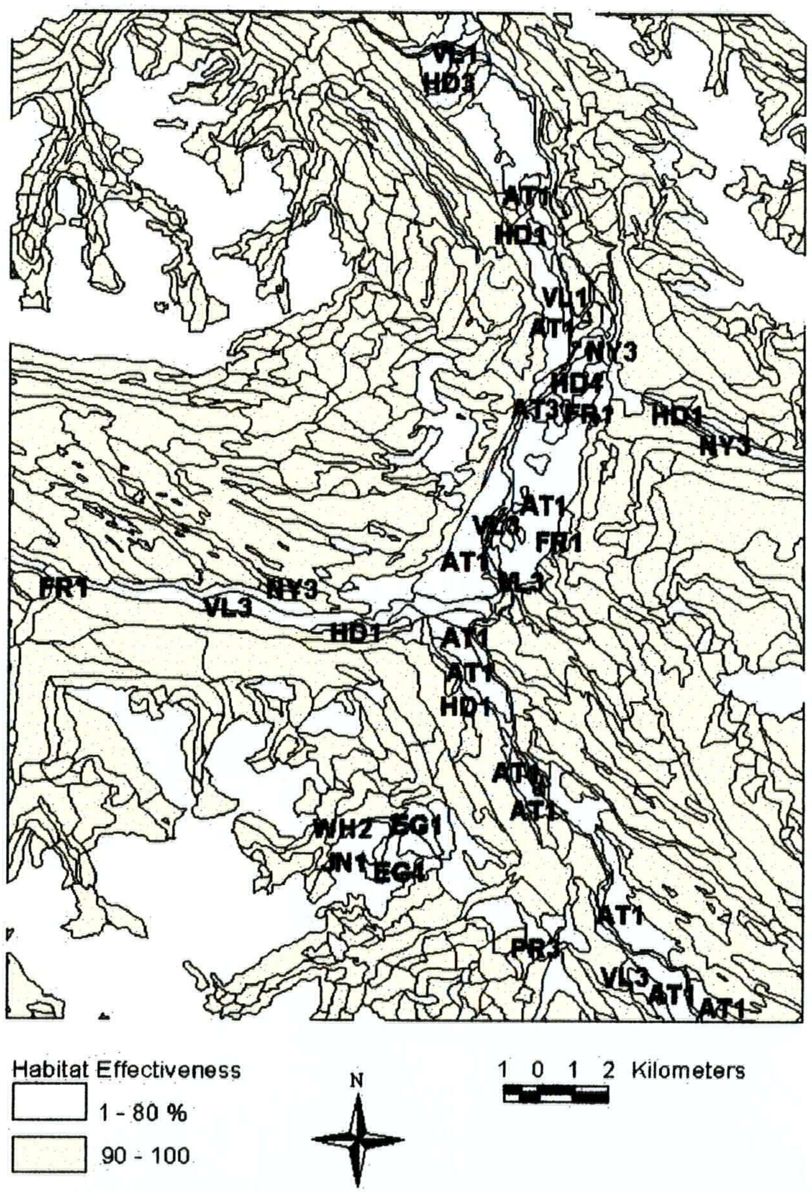


Figure 23. Reference map to identify ecosite patches in Figure 22 shown to have been affected by cumulative effects.

Table 13. Habitat effectiveness by ecosite patch. This table includes ecosite patches with habitat effectiveness values below 80 % at the present level of human use.

Impacted Ecosite	Richness	Disturbance Coefficient	Habitat Effectiveness for Ecosite Patches
AT1	19	0.68	65 % 29 % 56 % 60 % 29 % 63 % 70 % 67 % 77 % 61 % 59 %
AT3	21	0.86	55 %
BP1	8	0.75	74 %
CA1	26	0.69	56 %
EG1	34	0.74	51 % 3 %
EG4	22	0.84	0 %
FR1	29	0.72	45 % 34% 75 % 73 %
HD1	60	0.75	74 % 75 % 43 %
HD3	21	0.62	47 % 78 %
HD4	25	0.88	61 %
JN1	15	0.93	0 %
NY3	56	0.68	76 % 79 % 76 % 76 %
PR3	22	0.55	79 %
VL1	71	0.73	71 % 78 % 79 %
VL3	53	0.70	65 % 73 % 77 % 79 % 79 % 76 % 71 % 79 % 48 % 70 %

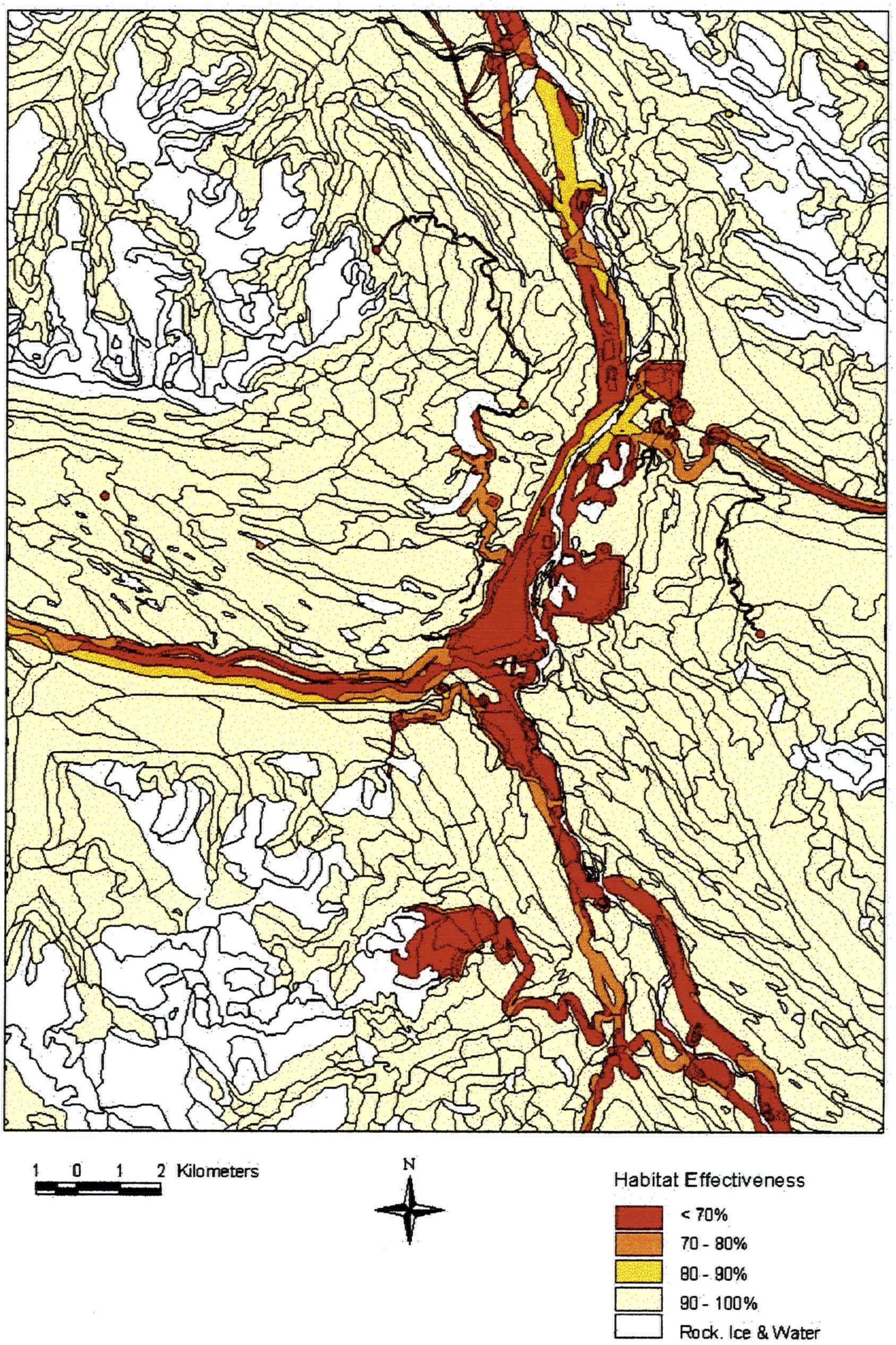


Figure 24. Habitat effectiveness values within disturbance buffers. This map shows the pattern of land use and associated disturbance in Three Valley Confluence and illustrates where specific land uses have the greatest impact on habitat important for sensitive breeding bird species.

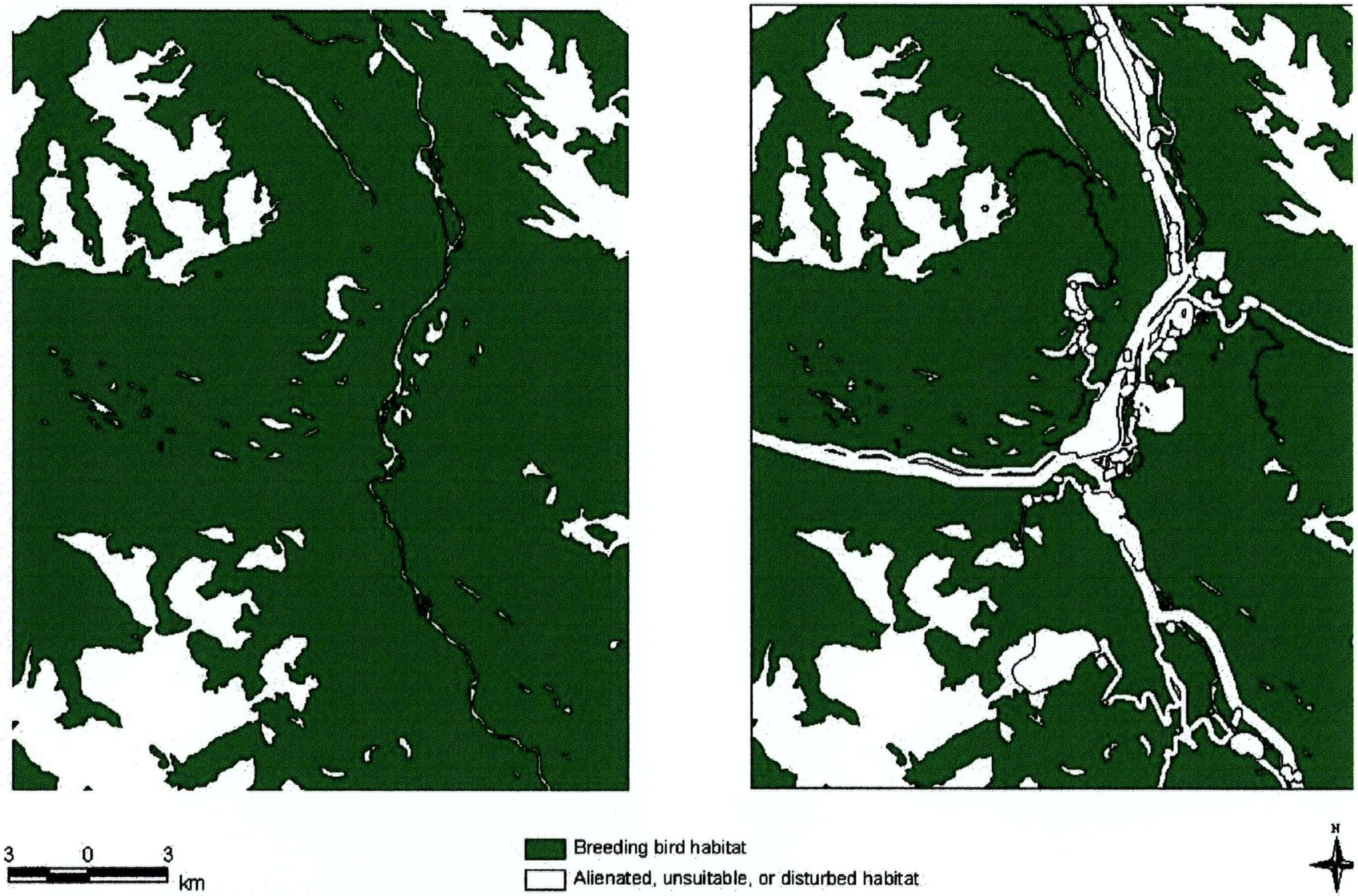


Figure 25. A coarse-scale view of Three Valley Confluence displaying the study area from the perspective of a sensitive breeding bird. The ecosite boundaries have been dissolved and displayed collectively as 'habitat'. Habitat is fragmented by natural features and by land use features and their associated buffers. Unsuitable habitat includes rock and ice habitat types.

Land Use Scenario Results for Both Models

Table 14 shows the habitat effectiveness results for both models in response to the hypothetical land use scenarios. The *Twinning the Highway* scenario resulted in cumulative impacts for several ecosite patches that presently parallel the highway. At the scale of Three Valley Confluence, the incremental effect of a hypothetical highway twinning is detectable for several ecosite types currently impacted by cumulative effects. The model predicts losses in effective representation of ecosites (summed across the study area) of 2%, 3 %, and 4 % for AT3, HD4 and VL3 respectively. Loss in breeding bird habitat effectiveness is up to 0.8 % in VL3. In constructing this land use scenario, I simply increased the disturbance buffers by 30 m on either side of the highway from the current buffer width for an un-twinned highway. The complete loss of habitat due to highway construction has not been included. Therefore, this scenario represents the minimum impact due to highway twinning and likely underestimates the cumulative impact.

Table 14. Changes in habitat effectiveness as a result of land use changes depicted in the three land use scenarios. Gains and losses were detected in several ecosites in response to the hypothetical changes in land use features.

Ecosite	(1) Highway Twinning		(2) Plausible Polygons		(3) Plausible Features	
	ER	BB (summary)	ER	BB (summary)	ER	BB (summary)
AT1	- 0.9	- 0.1	+ 2.5	+ 0.3	+ 3	+ 2
AT3	- 2.1	- 0.4	+ 11	+ 7	+ 12	+ 7
FR1	- 0.7	0	+ 7	+ 5	+ 7	+ 5
HD1	- 1.3	- 0.1	+ 1	+ 0.5	+ 1	+ 0.5
HD3	- 0.3	- 0.1	+ 4	+ 2	+ 4	+ 2
HD4	- 2.7	0	+ 16	+ 13	+ 16	+ 13
PT4	0	0	0	0	0	0
VL1	- 1.3	- 0.5	+ 0.5	+ 0.3	+ 0.5	+ 0.3
VL3	- 4.1	- 0.8	0	+ 0.3	+ 0.5	+ 0.5

The (2) *Plausible Polygon* scenario (elimination of plausible Parks Canada polygon features) resulted in increases in breeding bird habitat effectiveness in HD4 (13%), AT3 (7%), and FR1 (5%). The effectiveness of ecosite representation increased by as much as 16 % in HD4 and 11 % in AT3. Finally, the (3) *Plausible Land Use Feature* scenario resulted in similar outcomes for breeding bird habitat effectiveness as in scenario two with further increases in AT3 (2%)., and HD3 (2%). Ecosite representation responded similarly with slight increases in AT1 and AT3

5.4 DISCUSSION AND SUMMARY

5.4.1 Ecosite Representation (Model 1)

Results of the ecosite representation model indicate that cumulative effects have impacted the ability of several ecosite types to contribute to park-wide representation.. A number of these ecosite types were originally rare in abundance and limited in extent. Accumulated land uses on rare ecosites threaten representation at the park level. Further, when they are located on or adjacent to a transportation corridor, there is a risk of further cumulative effects due to potential expansion or increased use and disturbance.

Cumulative effects on ecosite representation are concentrated centrally around the townsite, to the north along the Highway 16 and the railway corridor, and to the south along Highway 93. Three ecosite types: AT1, AT3, and HD4 have been most impacted by cumulative effects. AT3 has been affected in the central portion of Three Valley Confluence by a cottage development at Lake Edith and by the Maligne Road. Highway 16 and the airstrip have alienated or disturbed another portion of this ecosite type. Prescribed burns undertaken by Parks Canada in AT3 habitats may be increasing the representation of this open grassland habitat within Three Valley Confluence.

The most significant loss in effectiveness for AT1 has been due to the 'nibbling effect'. AT1 is relatively abundant and is dispersed throughout the valley bottom of Three Valley Confluence. Various developments along the river corridors including the townsite, two major highways and visitor accommodations, are in patches of this ecosite type. Three Valley Confluence contains half of the AT1 in the park. The model predicts that accumulated land uses have reduced the representation of this ecosite type by 50 %.

The six patches of HD4 in Three Valley Confluence, represent a third of the existing HD4 in the park. The effectiveness of the Three Valley Confluence portion has been reduced by over half due to cumulative effects. The greatest impacts occur for a patch of HD4 containing the old warden office, a picnic site, access roads, a horse pasture and a riding stables and arena. Impacts due to the horse pasture may be overestimated as the area is not entirely grazed and portions of the pasture are still representative of an HD4 ecosite. Plans by Parks Canada to remove and rehabilitate the nearby old warden office will improve the representation for this ecosite type.

While PT4 has not been impacted to the same extent as the first three ecosites, the model highlights it as an ecosite of concern. PT4 is relatively rare. Moreover, Three Valley Confluence contains the majority of the PT4 in the park, with most in a limited area to the north of the townsite. Present levels of land use in this area have impacted these ecosite patches. The concentration of PT4 in an area of high visitor use puts it at risk of increased cumulative effects.

In addition to these four ecosite types, five others (FR1, HD1, HD3, PT4, and VL3) have been impacted by accumulated land uses.

Summary

The Ecosite Representation Model suggests the present level of land use has impacted the representation of selected ecosite types in Three Valley Confluence. The dispersed pattern of land use along the river corridors has resulted in eight ecosite types associated with valley-bottoms receiving the greatest cumulative effects. In contrast, the majority of ecosite types in the study area remain above 90 % habitat effectiveness. Essentially, the majority of the land use in the study area occurs in a few ecosite types.

5.4.2 Breeding Bird Habitat Effectiveness (Model 2)

While the habitat effectiveness summary statistic is useful in highlighting which ecosite types are most impacted by land uses, impacts in some ecosite patches become diluted when results are summed across the study area. For example, VL3 extends from the townsite west toward the British Columbia border. Highway sixteen and the CN Railway run parallel through the ecosite. Within this patch of VL3 these two land use features impact a considerable portion of the ecosite area resulting in 70 – 80 % habitat effectiveness. However, VL3 ecosites are relatively abundant throughout the study area with few land uses in most patches. When the potential and realized habitat values are summed for all patches and compared, the impacts on the patch of VL3 with the highway and railway become diluted. The result is a summary habitat effectiveness value of 80 – 90 %. The relative impact of a single land use varies inversely with the size of the analysis area. The summary statistic still indicates cumulative effects, but does not identify the pattern of land use causing the effects. The summary statistic provides insight into 1) nibbling effects resulting from dispersed land uses and 2) a good indication of which ecosite types are most impacted by cumulative effects as long as all ecosite types falling below 90 % effectiveness are included for finer scale investigation.

When habitat effectiveness is calculated by ecosite, the results highlight those individual sites most impacted by land uses. Further, mapping the results displays the pattern of cumulative effects on the landscape. Ecosites south and north-east of Jasper townsite are most impacted by land use. Ecosites with habitat effectiveness values below 80 % include AT1, VL3, HD1 and FR1 in and directly south of the townsite. North of the townsite VL1, HD4, AT3 and NY3 are also impacted. To provide context for these impacts, several of these ecosites are among the richest in the park. VL1, HD1, NY3, and VL3 are the first, third, fourth and fifth richest ecosites respectively for breeding birds in the park. In addition, the Vermillion ecosites (VL1 and VL3) include many species that occur in no other ecosites. VL3 and AT1 have the greatest number of ecosite patches with cumulative effects below 80 %. These two ecosites have high levels of land use due to the townsite, recreation developments, and major highways. They also both have relatively low disturbance coefficients meaning they have a higher ratio of sensitive birds relative to other ecosite types. The low coefficient contributes to the low habitat effectiveness values for these ecosites. This relationship deserves some explanation. Loss of habitat effectiveness is greater for ecosites with a higher ratio of sensitive birds. For example, a 10 m^2 ecosite area with a richness of 15, a coefficient of 0.6, and a potential habitat value 150 (10 x 15) is reduced to a realized habitat value of 90 when it falls within a buffer. An equal area with a richness of 12, a potential habitat of 120 (10 x 12) and a coefficient of 0.9 is reduced to a realized habitat value of 108 when in falls within a disturbance buffer. Even though the potential habitat of the second site is lower, the realized value with human use ends up being greater than the first, due to the higher ratio of tolerant birds in the ecosite. Thus, the higher the number of sensitive birds the more strongly influenced the ecosite is by disturbance.

I broke Three Valley Confluence into three areas to investigate: 1) the pattern of land use which is causing cumulative impacts, 2) any additional impacts or alleviating factors the model does not take into consideration, and 3) how important the impacts are in terms of overall breeding bird habitat quality.

North & East

The northern and eastern sections of Three Valley Confluence contain a mix of polygon and line features. The impacts are concentrated along the transportation corridors which branch in the northern portion of the study area into Highway 16, the railway and Snaring Road. The separation in line features results in increased cumulative effects due to increased buffer impacts. Highway 16 and the railway are located in ecosites with high percentages of sensitive bird species, thereby reducing effectiveness below 70 % within buffers in VL3, NY3, and AT1. Polygon features that contribute to a decline in habitat effectiveness along this corridor include an airstrip, several utilities, a transfer station and two campgrounds.

The 'bench' is directly to the north of the townsite. Land uses in this area are generally associated with the road. A fireroad extends north into sub-alpine ecosites. Additional land use is relatively dispersed through the bench area and includes two lodges and a stable. PT4 is the most impacted ecosite on the bench. It has a moderate richness but has one of the highest bird densities in the park. This means that while the species richness is 29, the habitat supports a high density of these 29 species. For example, similarly sized patches of PT4 and FR1 may both have richness values of 29, however PT4 may support on average 3 of each species while FR1 may only support an average of one per species.

The eastern portion of the study area includes several line features and a concentration of polygon features. Land uses concentrated along the Maligne Road include the Lake Edith Cottage Development, a horse range, the old warden office, several gravel pits and a teahouse and hostel. The greatest impacts occur at the cottage development, horse range and old warden office. Impacts are particularly important in: 1) NY3 and HD1 because they support high breeding bird richness, 2) HD4 because it is a relatively rare ecosite; and 3) AT3 which provides rare grassland habitat in the park.

Cumulative effects in this portion of the study area are of concern due to the abundance of high quality habitat for breeding birds. Land use in this area has been concentrated on VL1, NY3 and HD1 ecosite types. These ecosites are at further risk from expanded land use. These habitats support the highest levels of bird richness in the park and contain relatively high ratios of sensitive birds. Therefore, development within these ecosites has greater impact on habitat effectiveness.

Several factors in this area have not been considered in the model. First, the waste transfer station (garbage dump) may provide an unnatural food source for non-native or tolerant species. The result may be increased competition for breeding areas or increased predation rates due to higher populations of gulls, ravens and crows. Similarly, the horse range may be an attractant for the parasitic brown cowbird, which reduces the nesting success of some songbird species. Therefore, the impact of the transfer station on the quality of surrounding habitat may be underestimated in the model. Second, several polygon features provide habitat within their development footprint for breeding birds. They include portions of the campground, horse range and airstrip. Within the footprint of the land use, habitat alteration occurs with mowing of the airstrip, development of campsites and access roads, and grazing. The model may underestimate the value of these land uses in providing habitat for tolerant species. Lastly, prescribed burns in this area over the last 10 years may be increasing the abundance of the AT3 grassland habitat.

West

The wetland areas of VL3, NY3 and HD1 form the western portion of the study area and provide high quality bird habitat. Highway 16 and the CN Railway also extend west from the townsite to the B.C. border. In addition, several access roads parallel the highway and railway. These linear features have wide disturbance buffers (260 m and 130 m respectively). Occasionally, the disturbance buffers overlap, but for most of their distance they separately reduce effectiveness in adjacent habitat (see Figure 24). The model predicts these features displace sensitive species from habitat for most of their length to the park boundary. For ecosites with a high proportion of sensitive species (VL3, NY3), habitat effectiveness values fall below 70 %.

Cumulative effects in the western portion of the study area are defined by linear land use features which are not concentrated on the landscape. Because they do not share the same corridor, their effects are more significant for breeding bird habitat.

South and Central

The pattern of land use in the central and southern portions of the study area is characterized by diffuse road development. This area is dominated by AT1 ecosites with several rich VL3 and HD1 sites. This is the most highly developed portion of the study area as reflected in the low habitat effectiveness summary value for AT1 (64 %) and ecosite patch values as low as 29 %. While AT1 has moderate bird richness, the proportion of sensitive birds is high, with a coefficient of 0.68.

The townsite is also located on AT1 ecosites and represents the largest single land use feature in the park. While the townsite is habitat for some breeding songbirds, the resolution of mapping does not allow for fine scale habitat classification. The townsite is a food source for some breeding songbirds, however it also may act as a population source for competitive species such as house sparrows and starlings, and may result in increased predation due to domestic cats. Directly south of the townsite are several lodges, and on the opposite side of the Athabasca River, the Jasper Park Lodge and golf course. These dispersed land use features are on FR1, AT1 and VL3 ecosites and result in habitat effectiveness values below 70 % for several patches.

Highway 93 to Banff runs south from town with a wide disturbance buffer. Highway 93a parallels 93 through the southern portion of Three Valley Confluence with the Marmot Ski Hill Road and Edith Cavell Road branching off to the west. Generally, the roads run through ecosites with high ratios of sensitive birds resulting in low habitat effectiveness values within the buffer zones. The area is dominated by AT1 ecosite patches. Several patches along the highway are below 70 % effectiveness due to cumulative effects. Associated land use features include three campgrounds, several lodges, a sky-tram and a skihill. The features are concentrated along the transportation routes. Impacts to alpine ecosites (WH2, JN1, EG1) are limited in Three Valley Confluence and are related both to the ski hill and Skytram.

It is important to note breeding bird habitat still exists within the leaseholds of several lodge developments and campgrounds. Sensitive species may be displaced and habitat alteration may have reduced the quality of the habitat. However, the habitat may still support a community of native bird species. The scale of mapping used in this model does not enable fine resolution assessment of habitat at the scale of a leasehold. Therefore, the model may overestimate the incremental impact that several lodges make to cumulative effects. Protection or rehabilitation of breeding bird habitat within leaseholds and campgrounds may increase habitat effectiveness for some ecosite patches.

Summary

Due to the dispersed pattern of road development and visitor accommodation, the cumulative impacts on ecosite patches is more significant because disturbance buffers often exert their full effect on habitat. If the same amount of development was concentrated, disturbance buffers for two or three features could overlap, leaving surrounding habitat unaffected. The impact of dispersed land use is particularly evident for AT1, VL3, NY3, FR1 and HD1 patches.

Throughout Three Valley Confluence cumulative effects are greatest for VL1, HD1, NY3 and VL1 ecosite types due to high breeding bird richness. Cumulative effects are important in PT4, because this ecosite supports a high density of birds, and in HD4 and AT3 ecosites because they are rare, support a unique composition of breeding birds, and are limited in extent. It is important to restate that for the breeding bird model, the loss in habitat effectiveness cannot be translated into the number of breeding bird species lost. It would overstep the bounds of the model and current understanding of the impact of development on breeding birds to attempt to determine the number of species lost due to land uses, or the species that could be supported through habitat restoration.

Chapter Six Sensitivity Analysis

6.1 Introduction

Before using the models to run land use scenarios, I performed sensitivity analyses to assess the responsiveness of each model to ecological uncertainty. A sensitivity analysis tests the degree of sensitivity in a model to changes in its assumptions. In other words, I produce multiple runs of each model with each run varying the value of a single parameter at a time (e.g. disturbance buffers). By comparing the outcomes from these multiple runs to results using default parameters I gain information on the robustness of the results.

6.2 Methods

I tested two parameters: disturbance buffers and coefficients of disturbance. I also tested the responsive of the indicators to land use strategies at the scale of mapping. Because I developed the default parameters as predictions, the sensitivity of the models to ecological uncertainty in the parameters had to be assessed. In addition, the models predict how the indicators (breeding bird habitat and ecosite representation) respond to changes in the pattern and abundance of human use across the study area. I assume that these indicators are sensitive to land use feature changes at the mapping scale of 1:50 000. While land use features contribute incrementally to cumulative effects, different patterns of land use may affect habitat effectiveness to different degrees. I assume that a lodge with a buffer in an ecosite with a richness of 30 has a similar effect to another lodge of the same size in an ecosite with the same richness. However, surrounding land use patterns may play a role in the incremental cumulative effect of the lodge. I therefore tested the model to determine the effect of surrounding land use features on feature-by-feature cumulative impacts. I asked two general questions to direct the sensitivity analysis.

- *Do the indicators respond similarly to a feature type regardless of the existing land use pattern? Or does the pattern of surrounding land use influence the incremental cumulative effect of the land use feature?.*

- *How sensitive is the model to uncertainty in the ecologically-based default parameters that describe the land use – indicator relationship?*

6.2.1 Responsiveness of Models at the Scale of the Ecosite Mapping

To address the first question I developed a series of land use scenarios based on the present level of human land use in area to determine if the model indicators are responsive to the incremental removals of land use features. By editing the human use map layer a single land use feature, trail, or a set of facilities in a concentrated area could be removed. Removing a feature portrayed a landscape in which the land use had been removed and the land rehabilitated to its former ecosite type. Similar to the development of the land use scenarios in the cumulative effects analysis, I edited the human use data in the GIS to remove and rehabilitate the following features to their previous ecosite type:

- a series of single land use features
- three features: one of each land use type (point, line, polygon)
- a set of line features
- a selection of land use features spread randomly across the study area
- a concentrated selection of land use features
- all features in a large area

I ran the model for each scenario with default parameters for buffers and coefficients so that each run result could be compared to the present level of human use. Thus any change in cumulative effects could be entirely attributed to the removal of the feature(s).

6.2.2 Testing the Model Parameters

Disturbance Buffers

This analysis tested the sensitivity of the model results to variation in buffer distances associated with the human use features. I ran the models four times, increasing and decreasing the disturbance buffers by 50 % and 25 % to test the robustness of the model to uncertainty in the disturbance buffer assumptions. For all runs, coefficients were at their default values with the land use coverage at the present level of human use. The test parameter values are included in Appendix VI.

The user interface was constructed so default settings for disturbance buffer and coefficients of disturbance could be updated and tested. Every time a default parameter was keyed in manually through the user interface (see Figure 18), the model flagged the result as 'non-default', thereby ensuring that the results could not be misinterpreted.

Disturbance Coefficients

This analysis addresses the question: *If I have mis-classified some bird species and have thereby underestimated the ratio of birds sensitive to disturbance, what is the effect on the model results?* The breeding bird coefficients are stored in a file that the user of the model picks from a list. I created two new files containing new coefficients of disturbance. Table 16 is a subsection of the table summarizing all the coefficient of disturbance values. The coefficients reflect an increase and decrease of up to 50 % in the number of birds displaced within a disturbance buffer. This analysis tests the sensitivity of the model to uncertainty in classifying birds.

Table 15. A subsection of Table 27, Appendix VI showing the coefficients of disturbance used in the sensitivity analysis. This sensitivity analysis altered the coefficient of disturbance in two scenarios by increasing and decreasing the percentage of sensitive birds by 50 %.

Ecosite	Default Coefficient	Reduce % of Sensitive Birds by 50 %	Increase % of Sensitive Birds by 50 %
AL1	0.59	0.80	0.39
AL2	0.72	0.86	0.59
AT1	0.68	0.84	0.53
AT2	0.79	0.89	0.68
AT3	0.86	0.93	0.79
BK1	0.63	0.81	0.44
BK2	0.67	0.83	0.50
BK4	0.68	0.84	0.51
BK6	0.67	0.83	0.50
BP1	0.75	0.88	0.63
BP2	0.63	0.81	0.44
BS1	1.00	1.00	0.50

6.3 RESULTS

Testing Disturbance Buffers for the Ecosite Representation Model (Model 1)

Habitat effectiveness values varied from the results derived using default parameters by up to 15 %.

Table 16 summarizes the values for the ecosites that showed the greatest impact due to changes in default values. The habitat effectiveness results that varied the most were ecosites with the greatest levels of land use and low habitat effectiveness values. However, many ecosites with little use showed new impacts on effectiveness. Figure 26 displays the change in habitat effectiveness from default buffer width results for all ecosites in Three Valley Confluence. A general pattern can be detected in the results. For ecosites with habitat effectiveness values at 50 % (AT1, AT3, and HD4), overestimating buffer distances may cause the results to be overestimated by 15 %. The model is less sensitive to underestimates of the buffer distances with results varying by 10 %. For ecosites in the 70 – 85 % habitat effectiveness range, the model is less sensitive to uncertainty, resulting in variations of approximately 5 % in either direction. The anomaly is VL3, ranging 10 % in either direction. While no new features were added to this ecosite, expanded buffers from adjacent ecosites into VL3 introduced disturbed areas to this ecosite. Finally, ecosites with habitat effectiveness in the 90 % ranged 2-3 % from results derived using default parameters.

Table 16. Range in habitat effectiveness outcomes for ecosite representation due to an increase and decrease of 50 % from the default disturbance buffer width. Only the ecosites most affected by changes in buffer width designation are included.

Ecosite Type	Ecosite Representation Habitat Effectiveness (%) (based on default parameter values)	Ecosite Representation Habitat Effectiveness Range (%) (buffer widths increased and decreased by 50 %)
AT1	56	48 – 65
AT3	55	47 – 69
FR1	75	70 - 82
HC4	93	82 - 99
HD1	82	78 - 87
HD2	94	92 -97
HD3	89	86 - 92
HD4	46	37 - 61
NY1	94	91 - 97
NY3	91	88 - 94
PT1	95	93 - 97
PT4	89	85 - 93
TZ1	98	90 - 100
VL1	95	92 - 97
VL3	79	69 – 89
VL5	95	93 - 97

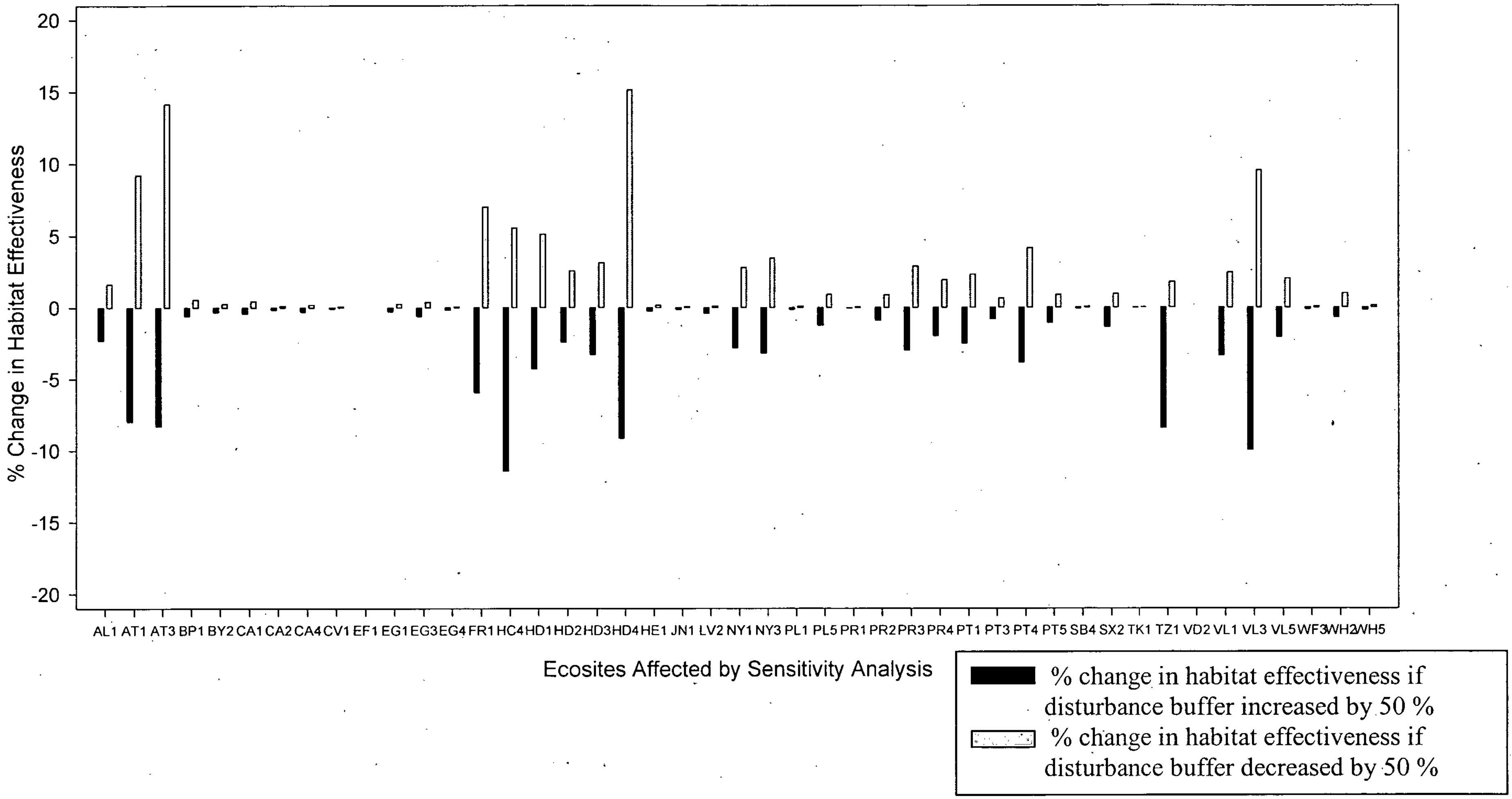


Figure 26. Sensitivity analysis for the disturbance buffer parameter in the Ecosite Representation Model. Disturbance buffers were increased and decreased by 50 %. Sensitivity analysis results are shown in comparison to habitat effectiveness results based on default values. Therefore, variation in habitat effectiveness is entirely attributable to changes in the disturbance buffer parameters only

Testing Disturbance Buffers for the Breeding Birds Habitat Effectiveness Model (Model 2)

Generally, the breeding bird model is less sensitive than the ecosite representation model to uncertainty in buffer width assumptions. Changing buffer widths by 50 % in either direction (default = 100 m, tests = 50 m & 150 m) results in habitat effectiveness values that vary up to 8 % from results based on default buffer distances. Table 17 summarizes the sensitivity of the model to uncertainty in the buffer width assumptions. Ecosite types with habitat effectiveness below 80 % (AT1, WH2, AT3 and HD4) vary up to 4 % from the default-based results. Within each ecosite type, patches contain varying degrees of land use and thus respond by different degrees to changes in the buffer widths. For individual ecosite patches, results vary up to 9 %.

For ecosite types with habitat effectiveness in the 80 – 90 % range, results vary at most by 8 %, and in the 90 % range results vary by 3 %. The exceptions are VL1 and VL3, where results vary up to 8 %. For some individual patches of VL1 and VL3, changes in the buffer widths resulted in habitat effectiveness values that varied up to 25 % from the default-derived values. Figure 29 shows that increasing buffer widths by 50 % results in values that vary less than those derived using a reduced buffer width. In other words, if I have underestimated buffers widths, and they are 50 % wider than the default parameters, habitat effectiveness values may be up to 5 % less than the model predicts. However, if I have overestimated buffer widths, the habitat effectiveness results may be as much as 8 % higher than the model predicts. Ecological uncertainty in defining disturbance buffers affects selected ecosites only, with habitat effectiveness varying by up to 18 %.

Table 17 Ecosites most affected by buffer width uncertainty for the breeding bird model.

Ecosite Type	Breeding Bird Habitat Effectiveness (%) (based on default parameter values)	Breeding Bird Habitat Effectiveness Range (%) (buffer widths increased and decreased by 50 %)
AT1	64	61 – 68
AT3	80	78 – 83
FR1	83	80 – 85
HD1	88	87 – 90
HD2	95	92 – 97
HD3	92	91 – 94
HD4	77	77 – 79
NY3	94	92 – 96
PT4	95	94 – 96
VL1	94	91 – 98
VL3	82	77 – 90
WH2	63	63 – 63

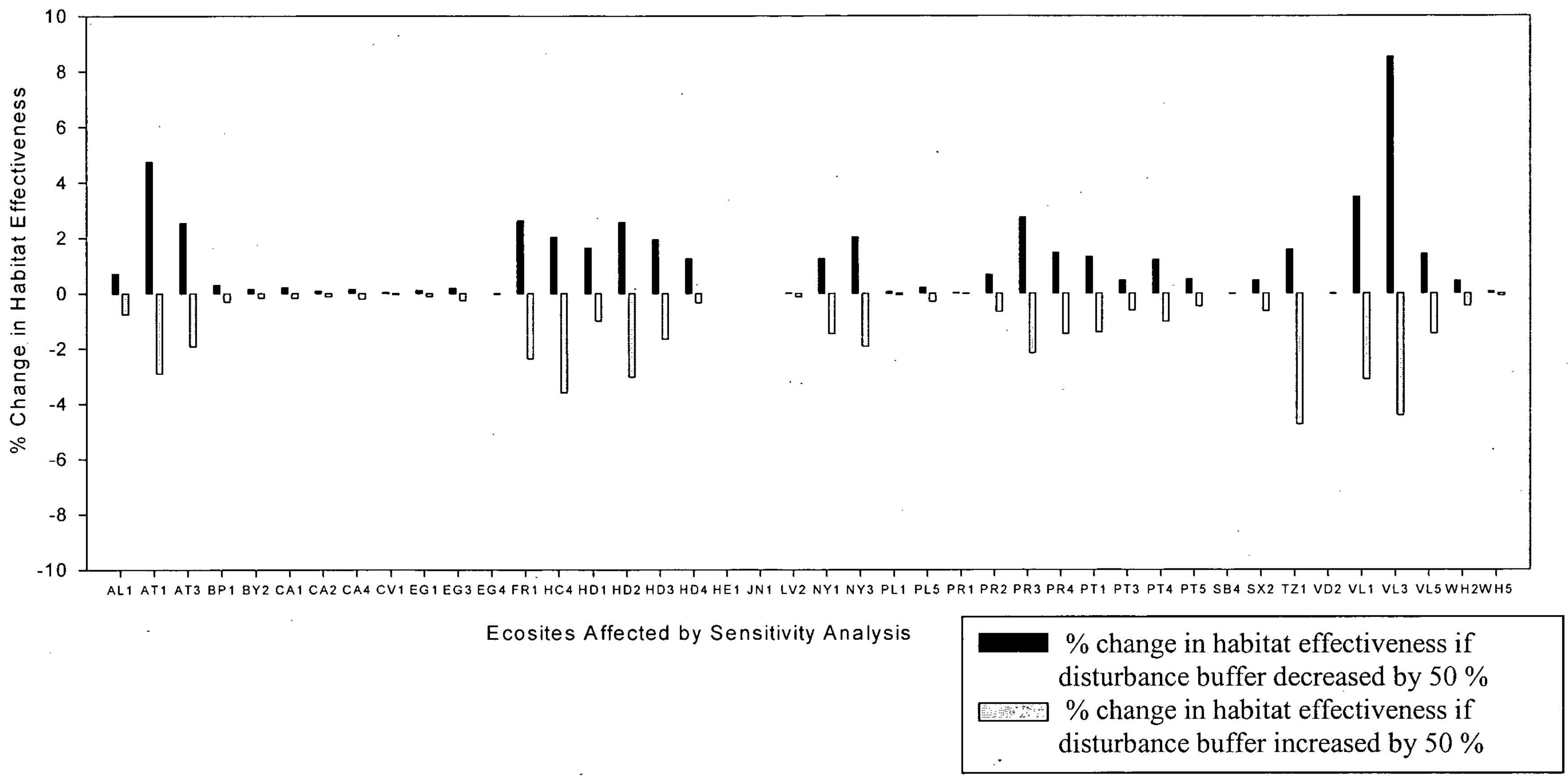


Figure 27. Sensitivity analysis for breeding bird disturbance buffers. Disturbance buffers were increased and decreased by 50 % . Sensitivity analysis results are shown in comparison to habitat effectiveness results based on default values. Therefore, variation in habitat effectiveness is entirely attributable to changes in the disturbance buffer parameters only.

Testing Coefficients of Disturbance in the Breeding Bird Habitat Effectiveness Model

This analysis was conducted to understand the influence of ecological uncertainty in the breeding bird classification of habitat effectiveness results for the model. The pattern identified in testing disturbance buffers also emerged in the sensitivity analysis for disturbance coefficients. Table 18 shows that ecosites with moderate to high accumulated land uses were affected the most by uncertainty in bird classification. In addition, the Breeding Bird Model is more sensitive to uncertainty in the number of birds displaced within a buffer, than to uncertainty in establishing the widths of the buffers.

The effect of overestimating and underestimating breeding bird sensitivity resulted in similar responses in the model (see Figure 28). The most significant results were found for AT1 and VL3. These two ecosite types contain relatively high levels of linear land uses (e.g. pipeline right-of-ways, powerlines, and roads). These features have relatively wide disturbance buffers associated to them. Therefore, changing the disturbance coefficient within these buffers (which represent a large proportion of the ecosite area) results in high levels of variation in habitat effectiveness for the ecosite as a whole. The sensitivity analysis indicates the model results respond linearly to incremental increases and decreases in the number of sensitive birds within buffers. An addition of 50 % to the number of birds displaced within a buffer results in an increased habitat effectiveness that is twice as great as a 25 % addition.

For ecosites with high levels of land use and low habitat effectiveness (AT1, HD4, WH2), results vary up to 7 % if the number of sensitive birds are decreased by 50 % and by up to 6 % if the number of sensitive birds is increased by 50 %. Ecosites in the 70 to 80 % habitat effectiveness range vary in either direction up to 9 %. For ecosites with habitat effectiveness above 90 %, sensitivity analysis results vary by about 3 %.

Table 18. Range in habitat effectiveness outcomes for breeding bird habitat due to an increase and decrease of 50 % from the default disturbance coefficient values. Only the ecosites most affected by changes in disturbance coefficients are included.

Ecosite	Breeding Bird Habitat Effectiveness (%) (based on default parameter values)	Breeding Bird Habitat Effectiveness Range (%) (Coefficients of Disturbance increased and decreased by 50 %)
AT1	64	58 – 71
AT3	80	76 – 84
FR1	83	80 – 86
HD1	88	86 – 91
HD2	95	93 – 97
HD3	92	90 – 94
HD4	77	74 – 80
NY3	94	91 – 96
PT4	95	93 – 96
VL1	94	91 – 97
VL3	82	73 – 90
WH2	62	62 – 64

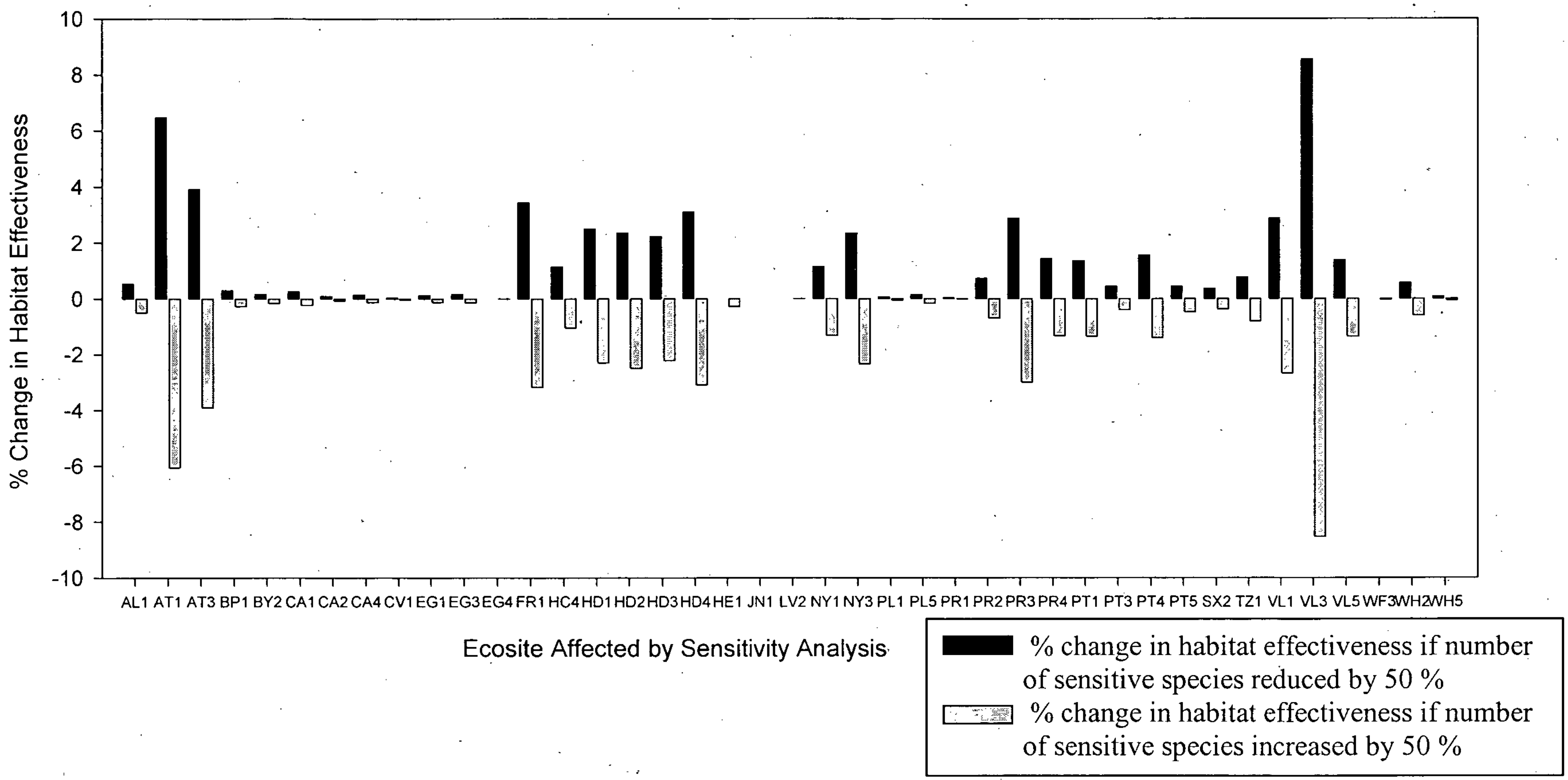


Figure 28. Sensitivity Analysis to determine the influence of ecological uncertainty in the breeding bird classification on habitat effectiveness results in the model. Sensitivity analysis results (increasing and decreasing the proportion of sensitive species in each ecosite type) are presented in comparison to results using the default parameters at the present level of human use. Any change is habitat effectiveness is due to uncertainty in the species sensitivity parameter. Uncertainty in bird classification affects habitat effectiveness results in some ecosites more than others.

Testing Responsiveness of Both Models to Changes in Land Use

I developed several land use scenarios to assess the relative impact of different land use features on the models and to investigate sensitivity in the models to specific patterns of use. Table 19 summarizes the land use scenarios and the insight each provides into the sensitivity of the model.

The removal of the warden office (scenario 1), a fairly isolated land use, increased habitat effectiveness for birds by 1.3 % and ecosite representation by 2.5 % in HD4. In contrast, in scenario 2, I removed a large lodge located in an area with high levels of remaining land use, and this resulted in only a 0.2 % gain for breeding bird habitat effectiveness. The removal of a random selection of feature types (scenario 6) also resulted in minimal gains in effectiveness. However, the elimination of a concentrated selection of features (scenario 5), or the removal of isolated polygon features increased habitat effectiveness values in several ecosite types. The removal of the road, fireroad and polygon features on the Benchlands in scenario 7 resulted in an 11 % (ecosite representation) and 5 % (breeding bird habitat) gain in overall effectiveness for the Patricia 4 ecosite type. The elimination of trails (scenario 8) has a negligible effect on habitat effectiveness for both models. In scenario 9, I removed all land use features that receive high levels of human use, yet are not completely developed (e.g. pyramid beach, campgrounds, airstrip). The habitat effectiveness results show that these features contribute to cumulative effects. By totally removing these features from the landscape, which assumes 100 % effectiveness for the habitat (which is unlikely because there are still high levels of human use), results vary at most by 12 % from the present level of human use. It is likely, sensitive birds are displaced from the habitat which is disturbed by campers, airplanes and picnickers. Therefore, these features likely do not exert a 12 % effect (predicted when the features are removed) which would be total loss of habitat, but also are not likely benign because activity alone may displace sensitive birds.

For the Breeding Bird Model, assessing gains at the scale of Three Valley Confluence and at the scale of the individual ecosite patch is required. At a finer scale, the ecosite patch of breeding bird habitat, several scenarios showed gains. For example, PT4 ecosite patches for the bench scenario (scenario 5) had their effective habitat increased by 13 % compared to a 5 % increase at the scale of Three Valley Confluence. While the concentrated removal of features in scenario 5 resulted in gains detectable at the scale of the study area, at the scale of the individual ecosite, an

11 % gain for a patch of AT1 and an 11 % gain for a VL3 resulted. Figure 29 illustrates scenario 5 in which land use features were removed from a patch of VL3. The map shows how the disturbance buffers from several features overlap. Therefore, removing a single feature may not ensure 100 % effectiveness of the habitat if the disturbance buffer of an adjacent feature still affects the habitat. Both models indicate that strategically removing land use features as well as associated or adjacent features (whose buffers overlap), results in greater changes than randomly removing dispersed land use features.

Table 19. Results of sensitivity analysis scenario runs for the breeding bird (BB) and ecosite representation (ER) models.

Scenario	Features removed	Appprox. Area of polygons	Gain in BB Habitat Effectiveness	Gain in ER Habitat Effectiveness	Remarks on Model Sensitivity
1. Remove warden office	Single polygon	0.04 km^2	1.3 % - HD4 •2.7% for the ecosite patch	2.5 % - HD5	Feature has no overlapping buffers from adjacent land uses because it is relatively isolated. • removing buffers results in gains even with a small feature changed.
2. Remove bungalow camp	Single polygon	0.025 km^2	0.3 % - PT4 •0.7% for the patch of PT4	0.3 % - PT4	Models are less sensitive when adjacent land uses (+ buffer) remain. • remaining buffer limits the habitat effectiveness gains.
3. Remove bungalow camp + road	Polygon + adjacent road	0.025 km^2 + 0.8 km road	0.6 % - PT4 •1.4 % for the ecosite	1.2 % - PT4	When the adjacent road was removed along with the buffer this allowed gains in habitat effectiveness from bungalow removal to be realized. • model is more sensitive to removal of many concentrated features.
4. Remove single feature	Single polygon	0.03 km^2	1.0 % - PT5 • (0.85 % for patch)	0.1 % - PT5	• While feature is only marginally smaller than warden office, only minor gains were made. Figure 30 shows why overlapping buffers reduce effectiveness.
5. Remove all features in area	Line,point, polygons high use area	0.15 km^2 + (powerlines and roads)	0.65 %- AT1 0.7 % - VL3 •11% gain in 2 patches of AT3 •14 % for VL3	1.2 % - AT1 1.2 % - VL3	Model is sensitive to the removal of all features from areas with highly concentrated land use (see Figure 29). • gains are higher for the area removed where richness is high and a where a high percentage of birds in buffer are sensitive (VL3).
6. Remove random selection of features	Single dispersed line, point, polygon	0.06 km^2 (lodge)	1.0 % - AT1 • 1.2% for a patch with habitat effect-ive ness of 30%	0.3 % - AT1	Models are not as sensitive to single land use removals in areas with highly concentrated human use. • overlapping buffers and coarse scale of mapping limit detection of gains in habitat effectiveness. Gain in AT1 is due to the removal of the lodge feature.
7. Remove all features from large area	All features from Bench	0.15 km^2 polygons + road, fireroad, powerline buffers)	4.8% - PT4 0.3% - PT1 0.3 % - BY2 0.2 % - NY3 0.1 % - EG3	11 % - PT4 1.0 % - PT1 0.5 % - BY2 0.6 % - NY3 0.3 % - EG3	Both models are responsive to the removal of features where the buffers overlap, especially for ecosite types that are limited in extent to the area (e.g. PT4). (12 % for a couple of PT4 patches and 18 % for a few PT1 patches and 1 % for a VL1 patch)
8. Remove trails only	2 single trails	No area, trails buffered only	no disturbance buffer for BB	0.3 % - PT1 0.2 % - VL5	Model is not sensitive to removal of trails. Scale not fine enough (at 1:50 000) to detect gains made in 1 m wide trail removals.
9. Remove features containing habitat	Land use features containing habitat	Land uses disturb habitat, but not complete loss:	6 % - AT1 7 % - AT3 5 % - FR1 12 % - HD4 1 % - VL3	6 % – AT1 11 % – AT3 5 % – FR1 12 % – HD4 1 % – VL3	If land use features that contain habitat (e.g. campgrounds and the airstrip) are removed from the landscape, this has an impact on several ecosite types. Impacts are limited considering removing the features assumes 100 % habitat effectiveness (which is unlikely because activity alone may displace birds).

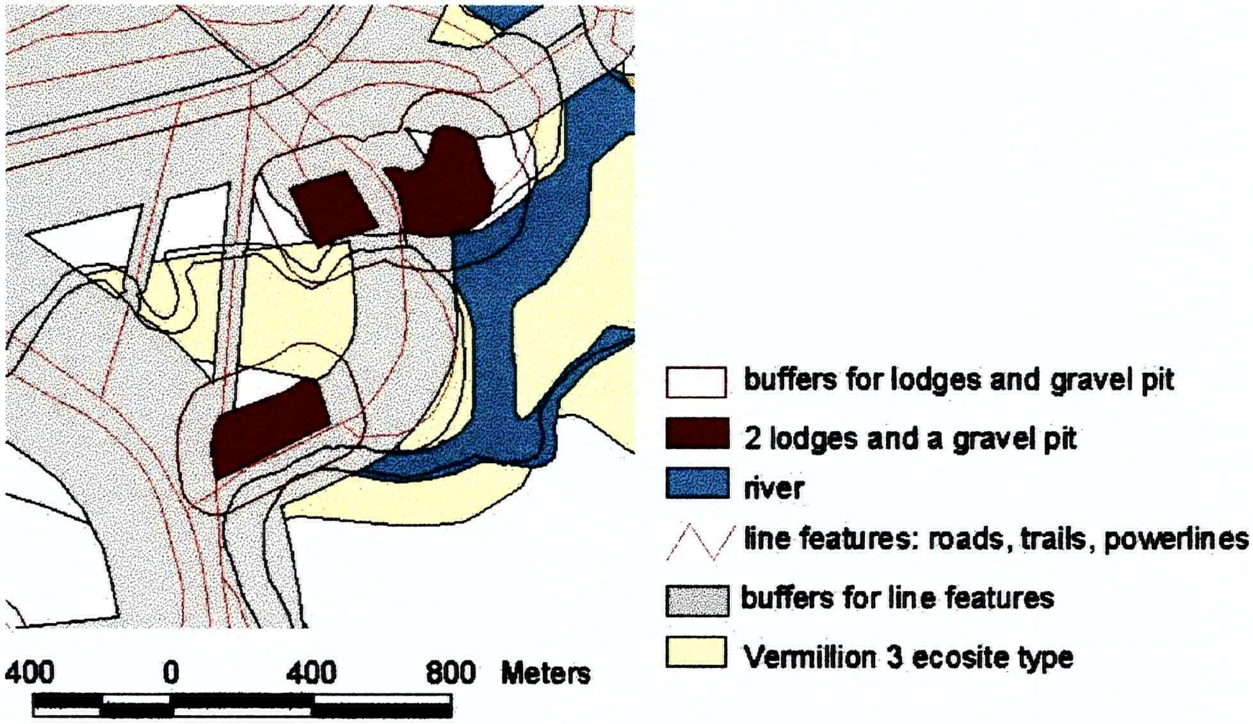


Figure 29. A visual display of the sensitivity analysis (scenario # 5) removing all the land use features within approximately a 1 km^2 area. This included two lodges, a gravel pit, roads, powerlines and trails. The major highway in the top left of the map was not removed.

6.4 Discussion and Summary

Testing Disturbance Buffers and Coefficients of Disturbance in the Models

Uncertainty in assigning buffer widths and coefficients impact the outcome of the model in selected ecosites only. Increasing and decreasing buffer widths affects the habitat effectiveness result. However, the variation in results does not obscure the general pattern indicating which ecosites are most affected by cumulative effects.

This sensitivity analysis identifies that the models are more sensitive to buffer width assumptions in ecosites with higher levels of land use. Further, the Ecosite Representation Model is more sensitive than the Breeding Bird Model to buffer width uncertainty. This is expected because the bird model assumes buffers still provide habitat for many tolerant bird species. In contrast, the ecosite model assumes disturbed habitat is no longer representative to any degree. While buffer widths are generally greater in the Breeding Bird Model than in the Ecosite Representation Model, they have a greater impact in the ecosite model because representation is entirely lost. Increasing a buffer by 50 % in the ecosite model results in total loss of representation in that area. Increasing buffers in the bird model displaces sensitive birds from the area, but still provides habitat for tolerant species. For the Ecosite Representation Model, mis-assigning buffer widths for the most impacted ecosite affects results up to 15 %. For an ecosite with an effectiveness of 46 % this means the effectiveness is between 37 % and 61 %. At best, the ecosite still remains within a value range that indicates cumulative effects. For ecosites with less land use, uncertainty in buffer assumptions causes less variation in the results.

For the Breeding Bird Model, uncertainty in sensitivity classifications introduced more variation in habitat effectiveness results than uncertainty in establishing buffer widths. However, even if the number of sensitive birds is overestimated or underestimated by 50 %, results for ecosites generally remain within the range (described in the following paragraph) predicted using the default coefficients.

To account for uncertainty in the models the sensitivity analysis indicates that the most meaningful way to communicate cumulative effects is as falling within a range rather than as a precise value. This reflects the uncertainty in the assumptions of both models. As such, we do not create an expectation of the accuracy or of knowledge that is not presently available. The following comments apply to ranges of habitat effectiveness values for both models:

90 – 100 % Uncertainty in buffer designation does not have a large impact on the results in this range. However, for the ecosite model, if buffers are greater than predicted in the model, ecosites with highly effective habitat may be affected if buffers from adjacent ecosite land uses extend into the ecosite.

80 – 90 % Effectiveness values in this range are the most robust to uncertainty in buffer width designation. Within this range, uncertainty in assumptions may result in effectiveness dipping just below 80 %.

70 – 80 % Increased or decreased buffer widths generally do not result in ecosites dropping outside the 70 - 80 % range.

< 70 % Several ecosites currently have default results in this range. Therefore, uncertainty in this range has a greater impact on the results, especially for the Ecosite Representation Model. Generally, if the models have overestimated buffer widths by 50 %, results remain below 70 %. Underestimating buffer widths by the same degree may reduce effectiveness values by up to 10 %.

The model results are robust for land use planning at the scale of Three Valley Confluence. At or below the scale of the ecosite patch, the model may be used to help define and describe current cumulative effect conditions for proposed projects. Given the impact of buffer width designations and disturbance coefficients in high land use ecosites, assessing the incremental cumulative effect of a single proposal may be subject to considerable uncertainty.

Testing Responsiveness of Both Models to Changes in Land Use

Land use scenarios aimed at increasing habitat effectiveness must involve land uses of a large size or involve the strategic removal of several features in combination to result in changes in the model outcomes. There are several reasons for this pattern. The removal of the bungalow camp (see Figure 30) illustrates the impact of disturbance buffers from adjacent land uses. When the bungalows were removed in scenario 2, the adjacent roadway still remained with its 100 m wide buffer overlaying the 'rehabilitated' area. With a coefficient in PT4 of 0.21, this means only 80 % of the birds in this ecosite are displaced. The disturbance buffer for both models continued to limit increases in habitat effectiveness made in removing the bungalow camp. As summarized in Figure 30, adjacent disturbance buffers limited habitat effectiveness gains for several scenarios in the sensitivity analysis.

The pattern that emerged in all the scenarios was that greater gains in habitat effectiveness were observed when concentrated land use features were removed than when dispersed features were randomly removed. The exception was the removal of the warden office, which resulted in gains in effectiveness due to the high value of the habitat as well as its isolated location. There were no disturbance buffers from adjacent land uses overlapping this area, which would have reduced any gains. Therefore, land use strategies should concentrate development and rehabilitation efforts to manage the impact of disturbance buffers. These results are also applicable in choosing sites for future land uses. By concentrating land uses, both in selecting the shape of a land use and its location, the buffer of a new development can be designed to overlap an existing buffer, thereby reducing the amount of new habitat disturbance.

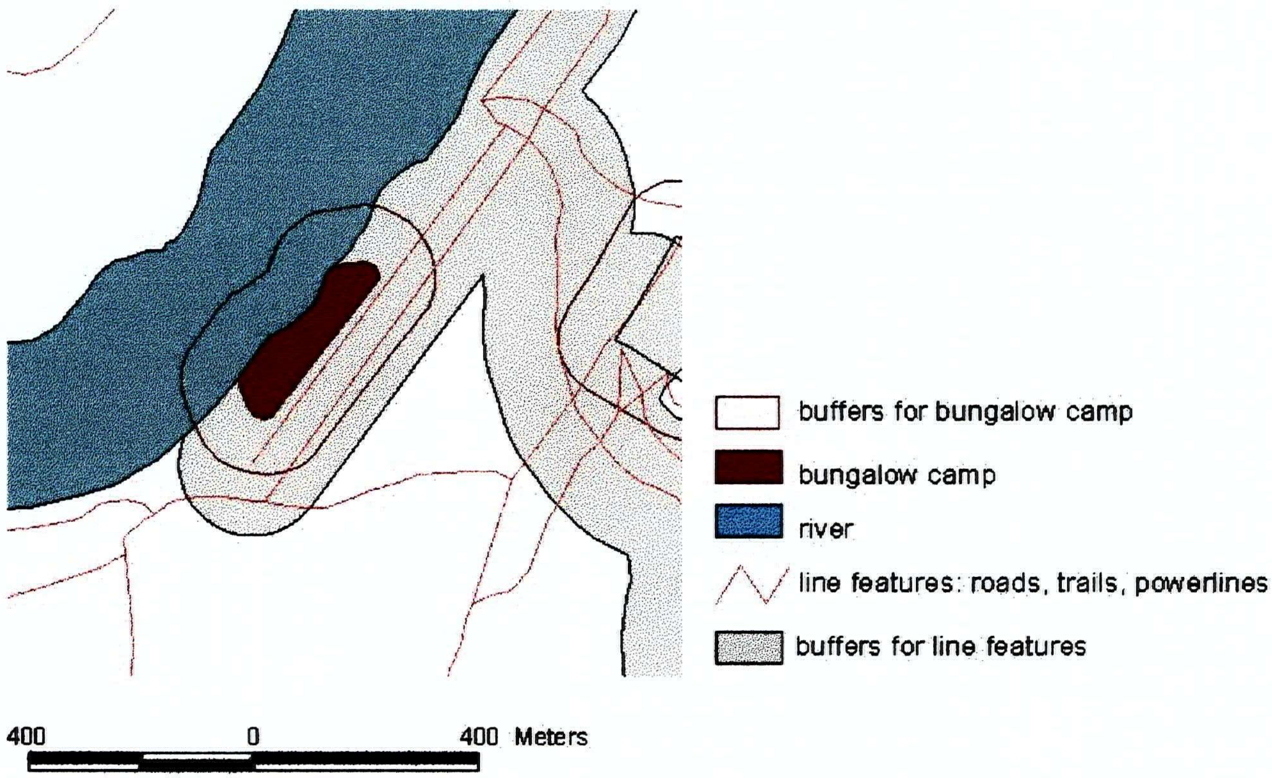


Figure 30. This figure depicts land use scenario 5. The buffers for the bungalow camp and access road overlap. Removing the bungalow camp alone does not remove the disturbance in the surrounding habitat because it is still influenced by the disturbance from the access road.

Caution should be used in evaluating gains in habitat effectiveness on a project-by-project basis. The model assumes rehabilitated habitat will return to the previously classified ecosite type. This likely depends on specific site conditions and the funding available for rehabilitation. Also, the scale of mapping can detect a minimum ecosite patch size of 35 ha. However, within this ecosite patch it is likely a mosaic of habitat types actually occur with the dominant type defining the classification. The lack of habitat classification to a finer scale within ecosites limits the utility of the model for project-by-project assessment. The coarse scale of mapping also introduces uncertainty issues related to buffers and the ability of the models to accurately represent buffer distances on the ground. At a 1:50 000 mapping scale, a 0.1 mm line on a map is equivalent to 5 m on the ground. With buffer zones of 9 m, the line delineating the buffer itself represents 5 m of habitat. Therefore, the ability of the model to represent loss in habitat effectiveness within these zones is seriously constrained. The buffer sensitivity analysis helps diffuse this problem somewhat. However, to improve the accuracy of the models, mapping Three Valley Confluence at a scale of 1:20 000 is necessary.

Given these concerns, and the findings of the sensitivity analysis, at the scale of Three Valley Confluence, but should be interpreted with caution for project-by-project assessment. The models are suitable for broad-based land use planning and for investigating and comparing gains in habitat effectiveness due to reduction in disturbance.

Summary

To conclude, the sensitivity analysis defined ranges in habitat effectiveness results that incorporate and communicate the uncertainty inherent within the models. The ranges are useful in interpreting cumulative effects results and reflect that these models are based on invalidated data. These ranges may be more clearly defined once model parameters are validated through data collection and testing buffer widths and coefficients in the park. The land use scenarios illustrate a principle that also became apparent when the Grizzly Bear Cumulative Effects Model was tested (Hood 1998). Removing several features in combination or single large features result in greater gains in habitat effectiveness than removing dispersed random land uses. Removing a feature while overlapping buffers from adjacent features remain limits potential gains in habitat effectiveness. Lastly, this analysis emphasized: 1) that both models are useful for land use planning at the scale of Three Valley Confluence; and 2) assessing the effect of accumulated land uses at the ecosite patch level for the Breeding Bird Model provides insight into strategies for managing the pattern of land use to minimize cumulative effects, but should be interpreted with caution due to resolution of mapping. For both models, project-by-project assessments are subject to higher levels of uncertainty.

Chapter Seven Recommendations and Conclusions

7.1 Introduction

> "When faced with complex systems, researchers and managers alike may respond by ignoring the complexity and seeking a simple solution, or by hiding behind the complexity and stating that a solution is not possible."
>
> Richard J. Hobbs, 1998

This chapter makes recommendations that stem from the data collection, model development process and cumulative effects analysis in light of the role of uncertainty and model sensitivity. The cumulative effects analysis demonstrated that failure to assess and act on cumulative effects of land use has resulted in losses in habitat effectiveness for breeding birds and reduced ecosite representation.

7.2 Recommendations for Managing Cumulative Effects in Three Valley Confluence

> "The future is not just what lies ahead; it is something that we create.'
>
> R.T.T. Forman and S.K. Collinge 1997.

This thesis provides an analysis of current cumulative effects in Three Valley Confluence. These results paint a picture of the impact of current land use and can be applied to land use decision making. The usefulness of these models in the future for assessing alternative land use strategies is dependent upon support for ecological validation, access to the models by decision-makers, and continued development of the Three Valley Confluence Cumulative Effects Framework. I suggest the following series of recommendations be considered in land use planning in the study area:

Manage Land Use to Minimize Potential and Existing Cumulative Effects

The results of the sensitivity analysis I conducted suggest that for management purposes, Parks Canada should use the four category system (<70%, 70-80%, 80-90% and 90-100%) rather than using integer values (82%) when expressing cumulative effects results for both ecological indicators. Due to uncertainty in both models stemming from resolution of mapping and ecological uncertainty in designating parameter values, using categories rather than integers better reflects the ability of the models to accurately evaluate cumulative effects on the ground.

Recommendation #1. Implement specific land use strategies and practices that will help minimize cumulative effects on ecosite representation and breeding bird habitat effectiveness.

Management of cumulative effects means both limiting land uses that may contribute an additional increment to cumulative effects, and reducing existing cumulative effects through reconfiguration of land uses and active rehabilitation. Land use proposals and planning should be considered in light of the following results from the cumulative effects analysis:

1. Six montane ecosite types have received a disproportionate impact on breeding bird habitat effectiveness in Three Valley Confluence: AT1, AT3, FR1, HD1, HD4, and VL3. Any proposals for future land use in these ecosites should be considered as additional incremental impacts to the current levels of habitat effectiveness

2. At the scale of the individual patch, many patches have lost over 20 % of their effectiveness due to land use within the ecosite. Proposals within an ecosite patch should consider the effect of: 1) adding another increment of impact to accumulated land use within the patch, 2) the richness and rarity of the ecosite type, and 3) the benefits of clustering development and overlapping buffer zones.

3. Cumulative effects have impacted several ecosite types that support the highest bird richness values in the park. Land use proposals in the following ecosites should be carefully assessed for their potential impact on bird rich habitat: VL3, VL1, NY3 and HD1 as they are the first, third, fourth and fifth most bird rich ecosites in the park and are already impacted by cumulative effects. In addition, several impacted ecosites in Three Valley Confluence support some of the highest densities of breeding birds in the park. In the montane these include: HD1, PT4, VL1, VL3 and VL5 (note several have the highest richness as well as the highest density).

4. The outcome of the ecosite representation model also applies for bird habitat. Richness is not the only objective in managing for bird habitat. Some ecosite types that are rare support a unique suite of breeding birds in the park (e.g. AT3, HD4).

5. Proposals for land use should be assessed based on the current levels (and future potential levels) of cumulative effects for ecosite representation, and for the significance of the contribution they make to park-wide representation.

    - The following eight montane ecosite types have habitat effectiveness values below 90 %: AT1, AT3, FR1, HD1, HD3, HD4, PT4, and VL3.

    - Of the eight impacted ecosite types, Three Valley Confluence (6% of the park) contains half the park-wide representation for AT1, AT3, and PT4.

    - Of the eight impacted ecosite types, HD4, AT3 and PT4 occur in less than 0.1 % of the park, making them among the 10 rarest ecosite types.

6. The sensitivity analysis demonstrates that land uses with overlapping buffers have less impact on representation than the same land uses that are dispersed. When widely separated, buffers exert their full effect on the ecosite. Both models are more responsive to strategies that remove a land use feature as well as associated or adjacent land uses rather than random single features. The following land use planning approaches could be undertaken to reduce cumulative effects in Three Valley Confluence.

    - Cluster development: Clustered development reduces the overall habitat disturbance due to buffers. However, the pattern of clustering is also important. Clustered development around an interior habitat patch may result in a patch too small to provide interior habitat for breeding birds, or clustering along a linear corridor may fragment habitat or impact movement patterns (Theobald 1997). In land use planning, the option of clustering development in an area should consider the breeding bird richness and ecosite rarity for ecosites receiving the land use as well as the current level of cumulative effects.

- Reduce access points: Results of the cumulative effects assessment show the pattern of land use in the study area to be defined by road access. As developments can be clustered, so too can roads. Several areas within Three Valley Confluence have more than one access point where only one is necessary (e.g. Highway 93a South between Cavell Warden Station and Geraldine Lakes Road parallels Highway 93 and Highway 93a North between Tekerra Lodge and Alpine Village parallels Highway 93). For these areas, access to the sites in the National Park can be maintained while reducing the number of linear developments in the study area that bring people to these points. Reducing roads in the montane is an important consideration in managing for cumulative effects.

- Promote protection of habitat within leaseholds: Breeding bird habitat and ecosite representation impacts may be reduced by creating incentives for leaseholders to protect remaining habitat (especially around edges) within leaseholds (e.g. economic incentives to limit development, rehabilitation programs).

Recommendation # 2. Establish Management Thresholds:

Thresholds are limits beyond which a cumulative impact may cause a collapse, permanent loss or flip in a system (Hegmann et al. 1999). Unfortunately, we often only know the threshold for a system once it has been crossed. It is useful in decision making to establish threshold targets by which an incremental impact can be compared. Thus, if the accumulated effects of all actions within a region do not exceed the target, the cumulative effects of a project may be deemed to be acceptable (Ibid.). However, objective techniques for determining appropriate thresholds are lacking. A number of methods have been relied upon to establish thresholds for study areas including professional or expert judgement and consultation among stakeholders, agencies and experts (Ibid.).

Improve Understanding of Cumulative Effects and Reliability of Model Results

Recommendation # 3. Parks Canada should continue to develop the Three Valley Confluence Cumulative Effects Framework through the selection of additional indicators, monitoring and model validation.

Parks Canada has undertaken a method to assess cumulative effects using a hierarchical approach to select indicators. This requires selecting indicators and developing methods to assess cumulative effects at multiple levels of biological organization. Development of the Breeding Bird Model and Ecosite Representation Model are a part of developing this framework. While Parks Canada has selected additional indicators at different levels of biodiversity with some methods developed, continued commitment to completing and implementing this framework is needed to provide a scientific basis for land use decision making.

Recommendation #4. Consider ecosite mapping in Three Valley Confluence at a scale of 1:20 000 to improve accuracy of these models and for potential assessment of cumulative effects on a project-by-project basis.

Recommendation # 5. Develop research projects to validate the assumptions in the Breeding Bird and Ecosite Representation Models.

Several assumptions in the breeding bird model require validation. The data for both models are from the early 1980s. Future research could re-survey the breeding bird transect reference sites to compare bird richness in relation to disturbance over a fixed time period. In addition, research is required to validate the buffer distances by land use feature, the classification of breeding birds for their sensitivity to land use and human activity and the breeding bird richness by ecosite data. For the ecosite model, the buffer distances as well as an update through field-checking of the original Ecological Land Classification would improve certainty in the model.

Integrate the Models into Existing Planning Processes

Effective management of cumulative effects requires a clear commitment to the environmental assessment process and managing land use in the park for ecological integrity. Cumulative effects assessment has been established by Parks Canada in the Park Management Planning Process and under the *Canadian Environmental Assessment Act* both as a proactive planning tool and as a requirement for environmental assessment. To continue to meet cumulative effects responsibilities, Parks Canada could adopt the following recommendations.

Recommendation # 6. Use the models to set the context for cumulative effects and then identify potential incremental effects of new project proposals.

Recommendation #7. Use the model results in the context of the Cumulative Effects Assessment Framework to inform the Park Management Planning Processes.

7.3 Reviewing the Research Objectives

In this section, I revisit the four research objectives presented in Chapter 1 and summarize my research findings.

Objective #1: To assess and analyze ecological concepts guiding cumulative environmental effects assessment, and in particular the selection and use of ecological indicators.

Objective # 2: To select ecological indicators that support the existing framework for cumulative effects assessment and describe a measurable relationship between human use and the response of the indicators.

The first objective of completing a literature review ensured that the second objective of selecting indicators and describing the relationship between the indicator and cumulative effects was based on the best available information and current understanding. The literature review guided the selection of breeding bird habitat and ecosite representation as indicators of ecological integrity. The indicators were selected to assess the overall status of biodiversity. These indicators complement existing indicators in Three Valley Confluence by representing levels of organization for biodiversity not currently included in the cumulative effects assessment framework. By selecting indicators based on the characterization of biodiversity, these indicators also support Parks Canada's approach for monitoring ecological integrity (Woodley 1993). While the Grizzly Bear Model assesses the impact of cumulative effects at the species-population level, the breeding bird habitat and ecosite representation are indicators that occur at the community and landscape levels respectively. Finally, current methods for cumulative effects assessment were adopted in developing the measurable relationship between the response of the indicators and land use. The models were designed to measure the impact of accumulated diverse land uses and stresses on processes of habitat loss and disturbance. They support a framework for integrating information about ecosystem components and human uses over spatial and temporal time scales. Their value is limited completely by the accuracy and availability of relevant and reliable data and the state of our knowledge about the likely behaviour of systems and ecological indicators under stress.

Objective # 3: To develop tools, namely the Ecosite Representation Model and the Breeding Bird Habitat Effectiveness Model, to portray indicator-cumulative effects relationships that: 1) are sensitive to cumulative effects at the scale of Three Valley Confluence, 2) are scientifically defensible, 3) allow for the repeated assessment of cumulative effects of current and alternative land use scenarios, 4) are operationally feasible, and 5) enable ecological validation to be carried out.

My second objective set a standard for the models. The models measure the impact of accumulated land use on the ecological indicators through a measurable relationship that compares the potential state of the indicator to the realized state once cumulative impacts have been applied. Existing models such as the Grizzly Bear Model already assess these impacts. However, the Grizzly Bear Model is not sensitive to land use changes at landscape scales as small as Three Valley Confluence. The results of the sensitivity analysis show that both models developed in this thesis meet the standard of being sensitive to accumulated land uses at the scale of Three Valley Confluence. While the mapping scale introduces uncertainty into the results, use of the models is appropriate for describing the current impact of accumulated land uses and for assessing land use planning alternatives at the scale of the study area. Although uncertainty increases at the scale of the ecosite patch, the models can provide the context for potential project-by-project incremental impacts. However, I caution that because the analysis is based on a 1:50 000 scale of mapping, the data may not be sufficiently accurate to predict project-by-project impacts.

My second standard was that the models be scientifically defensible. Both models are based on a combination of habitat and wildlife data collected in the study area and on a series of assumptions and parameters grounded in the scientific literature. The assumptions in the model are explicit. I have documented the references in the literature supporting each default parameter and have ensured that the model can be updated as new information becomes available. Finally, through the sensitivity analysis I tested how robust the results are given uncertainty in the parameters. Accordingly, the cumulative effects results have been communicated in a way that takes this uncertainty into account by establishing ranges of impact rather than precise values.

Standards three and four are related and have been addressed in the design of the model. The GIS enables the generation and evaluation of multiple land use scenarios. The models are flexible, allowing for the continued production of alternative development scenarios to examine the sensitivity of the models to uncertainty, and also to identify relationships between management actions and impacts. This flexibility in the models emphasizes the use of experience and the best available information to make decisions incrementally, and to feed back new knowledge about the system to inform future decisions. The results are displayed spatially in map form, providing a visual method for communicating complex interactions and comparing the cumulative impacts of different land use scenarios. The user interface makes the models accessible to non-GIS experts with a user and system guide to help ensure access by decision-makers once development is complete.

Lastly, by explicitly stating the assumptions and basis for the parameters, they can be validated through data collection in the park. Research projects designed to test the parameters, such as the buffer distance for a cabin, can result in updates to the models.

Objective #4: To assess the cumulative impact of present land use and alternative scenarios on the ecological indicators and present recommendations for management.

I completed a cumulative effects analysis of the impact of the current land use in Three Valley Confluence using both models. The results show that accumulated land use has impacted both indicators of ecological integrity. At the scale of Three Valley Confluence, several ecosite types have lost from 20 % to 60 % of their effective representative habitat due to direct loss and disturbance. A portion of these ecosites are either rare in Jasper National Park or are limited in extent to Three Valley Confluence. Breeding bird habitat has been impacted by cumulative effects as well. Eight montane ecosite types have lost from 20 % to 50 % of their effective habitat at the scale of the study area. A subset of these ecosite types support the highest levels of bird richness in the park, while two provide relatively rare breeding bird habitat.
In developing and testing alternative land use configurations, a feature of significant size or several features in a concentrated area had to be removed before changes in habitat effectiveness and representation could be detected in the models. This highlighted the importance of strategic land use planning based on clustered development and reduced access points.

7.4 CONCLUSION

The purpose of this research was to develop methods for cumulative effects assessment and to assess present cumulative effects on two indicators of ecological integrity: ecosite representation and breeding bird habitat effectiveness. Currently, land use in Three Valley Confluence is having a cumulative effect on the two indicators, focused primarily in eight montane habitat types. I suggested several strategies Parks Canada can adopt to manage the cumulative impacts of land use to improve conditions for these indicators of ecological integrity. Strategies include eliminating duplicate access roads for park destinations, clustering development and activities, rehabilitating areas, and ensuring development does not continue in habitat types already impacted by cumulative effects. A sensitivity analysis indicates the models are useful for considering cumulative effects at the scale of the study area. However, caution should be taken in interpreting results for project-by-project assessments. The models can be strengthened through validation of ecologically-based parameters, mapping at a finer resolution and continued development of additional and complementary ecological indicators for the cumulative effects framework.

Increasingly, ecosystem science-based decision making is expected in protected areas. As I discussed in the introduction, with increasing human population levels and consumption trends, protected areas are seen by many biologists as the most secure option for protecting biodiversity. However, protected areas need to be large enough (or linked) to preserve ecological processes and an area's top carnivores. In addition, as the primary mandate of Parks Canada suggests, human activities need to be managed toward ensuring species and processes are unimpaired by human-caused stresses. New partnerships between resource planners and conservation biologists are emerging to take ecological knowledge and effectively apply it to implement real change on the ground for biodiversity protection. Development of the cumulative effects models in this thesis are borne from this trend. Planning tools, such as the ones in this thesis attempt to address a mis-match of scales. They allow decision-makers to consider land use proposals on more ecologically appropriate time scales, at regional levels, and in relation to other disturbances on the landscape. With an assessment of their utility and results, these models provide Jasper National Park with additional tools to predict the ecological impact of land use decisions, and take action to maintain ecological integrity.

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APPENDIX I ECOSITE CODES AND NAMES

Table 20. The code for each ecosite name relates to the ecosection to which it belongs.

Ecosection Name	Code for Ecosites
Altrude	AL
Athabasca	AT
Azure	AZ
Baker Creek	BK
Boulder	BP
Bow Summit	BS
Bow Valley	BV
Bryant	BY
Cavell	CA
Consolation	CV
Copper	CP
Cyclone	CN
Eiffel	EF
Endless Chain	EG
Eygpt	EN
Fairview	FR
Fireside	FV
Garonne	GA
Goat	GT
Heather	HE
Hector	HC
Hillsdale	HD
Ishbel	IB
Jonas	JN
Katherine	KA
Larch Valley	LV

Ecosection Name	Code for Ecosites
Merlin Castle	MC
Molar Pass	MP
Moraine	M
Mosquito	MQ ML
Nigel	NG
Norquay	NY
Num-ti-jah	NT2
Panarama	P PR2
Patricia	PT
Peyto Lake	PL
Pipestone	PP
Redoubt	RD
Rock	R RG
Sawback	SB
Snowflake	SF
Sphinx	SX2
Spray	SP
Talbot	TA
Tekarra	TK
Tyrrell	TR
Verdant	VD
Vermillion	VL
Warwick	WW
Water	ZZ
Whitehorn	WH
Wildflower	WF W

Miscellaneous Landscapes (not surveyed for breeding birds) : Colluvial Landslide (CL), Colluvial Rubble (CR), Glacier (GL), Recent Moraine (M), Pits (P), Rockland (R), Rock Glacier (RG), Recent Stream Channel (SC), Talus (T)

APPENDIX II CLASSIFICATION OF BREEDING BIRDS

Table 1: Classification of breeding birds for sensitivity to human-caused disturbance for Jasper National Park.

species	name	edge sensitive	forest interior	habitat specialist (other than edge/interior)	habitat generalist	disturbed by human activity	listed in Alberta	result
ALFL	ALDER FLYCATCHER	unk	unk	unk	unk	unk	n	not sensitive (unk)[1]
AMKE	AMERICAN KESTREL	n	n	n	n	n	n	not sensitive[2]
AMRE	AMERICAN REDSTART	y	n	n	n	y	n	sensitive[3]
AMRO	AMERICAN ROBIN	n	n	n	y	n	n	not sensitive[2, 4]
AMWI	AMERICAN WIGEON	n	n	n	n	n	n	not sensitive[2, 4]
BAEA	BALD EAGLE	n	n	n	n	y	yellow B	sensitive[2, 5 6]
BAGO	BARROW'S GOLDENEYE	n	n	n	n		n	not sensitive[2, 4]
BEKI	BELTED KINGFISHER	n	n	unk	n	y	n	sensitive[7]
BLCH	BLACK CAPPED CHICKADEE	n	n	n	n	n	n	not sensitive[8]
BLGR	BLUE GROUSE	n	n	n	n	n	n	not sensitive[2]
BLMA	BLACK-BILLED MAGPIE	n	n	n	y	n	n	not sensitive[2, 4]
BLSW	BLACK SWIFT	n	n	y (canyons)	n	unk	yellow B	sensitive[9, 6]
BLTE	BLUE-WINGED TEAL	n	n	n	n	y	n	sensitive[2]
BNSW	BARN SWALLOW	n	n	n	n	n	n	not sensitive[2, 4]
BOCH	BOREAL CHICKADEE	unk	y	unk	n	unk	n	not sensitive[2, 4]
BOOW	BOREAL OWL	unk	y	us forest service	n	unk	yellow B	sensitive[5, 6, 10]
BOWA	BOHEMIAN WAXWING	n	n	n	n	n	n	not sensitive[2, 4]
BPWA	BLACKPOLL WARBLER	unk	y	unk	n	unk	n	sensitive[2, 4]
BRBL	BREWER'S BLACKBIRD	n	n	n	y	n	n	not sensitive[2, 4]
BRCO	BROWN COWBIRD	n	n	n	y	n	n	not sensitive[5, 11]
BRCR	BROWN CREEPER	y	y	n	n	unk	yellow B	sensitive[2, 6, 5]
BRSP	BREWER'S SPARROW	unk	unk	unk	unk	unk	yellow B	not sensitive[2, 6, 4]
CAGO	CANADA GOOSE	n	n	n	n	n	n	not sensitive[2, 4]
CAHU	CALLIOPE HUMMINGBIRD	n	n	n	n	n	n	not sensitive[5, 12]
CEWA	CEDAR WAXWING	n	n	n	unk	n	n	not sensitive[13]
CHSP	CHIPPING SPARROW	n	n	n	unk	n	n	not sensitive[14]
CLNU	CLARK'S NUTCRACKER	n	n	n	y	n	yellow B	not sensitive[2, 6, 5]
CLSP	CLAY-COLOURED SPARROW	n	n	n	n	n	yellow A	sensitive[5, 6, 15]

species	name	edge sensitive	forest interior	habitat specialist (other than edge/interior)	habitat generalist	disturbed by human activity	listed in Alberta	result
CLSW	CLIFF SWALLOW	n	n	n	n	n	n	not sensitive[16]
COCR	COMMON CROW	n	n	n	y	n	n	not sensitive[2, 4]
COFL	COMMON FLICKER	n	n	n	n	n	n	not sensitive[17]
COHA	COOPER'S HAWK	unk	unk	unk	unk	y	cosewic/yellow B	sensitive[5, 6, 18]
COLO	COMMON LOON	n	n	n	n	y	y	sensitive[2, 19]
COME	COMMON MERGANSER	n	n	y	n	y	n	sensitive[2, 4, 61]
CONI	COMMON NIGHTHAWK	n	n	y	n	y	n	sensitive [2, 60]
CORA	COMMON RAVEN	n	n	n	y	n	n	not sensitive[2, 4]
COSN	COMMON SNIPE	n	n	n	n	n	n	not sensitive[2, 4]
COYE	COMMON YELLOWTHROAT	n	n	n	n	n	n	not sensitive[2, 4]
DAJU	DARK-EYED JUNCO	n	n	n	y	n	n	not sensitive[2, 4]
DIPP	AMERICAN DIPPER	n	n	y	n	y (water quality)	yellow B	sensitive[5, 6, 20]
DOWO	DOWNY WOODPECKER	n	n	n	n	n	n	not sensitive[2, 4]
DUFL	DUSKY FLYCATCHER	n	n	n	n	n	n	not sensitive[21]
EAKI	EASTERN KINGBIRD	n	n	n	n	n	n	not sensitive[22]
EVGR	EVENING GROSBEAK	y	y	n	n	n	n	sensitive[2, 4, 60]
FOSP	FOX SPARROW	n	n	n	n	n	n	not sensitive[2, 4]
GOEA	GOLDEN EAGLE	n	n	unk	n	y	yellow B	sensitive[2, 5, 6]
GOKI	GOLDEN-CROWNED KINGLET	y	y	unk	n	n	n	sensitive[5, 23]
GOSH	GOSHAWK, NORTHERN	unk	y	unk	unk	y	yellow B	sensitive[5, 6, 24]
GOSP	GOLDEN-CROWNED SPARROW	n	n	n	n	n	yellow B	not sensitive[2, 4, 5, 6, 61]
GRFI	GRAY-CROWNED ROSY FINCH	n	n	n	n	n	n	not sensitive[2, 4]
GRJA	GRAY JAY	n	n	n	yunk	n	n	not sensitive[2, 4, 25]
GRTE	GREEN-WINGED TEAL	n	n	n	n	n	n	not sensitive[2, 4, 60]
GRYE	GREATER YELLOWLEGS	n	n	y	n	y	n	sensitive[2, 4, 60]
HADU	HARLEQUIN DUCK	n	n	y	n	y	yellow A	sensitive[5, 6, 9, 60]
HAFL	HAMMOND'S FLYCATCHER	y	y	n	n	n	n	sensitive[5, 26, 60]
HAWO	HAIRY WOODPECKER	n	n	n	n	n	n	not sensitive[2, 4, 60]
HETH	HERMIT THRUSH	y	y	n	n	n	n	sensitive[5, 27]
HOLA	HORNED LARK	n	n	y	n	unk	N	sensitive[28, 60]
KILL	KILLDEER	n	n	n	n	unk	n	sensitive[2, 4, 60]
LEFL	LEAST FLYCATCHER	n	n	n	n	n	n	not sensitive[29]

species	name	edge sensitive	forest interior	habitat specialist (other than edge/interior)	habitat generalist	disturbed by human activity	listed in Alberta	result
LESP	LECONTE'S SPARROW	n	n	y	n	unk	n	not sensitive[30, 60]
LISP	LINCOLN'S SPARROW	n	n	n	n	n	n	not sensitive[31]
MALL	MALLARD	n	n	n	n	n	n	not sensitive[2, 4]
MAWA	MAGNOLIA WARBLER	unk	y	n	n	unk	n	sensitive[32]
MCWA	MACGILLIVARY'S WARBLER	n	n	n	n	unk	n	sensitive[33]
MOBL	MOUNTAIN BLUEBIRD	n	n	n	n	n	n	not sensitive[34]
MOCH	MOUNTAIN CHICKADEE	n	n	n	n	n	n	not sensitive[2, 5]
MODO	MOURNING DOVE	n	n	n	n	y -may not breed	n	sensitive (check)[35, 60]
NOWA	NORTHERN WATERTHRUSH	n	n	N	n	n	n	sensitive[5, 36, 60]
NOWO	NORTHERN 3-TOED WOODPECKER	n	y	n	n	n	unk	sensitive (check)[2, 4, 5, 60]
OLFL	OLIVE-SIDED FLYCATCHER	n	n	n	n	n	n	not sensitive [2, 4, 5]
ORWA	ORANGE CROWNED WARBLER	n	unk	N	n	n	n	not sensitive [5, 37, 60]
OSPR	OSPREY	n	n	n	n	y	yellow B	sensitive[2, 4, 5, 6]
PIGR	PINE GROSBEAK	n	n	n	n	n	n	not sensitive[2, 4, 5]
PISI	PINE SISKIN	n	n	n	y	n	n	not sensitive[38]
PIWO	PILEATED WOODPECKER	n (with good nest trees)	n	n	n	n	yellow B	not sensitive (JNP)[2, 5, 6, 39, 60]
PUFI	PURPLE FINCH	n	n	n	n	n	n	not sensitive[2, 4, 40]
PYOW	PYGMY OWL	unk	y	unk	n	unk	n	sensitive[2, 4, 5]
REBL	RED-WINGED BLACKBIRD	n	n	n	n	n	n	not sensitive[41]
RECR	RED CROSSBILL	n	n	n	n	n	n	not sensitive[42]
REGR	RED-NECKED GREBE	unk	unk	unk	unk	unk	yellow A	sensitive[2, 4, 6]
REHA	RED-TAILED HAWK	n	n	n	n	y	n	sensitive[43, 60]
RENU	RED-BREASTED NUTHATCH	y	y	n	n	n	n	sensitive[5, 60]
REVI	RED-EYED VIREO	unk	unk	n	n	n	n	sensitive[2, 4, 5]
RIDU	RING-NECKED DUCK	n	n	y	n	unk	N	sensitive (howunk)[2, 4, 44, 60]
RUGR	RUFFED GROUSE	n	n	n	n	n	n	not sensitive[2, 4]
RUHU	RUFOUS HUMMINGBIRD	n	n	n	n	n	n	not sensitive[2, 4, 45]
RUKI	RUBY-CROWNED KINGLET	unk	y	n	n	n	n	not sensitive[2, 4, 46]
SASP	SAVANNAH SPARROW	n	n	n	n	n	n	not sensitive[2, 4, 47]
SHHA	SHARP-SHINNED HAWK	n	n	n	n	n	n	not sensitive[2, 4]
SORA	SORA	n	n	y	n	y	n	sensitive[48, 60]

species	name	edge sensitive	forest interior	habitat specialist (other than edge/interior)	habitat generalist	disturbed by human activity	listed in Alberta	result
SOSA	SOLITARY SANDPIPER	n	n	y	n	y	n	sensitive[2, 4, 49, 60]
SOSP	SONG SPARROW	n	n	n	n	n	n	not sensitive[2, 4]
SOVI	SOLITARY VIREO	n	n	n	n	n	n	not sensitive[2, 4, 5]
SPGR	SPRUCE GROUSE	n	n	n	n	n	n	not sensitive[2, 4, 50]
SPSA	SPOTTED SANDPIPER	n	n	n	n	n	n	not sensitive[51]
STAR	STARLING	n	n	n	y	n	n	not sensitive[52]
SWTH	SWAINSON'S THRUSH	unk	y	n	n	n	n	sensitive[2, 4]
TEWA	TENNESSEE WARBLER	n	n	n	n	n	n	not sensitive[222, 4, 60]
TOSO	TOWNSEND'S SOLITAIRE	n	n	n	n	n	n	not sensitive[2, 4, 53]
TOWA	TOWNSEND'S WARBLER	unk	y	n	n	n	yellow B	sensitive[2, 4, 5, 6, 60]
TRSW	TREE SWALLOW	n	n	n	n	n	n	not sensitive[2, 4, 54]
VATH	VARIED THRUSH	unk	y	n	n	n	n	sensitive[2, 4, 5, 60]
VESP	VESPER SPARROW	n	n	n	n	n	n	not sensitive[2, 4]
VISW	VIOLET-GREEN SWALLOW	n	n	n	n	n	n	not sensitive[2, 4, 5, 55]
WAPI	WATER PIPIT	n	n	y	n	unk	N	sensitive[2, 4, 60]
WAVI	WARBLING VIREO	n	n	n	n	n	n	not sensitive[2, 4]
WCSP	WHITE-CROWNED SPARROW	n	n	n	n	n	n	not sensitive[2, 4, 56, 60]
WEFL	WESTERN FLYCATCHER	unk	n	y	n	n	yellow B	sensitive[2, 4, 6, 60]
WEPE	WESTERN WOOD PEEWEE	n	n	n	n	n	n	not sensitive[2, 4]
WETA	WESTERN TANAGER	unk	y	n	n	n	yellow B	sensitive[2, 4, 5, 6, 60]
WHCR	WHITE-WINGED CROSSBILL	n	unk	unk	n	n	n	not sensitive[2, 4, 57]
WHPT	WHITE-TAILED PTARMIGAN	n	n	y	n	n	n	sensitive[58, 60]
WIFL	WILLOW FLYCATCHER	n	n	n	n	n	n	not sensitive[2, 4, 5]
WIPT	WILLOW PTARMIGAN	n	n	y	n	n	n	sensitive[2, 4, 60]
WIWA	WILSON'S WARBLER	n	n	n	n	n	n	not sensitive[2, 4]
WIWR	WINTER WREN	n	n	n	n	n	n	not sensitive[2, 4, 5, 60]
WTSP	WHITE-THROATED SPARROW	n	n	n	n	n	n	not sensitive[2, 4, 59]
YESA	YELLOW-BELLIED SAPSUCKER	n	n	n	n	unk	n	not sensitive[2, 4]
YEWA	YELLOW WARBLER	unk	unk	N	n	n	n	not sensitive[2, 4]
YRWA	YELLOW-RUMPED WARBLER	n	n	n	n	n	n	not sensitive[2, 4]

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APPENDIX III ECOSITE REPRESENTATION AND BREEDING BIRD APPLICATION USER GUIDE

Ecosite Representivity and Breeding Bird Application

Version 1

User Guide

The Forestry Corp.
for

Jasper National Park
April 1999

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1. Introduction

The detection and management of cumulative effects is an important issue in Jasper National Park, particularly in the high use area around the townsite of Jasper called the ' Three Valley Confluence'. As a result, park staff have initiated the "Three Valley Confluence" Project which involves the design of a working cumulative effects framework which will use ecological indicators, social indicators and science to predict the consequences of proposed projects or activities. This framework will enable the consideration of environmental effects among projects when they interact and accumulate at the landscape scale, and against measurable criteria or thresholds.

In 1997, development began on a set of GIS applications to address the requirement for a suite of tools and indicators of compositional, structural and functional biodiversity at multiple levels of organization. Breeding bird richness and ecosite representation were selected as indicators to represent community and ecosystem levels of organization respectively and development of an appropriate GIS application began in 1998. The two models to be included in the application were:

1. Breeding bird habitat effectiveness – an analysis of the potential bird richness and human activities to determine the realized ability of an ecosite type to support the potential suite of breeding bird.
2. Ecosite representation – an analysis of the potential ability of a specific habitat area to represent an ecosite type compared to the realized ability once human use is accounted for. The output from this model is in the form of a comparison between the potential and realized contributions of ecosites within the selected study area to Banff and Jasper National Parks.

It is important to note that this document is meant to be a guide to using the breeding bird/ecosite representivity application and does **not** provide a detailed description of the models themselves or how they were developed. For more information regarding the models please refer to the documents listed in the reference section of this document.

2. Application Process

2.1 Overview

The breeding bird/ecosite representivity application is based on the concept of 'projects'. A **project** consists of one run of each of the models on a single set of data and parameters (this could also be called a 'scenario'). The models can be run in any order and need not necessarily be run within a given time period. A particular project can be dropped at any time then reinitiated and completed at a later date.

The application is designed to be as flexible as possible in terms of model parameters. Most of the parameters used, such as buffer distances, have default settings which can be changed by the user. This allows the application to adapt to changes in the models themselves and provides the user with a way to test the sensitivity of each parameter. As well, this flexibility means that the application can be used in other jurisdictions where model parameters may be different from Jasper National Park. However, **users should be aware of the consequences of changing model default parameters and the effect it may have on the validity of the results. In most cases the default model parameters should be used**. In general, the user will change the input data rather than the parameters to test various scenarios.

Specific parameter settings are not saved until a model has been run. Once a model has been run all inputs and parameters, including those displayed in the status box, are saved to an INFO database file. These values are then automatically reloaded if that particular project is selected again during another session. In order to maintain the integrity of the project output, once a given set of input data or parameters have been used they cannot be changed for subsequent model runs within that project. Therefore, in order to change input or parameters once a model has been run, a new project must be created and the models run again.

To complete a project the user must work through the application in a step by step manner. The menus are thus designed to be selected in a manner from left to right and from top to bottom. For example, the first general step which the user must complete is to define the project input and parameters. This is done by selecting the second button from the left in the main menu (the farthest left button is used for general file maintenance) and sequentially following the submenu choices from top to bottom. Once all of those submenu choices have been completed the user will then continue on to the right through the remainder of the main menu choices as required.

Following is a basic list of the steps to run the models, each of which is described in detail in a subsequent section of this document. Please refer to section 2.14 for a graphical flowchart of the application process and section 4 for examples of the application menus.

1. select an output workspace
2. select a unique project code (unique within that workspace)
3. select the input spatial layers (BB and ER)
4. set the BB model parameters (richness file and buffer distances)
5. set the ER model parameters (buffer distances)
6. input a project comment
7. create/edit the project README file (this can be done at any time)
8. run models (BB and ER)
9. view and print output reports (project status, BB and ER)

Note that the input spatial layers selected are used for both models and that the model parameters need only be set for the model which is to be run. For example, step #5 need not necessarily be completed prior to running the BB model in step #8.

It should also be noted that since this application uses the Arc/Info GIS software there may be some terms used which are specific to that software. However, generic GIS terms have been used where possible. For example, a spatial data set which includes a particular type of data (e.g. roads) is described as a *spatial layer*. However, the actual file containing some of that data is described by the Arc/Info term *coverage*.

2.2 Launching the Application

Before starting the application the user must login to the UNIX system on an available workstation or on a PC running 'X' emulation (e.g. Hummingbird eXeed). Note that the login ID used will be recorded with any projects run from that ID. See Appendix 1 for instructions on logging in to the local UNIX system.

To start the application simply type 'bird' in an open command window. This will initialize 3 additional graphic windows: the main menu along the top of the screen, a display window in the center of the screen, and the project status box at the bottom of the screen. Note that the application windows and menus were designed for a specific screen size and resolution. Windows and menus may not fit properly on the screen if the workstation or PC does not meet the design criteria. The application was designed for a screen resolution of 1152x900 (SUN workstation default size) and a 17" monitor.

The main menu contains 'pull down' submenus and provides the capability to perform the steps described below. Use the left mouse button to make the appropriate selections. The right mouse button can be used to display a brief help line at the bottom of the menu for buttons within any of the input menus. Where menu selections are listed in the descriptions below they are indicated in bold text and small capital letters (e.g. **FILE**).

The status box displays many of the parameters associated with the current project. As new selections are confirmed by the user the appropriate line(s) in the status box is updated. Note that the status box is for display purposes only and does not accept any user input. The contents of the status box can be viewed or printed in report format using the project code summary report.

The graphic display window can be used to view input or output data however there are no viewing tools provided through the application menus. In order to view data layers the user must enter the Arc/Info command mode from the **FILE** menu. See section 4.14 for information on how to use command mode.

The original command window from which the application was launched will likely be hidden behind the new graphic windows. However, it can be beneficial to the user to move this window to a more visible location. Since all commands executed within the application are echoed within this window the user can easily see when activity is taking place (i.e. the commands will be quickly scrolling by in this window). As well, should an error occur within the application, any error messages will also be displayed in this window in conjunction with the display of a graphic error notification box. To select or move this window simply use the right mouse button along the top of any window to move that window to the back of the screen or use the left mouse button to bring a window to the front or to click and drag any window to another location on the screen.

Because this application uses a variety of GIS functions it must switch between different software modules at various points. Often this switch results in graphic windows 'flashing' or closing and reopening. This is normal operation and should be ignored.

2.3 Output Workspace

The first step to complete when starting a new project is to select the output workspace. This is the location where all output from the project will be placed including spatial layers, reports and maps.

Select the **PROJECT DEFINITION** menu and the **SET OUTPUT WORKSPACE** option which will open the output workspace menu. The current directory will be displayed in the bar near the top of the menu, use the file navigation tools to select the desired workspace. The workspace can be changed by either typing the pathname directly, selecting the 'up' arrow to move up one level in the directory path, or selecting a subdirectory from the scrolling list. If the desired workspace does not yet exist it can be created by selecting the **CREATE NEW WORKSPACE** button. The user can also delete an existing workspace (assuming he/she has the appropriate permissions on the system) by selecting the **DELETE CURRENT WORKSPACE** button. Selecting the **HELP** button will provide help on how to use the workspace menu.

To confirm the selected output workspace use the **OK** button, to exit the menu without changing the workspace select **CANCEL**.

The confirmed output workspace is displayed in the status box at the bottom of the screen once the **OK** button has been selected.

2.4 Project Code

The combination of project code and output workspace is used to uniquely identify a breeding bird/ecosite representivity project. To begin a new project, a project code must be selected which has not previously been used in the selected output workspace. The names of all output generated for a given project, including data files, spatial layers and reports, will be preceded with the project code.

Due to software limitations in the length of spatial layer names, the project code must be 1 – 3 characters long and must begin with a letter of the alphabet. Also, the project code cannot contain the following special characters: . / \ or '. If an invalid project code is selected, the user will be notified as such and will have the opportunity to enter a different code. If a project code is entered which has already been used in the current output workspace, the user will be informed as to what functions can still be performed. For example, if the user had previously run the BB model for that project, a message will inform the user that only the ER model can still be run.

Select **PROJECT DEFINITION** from the main menu then choose the **SET UNIQUE PROJECT CODE** option to display the project code menu. To enter a project code simply type the appropriate characters (1 – 3 letters and digits) into the project code box in the center of the menu and hit the **RETURN** or **ENTER** key. To leave the menu without changing the code select the **CANCEL** button. Selecting the **HELP** button will display instructions on how to use the project code menu.

The current project code is displayed in the status box at the bottom of the screen once the **RETURN** or **ENTER** key has been selected.

2.5 Input Spatial Layers

Three different spatial data layers are required to run the two models. Note that the human use features layer will require the selection of three separate Arc/Info coverages, one for each feature type (point, line and polygon). All of these spatial layers are used by both models thus once either the BB or ER model has been run the selections cannot be changed. **See Appendix 2 for a list of the system specific input data layers to be used.**

To enter the spatial coverages begin by selecting the **PROJECT DEFINITION** menu followed by the **SELECT INPUT COVERAGES** submenu. Use the file navigation tools to select the directory which contains the input coverages. The directory can be changed by either typing the pathname directly, selecting the 'up' arrow to move up one level in the directory path, or selecting a subdirectory from the scrolling list. Note that all input coverages **must** exist in a single input directory.

The spatial layers required by each model are as follows:

1. study area boundary
2. ecosite
3. human use features
    - point features
    - line features
    - polygon features

For each coverage type listed select the appropriate Arc/Info coverage from the adjacent scrolling list. Note that the scrolling list will only display coverages which contain the appropriate feature type (e.g. only coverages with polygon features will be displayed next to the human use polygon heading). When a coverage is selected the application will automatically check that the selection contains the required data fields and format. If it does, the name of the selected coverage will appear on the left side of the menu under the coverage heading. If it does not, a message will be displayed for the user regarding what requirement the selected coverage does not meet. The user will then be allowed to select another coverage.

Pushing the **OK** button confirms the selected coverages and causes the application to copy the three human use input coverages (point, line and polygon) to the output workspace. The new coverages, called hu_point, hu_line and hu_poly preceded by the project code (e.g. jp1_hu_line) are created to allow manual (i.e. outside the application) feature attribute edits for the project without changing the original input coverages. To leave the menu without changing the selections choose the **CANCEL** button. Selecting the **HELP** button will display instructions on how to use the particular spatial coverage menu. Note that the help function also includes a list of field/format requirements for each spatial layer.

The input coverage directory and selected spatial coverages are displayed in the status box at the bottom of the screen once the **OK** button has been selected.

Following is a list of requirements for each input coverage.

Coverage	Field	Requirement
Study Area	*none*	outside boundary will be used to clip all other input coverages
Human Use Points	category	character, to link with buffer file
Human Use Lines	category	character, to link with buffer file
Human Use Polygons	category	character, to link with buffer file
Ecosite	ecosite	character, contains ecosite type (e.g. AT1)

2.6 Breeding Bird (BB) Model Parameters

Once the input coverages have been selected, the next step is to set the required parameters for the breeding bird model run. Select the **PROJECT DEFINITION** menu followed by the **SET BREEDING BIRD MODEL PARAMETERS** submenu. This will display another submenu of which each option is described below.

The breeding bird model can be run at any time once these parameters have all been set. The BB parameters can be changed as often as necessary before the model is run however, once the BB model has been run they can no longer be changed without starting a new project (i.e. the same input coverages must be used for the ER run once the BB run is complete and vice versa).

2.6.1 Load Richness File

This menu is used to load an INFO file containing the disturbance coefficients related to breeding bird richness.

Use the directory navigation tools to select the directory which contains the required INFO file. The directory can be changed by either typing the pathname directly, selecting the 'up' arrow to move up one level in the directory path, or selecting a subdirectory from the left scrolling list. The right scrolling list contains a list of all INFO files in the selected directory, regardless of whether or not they contain the required values. Select the appropriate INFO directory from the left scrolling list and the required INFO file from the right scrolling list by clicking them with the mouse.

Once a file has been selected the application will check that the items in the file meet the requirements outlined below. If the selected file does not meet the requirements the user will be informed and will be returned to the menu to select another file. If it does meet the requirements, the user is notified that the file was loaded successfully. However, even though a file may have been loaded successfully into the application, it will not be used unless the **OK** button on the menu is subsequently selected.

The field requirements for the INFO richness file are:

Field Name	Field Type	Description
ecosite	character	used to link the attribute record to the spatial coverage feature
richness	numeric	breeding bird richness within the ecosite (potential = area * richness)
coeff	numeric	disturbance coefficient (potential * coeff = realized)

Selecting the **OK** button confirms the selected richness file. To leave the menu without using the selections choose the **CANCEL** button. Selecting the **HELP** button will display instructions on how to use the richness input file menu. Note that the help function includes the list of field requirements for the input INFO file.

The richness input file name is displayed in the status box at the bottom of the screen once the **OK** button has been selected.

2.6.2 Load BB Buffer Distance File

This menu allows the user to load the distances to be used for buffering human use features in the breeding bird model. These values can either be loaded from an existing INFO database file or can be keyed manually. As well, values loaded from a file can subsequently be changed by the user. The top half of the menu contains the current values for all 20 buffer distances related to predefined feature categories. There are no default values supplied.

Use the directory navigation tools to select the directory which contains the required INFO file. The directory can be changed by either typing the pathname directly, selecting the 'up' arrow to move up one level in the directory path, or selecting a subdirectory from the left scrolling list. The right scrolling list contains a list of all available files in the selected directory, regardless of whether or not they contain the required values. Select the desired file by clicking it with the mouse.

Once a file has been selected the application will test the file for the required fields. If the required fields are not present the user will be notified and will then be allowed to select another file. If the fields are acceptable, the 20 buffer values in the menu will be populated based on the fields in the table. The user can now manually change any of the values by first clicking the mouse in the selected box then changing the value and hitting the **ENTER** or **RETURN** key. However, even though the items in the menu have been populated, they will not be used unless the **OK** button on the menu is subsequently selected.

The field requirements in a buffer distance INFO file are:

Field Name	Field Type	Description
dist	numeric	the distance (in metres) to buffer the feature
variable	character	a 3 to5 letter variable code in the form 'accom' where the codes represent the following feature categories: accom → accommodations cabin → cabins campg → campgrounds csite → campsites duse → day use areas froad → fire roads golfc → golf courses groad → gravel roads highw → highways horse → horse corrals mroad → major roads pit → pits

		pline → powerlines railw → railways road → roads rroad → railway roads ski → ski areas towns → townsites trail → trails util → utilities
Note: the info file should contain 20 records, one for each possible feature category		

Selecting the **OK** button confirms the displayed buffer values. To leave the menu without using the values displayed choose the **CANCEL** button. Selecting the **HELP** button will display instructions on how to use the breeding bird disturbance buffer distances menu. Note that the help function includes the list of field requirements for an input INFO buffer file.

If a buffer file has been selected the file name will be displayed in the status box at the bottom of the screen once the **OK** button has been selected. However, it is important to note that the **individual values from the file may have been changed by the user**. If any buffer value is manually keyed by the user, a flag is set within the application to indicate a change has been made. As a result, all BB model output reports will contain a note that default values were changed for that particular model run.

Due to the number of buffer values, the individual buffer distances are not displayed in the status box but are included in the output BB reports once the model has been run.

2.7 Ecosite Representivity (ER) Model Parameters

The required parameters for the ecosite representivity model can be set any time prior to running the ER model. The parameters can be changed as often as necessary before the model is run however, once the ER model has been run they can no longer be changed without starting a new project and rerunning the ER model. Also, the same input coverages must be used for the ER run once the BB run is complete and vice versa.

Select the **PROJECT DEFINITION** menu followed by the **SET ECOSITE MODEL PARAMETERS** submenu. This will display another submenu which currently only contains one option as described below.

2.7.1 Load ER Buffer Distance File

This menu allows the user to load the distances to be used for buffering human use features in the ecosite representivity model. Loading this file is the same procedure as that for the BB buffer distance file, please refer to section 2.6.2 for details on how to load the file.

2.8 Project Comment

The project comment menu allows the user to attach a descriptive comment to the selected project. This comment will be included in all output reports and therefore must apply to both model runs. Ideally the comment would contain such information as the purpose for the project or an explanation of any special parameters that may have been used. If no project comment is entered the line will appear blank on the output reports (there is no default). Note that the comment must be completed before running the first model (BB or ER) since the menu cannot be accessed once any models have been completed. Note that the comment can be a maximum of 80 characters (if more are entered it will be truncated at 80).

To enter a project comment first select the **PROJECT DEFINITION** menu followed by the **ADD A COMMENT TO THE PROJECT** submenu. This will display the project comment menu. Simply type in the desired comment, deleting any unwanted text. Selecting the **OK** button accepts the displayed comment. To leave the menu without changing the comment choose the **CANCEL** button.

The comment will be displayed in the status box at the bottom of the screen once the **OK** button has been selected.

2.9 Create/Edit the Project README File

The user can create and edit a 'README' file related to the project. This file would be used to store information relating to the reasons for and inputs to the project as well as observations regarding the project output. It is different from the project comment in that it can contain an unlimited amount of text and that it can still be changed *after* the project has been completed.

To create or edit the README file first select the **PROJECT DEFINITION** menu followed by the **CREATE/EDIT PROJECT README FILE** option. This will open a text editor window containing the file to be edited. The first time this file is opened it will contain the default documentation headings however any text in the file can be changed. Simply type in the desired text anywhere in the window, deleting any unwanted text. To save the file select the **FILE** button in the upper left corner of the window followed by the **Save** option in the submenu. To close the texteditor window use the right mouse button in the bar along the top of the window then pick **QUIT** from the submenu.

The texteditor window used with the README file is independent of the application thus can be left open and edited while performing other application functions. Also, there is no security on this file to ensure that the contents are not changed *after* running one or models. In fact, it may be desirable to enter an analysis of the model output into this file once it has been reviewed.

2.10 Running Models

Once the required inputs and parameters are complete the user is ready to run one or both of the models. The models can be run individually, in either order, or both together. To run a model simply select the **RUN MODELS** option from the main application menu then select the appropriate option from the displayed submenu (e.g. **RUN BREEDING BIRD MODEL**).

The length of time required to run a model varies with the type of model, the size of the input study area and the available processing power. In general the each model will take approximately 3 hours to run for the entire park. Various informational messages will be displayed for the user throughout each run as to what function is currently being performed.

Once a model run is complete the user will be informed as such and the date and login ID for the run will be displayed in the status box. As well, upon completion all variables (e.g. input parameter values, input coverage names, etc.) will be saved to an INFO database file for later use. Output report files are automatically created as part of a model run but must be printed manually by the user if required.

2.11 Output Reports

To view or print existing reports select the **REPORTS** option from the main menu and the appropriate option from the displayed submenu (e.g. **VIEW REPORTS**). Both of these submenu options will in turn display another submenu including the project status report, reports for the two models and the project README file. The project status report can be viewed or printed at any time and will display the current values as shown in the status box. The README file can also be viewed or printed at any time. All other reports can only be viewed or printed once the appropriate model run has been completed.

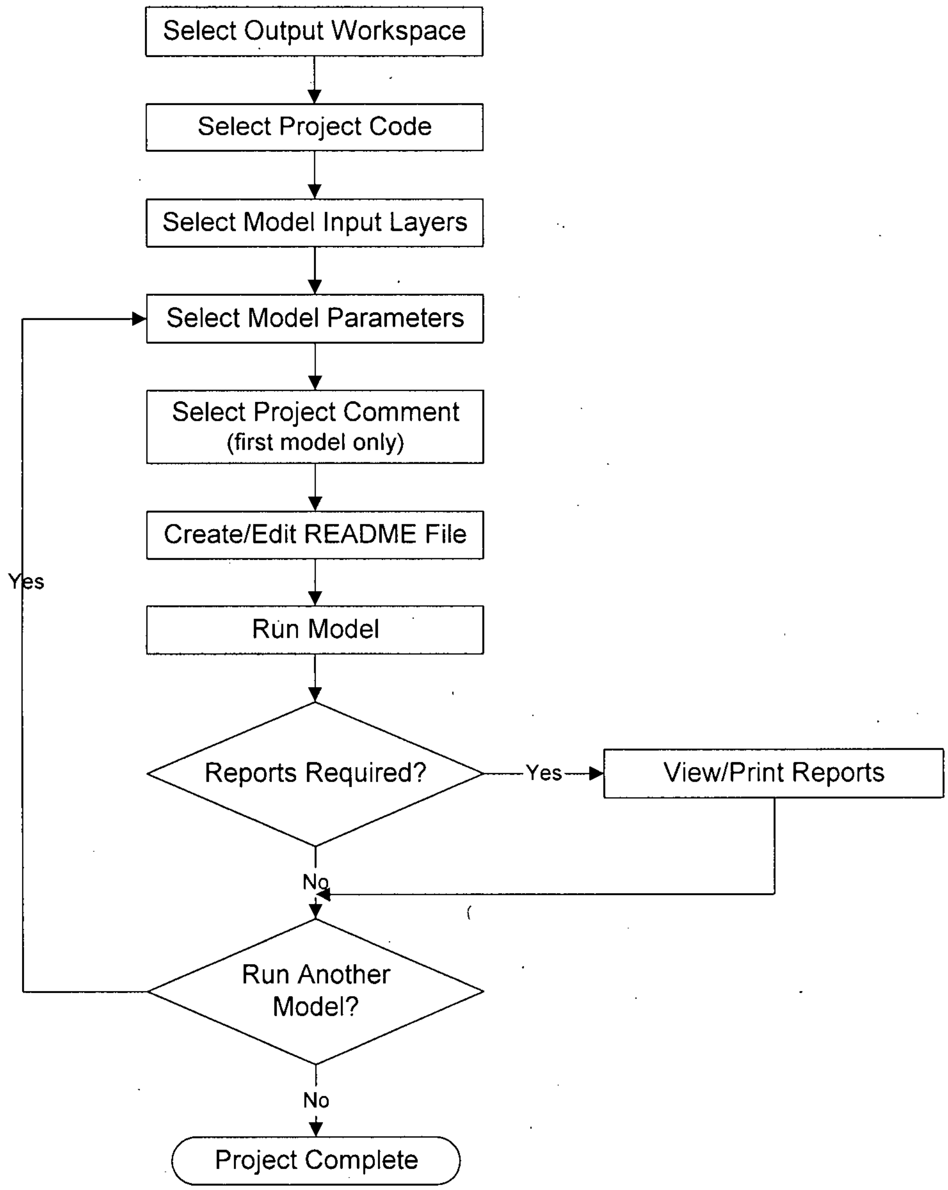
Each model will generate 3 reports, one containing a list of all model input and output coverages/files, one containing the model parameters (e.g. buffer distances), and one describing the contents of the output files. These reports can therefore be used as a reference in determining how a particular set of output coverages/files were achieved.

If the user selects to view a report a new window will pop up on the right side of the screen containing the report. This window may contain a number of controls including a scroll bar along one side, a **CONTINUE** button at the bottom left to display the rest of the report and a **QUIT** button at the bottom right to close the window. If there are multiple reports associated with the user's selection they will be displayed one after the other once the **QUIT** button has been pushed.

Selecting to **PRINT REPORTS** will automatically send the reports to the default printer. An information box will appear on the screen to tell the user that the reports have been sent to the printer.

2.11 Application Flowchart

The following flowchart illustrates the general steps to be followed when using the breeding bird/ecosite representivity application. Refer to sections 2.3 – 2.10 for a detailed description of each step.



2.12 Other Functions

2.12.1 General Data Maintenance Tools

The main application menu includes an option called **FILE** which contains a pulldown menu of general application tools. All of these tools are generic Arc/Info tools (i.e. not developed for any particular application) and thus may seem somewhat cryptic to non-GIS users. The first tool, **ARC/INFO COMMANDS**, opens a menu which provides the user with the ability to enter Arc/Info commands interactively. Since this option requires at least a basic knowledge of Arc/Info GIS commands, it should only be used by those with the appropriate level of knowledge and experience. Should a user accidentally open this menu, selecting the **DISMISS** button will close the menu.

The second submenu option, **COVERAGES**, opens a menu of tools used for general Arc/Info coverage maintenance. This menu provides the functionality to rename, copy, describe or delete coverages and to describe or list the associated feature attribute tables. The third submenu option, **INFO TABLES**, opens a menu for performing general maintenance functions on INFO database tables. This includes the ability to copy, delete, describe and list available tables. Both of these menus include the tools required to navigate through available directories and workspaces. Use the **HELP** button on each menu to display additional information on how to use the menus.

2.12.2 Getting Help

The user can get help both from this user guide and from the online application help features. The main application menu contains a **HELP** button which will open a submenu containing options for **GETTING STARTED** and **BIRD STATUS**. Selecting one of these options will open a window containing a description of either steps to run the application or of the application status box. Use the window scroll bar, **CONTINUE** and **PAUSE** buttons to view the window contents. Selecting the **QUIT** button at the bottom right of the window will close the window and return control to the main application menu.

Most of the other application windows also contain a **HELP** button. Selecting this button will display a window containing additional information on what the menu does, how to use the menu options and input requirements if applicable.

The command window from which the application was originally started (i.e. where 'bird' was keyed) will contain any system messages or errors. Application users do not normally need to check the contents of this window. However, if the application does not appear to be working correctly and an error message does appear in the command window, the user should contact the system administrator immediately.

3. Models

3.1 Introduction

The models used in this application were developed by Brenda Dobson for the Three Valley Confluence study in Jasper National Park. The following descriptions address how the models are used within this application but do not discuss development of the models themselves. Please refer to the references section at the end of this document for additional information regarding the models.

Throughout the model descriptions there are many references to files, coverages, etc. which are created by the application. The prefix '*xxx*' is used to represent the unique 3-character project code within each name. Also, since many temporary files and coverages are created during each model run but are deleted upon completion of the run, those files are not named in the model descriptions.

3.2 Breeding Bird (BB)

3.2.1 Overview

The breeding bird (BB) model is used to determine the effect of human disturbances on breeding bird habitat categorized by ecosite. Included are three types of analysis. First, a summary of habitat patch size before and after human disturbance is applied assuming that bird richness within the disturbance buffers is zero. The second analysis is the ratio of realized habitat (after human disturbance is applied) vs. potential habitat, expressed as a percentage and calculated by ecosite. Finally, total habitat patch size (regardless of ecosite) is measured both before and after human disturbance is applied.

The steps performed by the BB model within this application are as follows:

1. The input ecosite coverage is clipped to the study area boundary.
2. Values from the input richness INFO file are joined to the ecosite coverage using the ecosite field as the key.

3. Those features with a category value of 'not applicable' are deleted from the copied human use coverages (point, line and polygon features).
4. A lookup table for buffering the human use features is created based on the supplied buffer values.
5. Human use features are buffered using the category field values and the buffer lookup table (point, line and polygon). All three buffer coverages (one for each input feature type) are then combined into one coverage and clipped to the study area boundary.
6. Human use buffer coverage is combined with the ecosite coverage and the potential and realized value are calculated for each polygon. The potential value is the area (in hectares) multiplied by the richness value. For those polygons outside the disturbance buffers the realized value is equal to the potential value. The disturbance polygons themselves (i.e. the original human use polygons) have a realized value of 0 and the realized value within the buffers is equal to the potential value multiplied by the appropriate disturbance coefficient for that ecosite.
7. The potential and realized values are summarized for each ecosite and the effectiveness value is calculated (realized/potential * 100). This produces the output file: **xxx_eco_dist.sum**.
8. A statistical summary of total area, average area and standard deviation is calculated by ecosite for both undisturbed and disturbed patches. Percentage values are also calculated. This produces the output file: **xxx_eco_dist.patch**.
9. Ecosite coverage is dissolved in two categories: habitat (i.e. richness value > 0) or non-habitat then combined with the human use disturbance buffers.
10. A summary of habitat patch values is calculated for both the ecosite coverage and the disturbed ecosite coverage (i.e. before and after human use is applied). This summary includes total area, average size and standard deviation if the habitat patches. This produces the output file: **xxx_hab_dist.patch**.
11. Model reports are generated and run variables are stored.

3.2.2 Inputs

There are five coverages required to run the BB model: human use point features, human use line features, human use polygon features, ecosites and a study area boundary. The requirements for each of these coverages is described in section 2.5.

This model also requires an INFO format file containing bird richness and disturbance coefficient values by ecosite. This data is used to calculate the potential and realized breeding bird values. The requirements for the INFO file are described in section 2.6.1.

A set of human use buffer distances for each category of disturbance are also required to run the model. These values can either be keyed individually by the user or can be loaded from a file. See section 2.6.2 for details regarding the file requirements and section 3.2.3 for the default values.

Most of the inputs used to run the BB model for a particular project are recorded in that project's BB output reports. However, due to the number of values for richness and disturbance coefficients, they are not included in the reports but can be viewed in either the input file or the output variables file.

3.2.3 Default Values

Richness Values and Disturbance Coefficients

A set of richness and disturbance coefficient values is provided in an INFO file. As with the human use buffers, this file is NOT automatically loaded and must be selected by the user (see section 2.6.1). Additional coefficient files can also be created by the system administrator and provided to the user for alternative values if required.

The coefficient values provided in the BIRDCO.IN file are:

Ecosite	Richness	Coeff		Ecosite	Richness	Coeff
AL1	27	0.41		ML3	16	0.37
AL2	29	0.28		MP1	13	0.15
AT1	19	0.32		MQ1	15	0.27
AT2	14	0.21		NG1	10	0.20
AT3	21	0.14		NT2	14	0.14
BK1	35	0.37		NT3	10	0.00
BK2	15	0.33		NY1	15	0.13
BK4	37	0.32		NY3	56	0.32
BK6	21	0.33		PL1	33	0.30
BP1	8	0.25		PL4	23	0.26
BP2	8	0.37		PL5	29	0.17
BS1	4	0.00		PP1	20	0.30
BV1	27	0.22		PP3	27	0.41
BV2	12	0.50		PP4	18	0.17
BV3	7	0.57		PP6	28	0.32
BY1	42	0.26		PP7	23	0.17
BY2	32	0.34		PR1	22	0.27
BY4	21	0.52		PR2	49	0.35
BY6	7	0.43		PR3	22	0.45
BZ1	6	0.17		PR4	21	0.29
BZ2	9	0.22		PR6	20	0.40
CA1	26	0.31		PT1	36	0.28
CA2	22	0.50		PT3	31	0.23
CA4	12	0.50		PT4	29	0.21
CN1	24	0.21		PT5	44	0.27
CP1	15	0.07		RD1	9	0.11
CV1	28	0.39		SB1	38	0.32
DV1	10	0.00		SB2	20	0.45
DV2	17	0.24		SB3	10	0.60
EF1	19	0.16		SB4	21	0.29
EG1	34	0.26		SB5	11	0.09
EG3	20	0.25		SF1	15	0.27

Ecosite	Richness	Coeff		Ecosite	Richness	Coeff
EG4	22	0.18		SP1	11	0.36
EN2	20	0.15		SX1	27	0.15
EN3	4	0.00		SX2	30	0.33
FR1	29	0.28		SX3	22	0.14
FV1	27	0.37		TA2	17	0.12
FV2	13	0.62		TA3	33	0.33
GA1	27	0.33		TK1	14	0.11
GT1	16	0.25		TR1	25	0.12
GT2	21	0.14		TR2	15	0.00
HC1	34	0.32		TZ1	9	0.33
HC2	23	0.13		TZ2	12	0.42
HC4	60	0.22		TZ3	3	0.33
HD1	60	0.25		VD1	9	0.44
HD2	33	0.33		VD2	19	0.42
HD3	21	0.38		VL1	71	0.27
HD4	25	0.12		VL3	53	0.30
HE1	8	0.00		VL4	30	0.27
HE2	6	0.00		VL5	27	0.26
IB1	10	0.00		WF1	20	0.40
IB2	12	0.33		WF2	23	0.17
IB3	15	0.40		WF3	7	0.00
JN1	15	0.07		WF4	11	0.09
KA1	1	0.00		WF7	22	0.00
LV2	13	0.23		WH2	16	0.31
LV3	24	0.21		WH3	11	0.00
MC1	20	0.30		WH5	20	0.20
ML1	27	0.37		WW1	2	0.00
ML2	25	0.32				

Human Use Buffers

An INFO file containing buffer values, called BREEDBIRD.BUF is provided with the application. However, this file is NOT automatically loaded and must be selected by the user (see section 2.6.2). Additional such files could be created and provided to the user for alternative values, contact the system administrator if this is required.

The buffer values provided in the BREEDBIRD.BUF file are:

Category	Disturbance Buffer (m)	Variable
accommodation	100	accom
cabin	100	cabin
campground	100	campg
campsite	110	csite
day use	100	duse
fire road	17	froad
golf course	100	golfc
gravel road	110	groad
highway	260	highw
horse corral	100	horse
major road	145	mroad
pit	100	pit
powerline	34	pline
railway	130	railw
railway road	19	rroad
road	130	road
ski area	100	ski
townsite	100	towns
trail	0	trail
utility	100	util

3.2.4 Assumptions & Limitations

Buffering of human use features is based on the category to which each feature belongs. Any feature with a category value which does not match those provided in this application will not be buffered. Note that any features with a category value of 'not applicable' are not buffered.

Disturbance coefficients are based solely on the ecosite type and are not affected by the type or intensity of human use. The potential value within disturbance buffers is multiplied by the appropriate coefficient (depending on the ecosite) to determine the realized value. Note that the area within polygon human use features themselves is considered entirely disturbed and receives a realized value of 0. Potential and realized habitat values are calculated on a polygon basis whereas the habitat effectiveness calculations are at the ecosite level.

Any polygon with a richness value greater than 0 is considered habitat for the purposes of the habitat patch analysis.

3.2.4 Outputs

In addition to the standard outputs described below, there are a number of files and Arc/Info coverages which are created during the BB model run but are deleted upon run completion (i.e. these are temporary files). All such files begin with *xx_* and should no longer exist once the model run is complete. If any of these files do still exist after a run it is an indication that there was an error during the model run.

Reports

The application produces a set of three reports for breeding bird model runs. The first report provides a listing of the main project specifics including lists of input and output files and coverages and the project comment. Buffers distances used by the model are listed in report 2. The final report contains a listing and description of the fields in the three major output files. The first two reports also a note as to whether or not the default BB values were used for the run. The reports are produced in English only. See the file listing below for the names of the output report files.

Data Files and Coverages

A number of data files and Arc/Info coverages are generated as part of the BB model run and are created in the project output workspace. Following is a description of each.

Name	Type	Description
*xxx*_hu_point	A/I coverage	human use point features
*xxx*_hu_line	A/I coverage	human use line features
*xxx*_hu_poly	A/I coverage	human use polygon features
*xxx*_point_buf	A/I coverage	disturbance buffers for *xxx*_hu_point
*xxx*_line_buf	A/I coverage	disturbance buffers for *xxx*_hu_line
*xxx*_poly_buf	A/I coverage	disturbance buffers for *xxx*_hu_poly
*xxx*_total_buf	A/I coverage	final buffer coverage, all feature types, clipped to study area
*xxx*_eco	A/I coverage	input ecosite coverage clipped to study area boundary
*xxx*_eco_dist	A/I coverage	ecosite and disturbance buffer coverages combined
*xxx*_hab	A/I coverage	ecosite coverage dissolved on habitat
*xxx*_hab_dist	A/I coverage	habitat and disturbance buffer coverages combined
*xxx*_bb.buf	INFO file	buffer distance lookup table (by disturbance category)
*xxx*_variables.lut	INFO file	list of application variables, descriptions and values, used to reestablish the setup for a previous project
*xxx*_eco_dist.patch	INFO file	ecosite patch size summary file
*xxx*_eco_dist.sum	INFO file	ecosite habitat effectiveness summary file
*xxx*_hab_dist.patch	INFO file	habitat patch size summary file
*xxx*_bb1.rep	system text file	BB report #1
*xxx*_bb2.rep	system text file	BB report #2
*xxx*_bb3.rep	system text file	BB report #3

3.3 Ecosite Representivity (ER)

3.3.1 Overview

The ecosite representivity model (ER) is used to compare the total area of each ecosite before and after human use disturbances are applied. It also provides a look at the percentage of the total area of each ecosite to be found within the given study area in relation to both the entire area of Jasper National Park and the area of Jasper and Banff National Parks combined.

The steps performed by the ER model within this application are as follows:

1. The input ecosite coverage is clipped to the select study area boundary.
2. Total area, average patch size and standard deviation of patch size is calculated for each ecosite.
3. A buffer distance lookup table is created based on the supplied values.
4. Each human use input coverage (point, line and polygon) is buffered using the lookup table. The buffer coverages are then combined into a total buffer coverage and clipped to the study area boundary.
5. The ecosite and total buffer coverages are then combined. Total area, average patch size and standard deviation of patch size is then calculated for the remaining area of each ecosite.
6. Summary values for before and after human use is applied are then combined into a single file together with the total area values by ecosite for Jasper and Banff. The percentage for potential and realized values within Jasper and Jasper/Banff are also calculated for each ecosite. This produces the output file: **xxx_eco.sum**.
7. Model reports are generated and run variables are stored.

3.3.2 Inputs

The ER model requires five coverages as input, the same ones as required for the breeding bird model (human use points, human use lines, human use polygons, ecosites and a study area boundary). Refer to section 2.5 for a description of the input coverage requirements.

A set of human use buffer distances for each category of disturbance are also required to run the model. These values can either be keyed individually by the user or can be loaded from a file. See section 2.7.1 for details regarding the file requirements and section 3.3.3 for the default values.

All of the inputs used to run the ER model for a particular project are recorded in that project's ER output reports.

3.3.3 Default Values

Human Use Buffers

An INFO file containing buffer values, called ECOREP.BUF is provided with the application. However, this file is NOT automatically loaded and must be selected by the user (see section 2.7.1). Additional such files could be created and provided to the user for alternative values, contact the system administrator if this is required.

The buffer values provided in the ECOREP.BUF file are:

Category	Disturbance Buffer (m)	Variable
accommodation	80	accom
cabin	80	cabin
campground	80	campg
campsite	90	csite
day use	80	duse
fire road	9	froad
golf course	50	golfc
gravel road	30	groad
highway	80	highw
horse corral	80	horse
major road	65	mroad
pit	50	pit
powerline	14	pline
railway	40	railw
railway road	27	rroad
road	50	road
ski area	50	ski
townsite	80	towns
trail	3	trail
utility	50	util

3.3.4 Assumptions & Limitations

Buffering of human use features is based on the category to which each feature belongs. Any feature with a category value which does not match those provided in this application will not be buffered. Note that any features with a category value of 'not applicable' are not buffered.

Buffer distances are based solely on the ecosite type and are not affected by the intensity of human use. All areas within a disturbance buffer are considered totally disturbed for the purposes of this model.

3.3.5 Outputs

During an ER run there are a number of temporary files and coverages which are created, all beginning with the prefix *xx_*. If the run completes properly all such files should be automatically deleted. If any *xx_* files remain after a run is complete it indicates some type of error during the model run and should be reported to the system administrator. All permanent output from the model is described below.

Reports

Three reports are produced through running the ER model. The first report contains a list of all the input coverages/files/comment together with a list of the output coverages and files. Report #2 contains a list of the buffer distances used for the model run. The final report is a listing and description of the fields in the summary output file. The first two reports also contain the project code, date and login ID of the model run as well as a note indicating whether or not the default values were used for the input parameters. The reports are produced in English only.

Data Files and Coverages

Following is a list of the files and coverages created by the ER model.

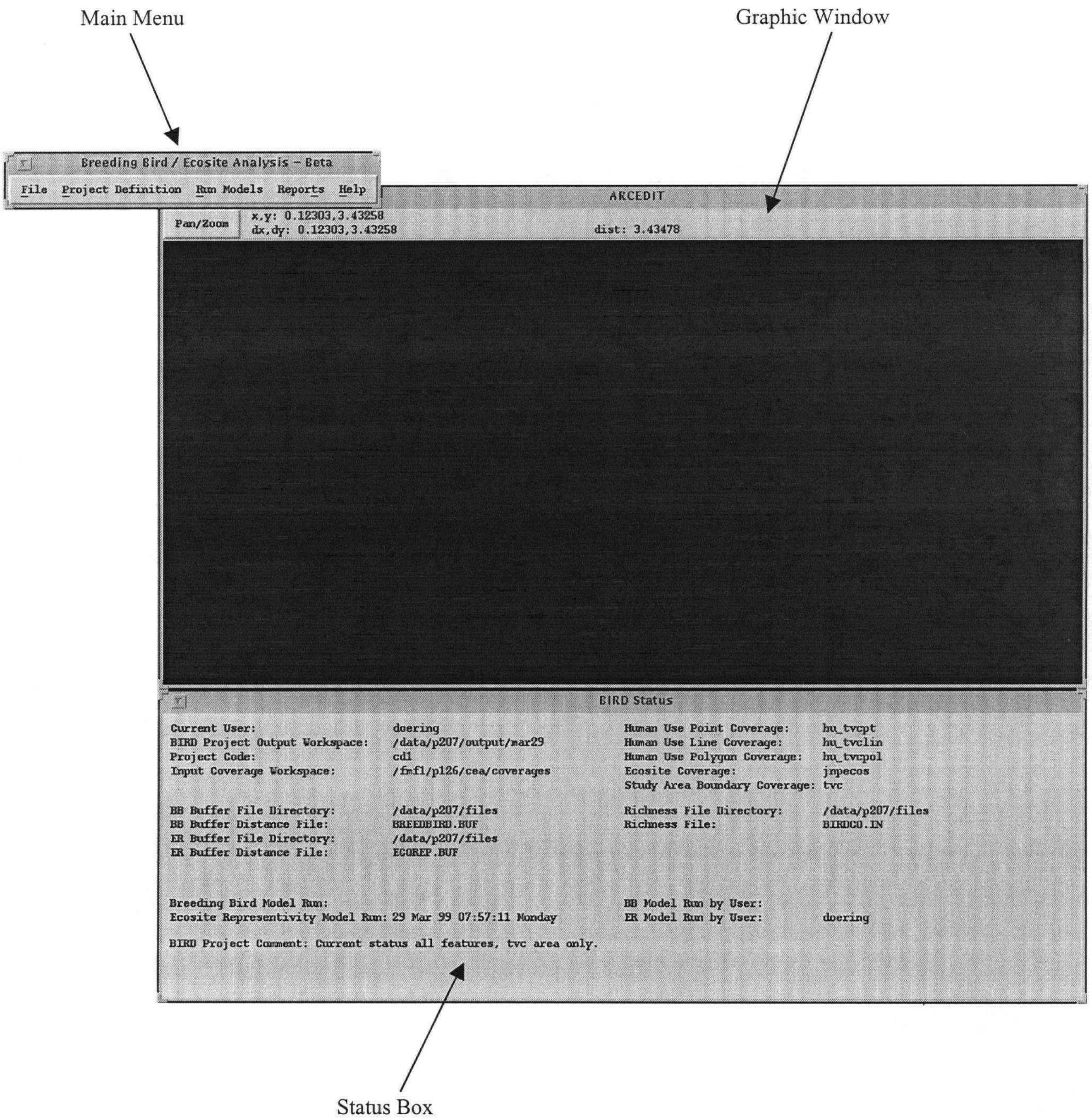
Name	Type	Description
*xxx*_er_pt_buf	A/I coverage	buffered human use point coverage
*xxx*_er_ln_buf	A/I coverage	buffered human use line coverage
*xxx*_er_py_buf	A/I coverage	buffered human use polygon coverage
*xxx*_totrepbuf	A/I coverage	combined buffer coverage clipped to study area
*xxx*_ecodis	A/I coverage	combined ecosite and disturbance buffers
*xxx*_er.buf	INFO file	buffer distance lookup table
*xxx*_variables.lut	INFO file	list of application variables, descriptions and values, used to reestablish the setup for a previous project
*xxx*_eco.sum	INFO file	model run area summary file by ecosite
*xxx*_er1.rep	system text file	SA report #1
*xxx*_er2.rep	system text file	SA report #2
*xxx*_er3.rep	system text file	SA report #3

4. Sample Menus & Forms

The forms/menus that the user sees while using the application are shown on the following pages. The menus are organized to follow a typical project from beginning to end and correspond to the textual descriptions in section 2.

4.1 Launching the Application

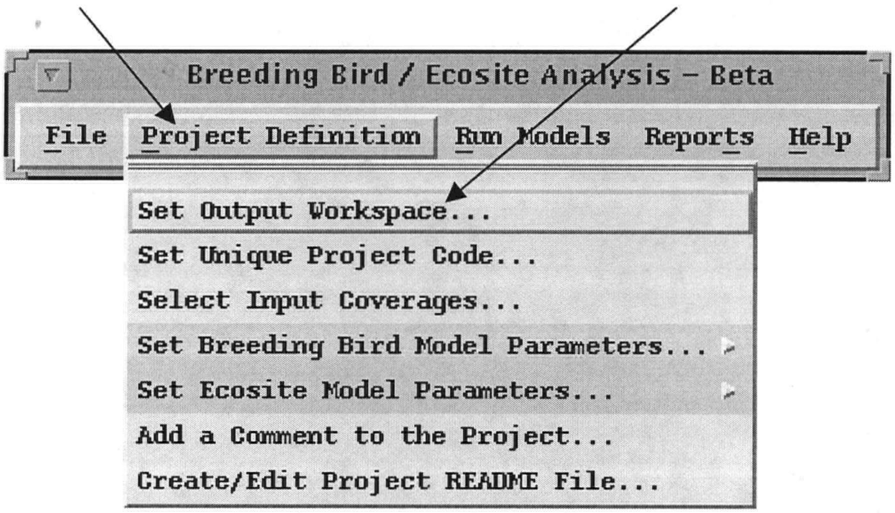
To launch the application simply type 'bird' into an open system window. That window becomes the program window where all application code can be viewed. Following is a picture of the initial application screen. Note that the program window is not viewable, it is hidden behind the large graphic window.



4.2 Setting the Output Workspace

To set the project workspace select **PROJECT DEFINITION** from the main menu then select **SET OUTPUT WORKSPACE** from the submenu.

Select **PROJECT DEFINITION** then... ...select **SET OUTPUT WORKSPACE.**

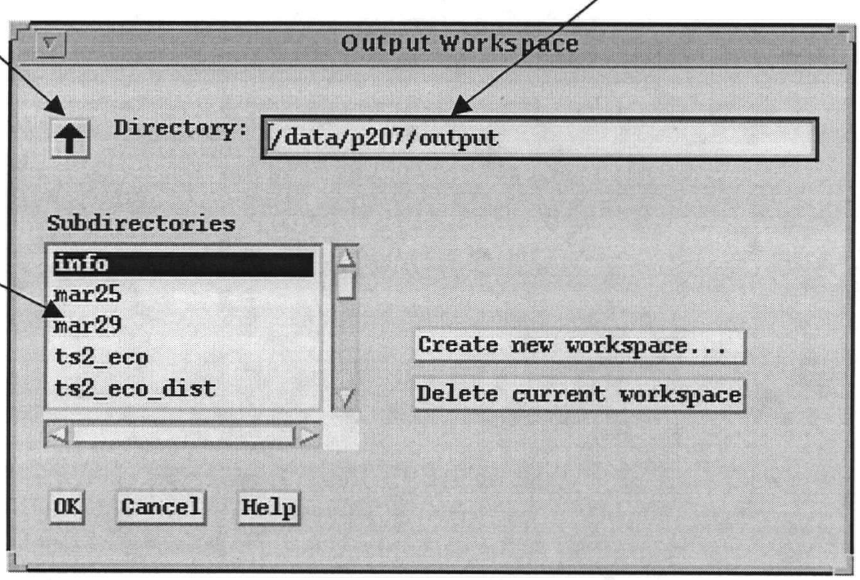


The output workspace input form will then appear. Use the up arrow and subdirectory scrolling list to select the appropriate workspace or type the full pathname in the directory box. Select the appropriate buttons to create a new workspace in the current directory or to delete an existing workspace.

Move up one directory

Selected output workspace

Available subdirectories

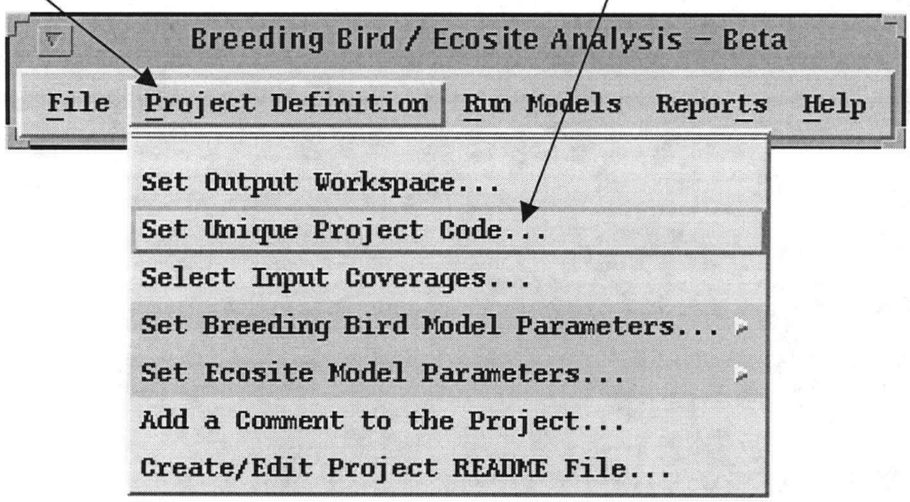


4.3 Setting the Project Code

To choose a unique project code first select **PROJECT DEFINITION** from the main menu then select **SET UNIQUE RUN CODE** from the submenu.

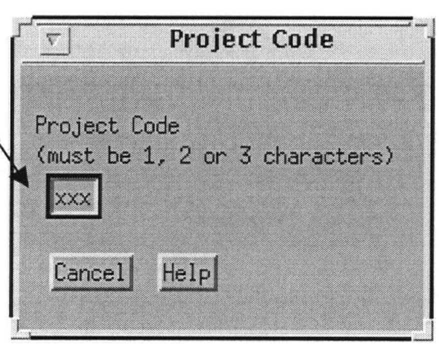
Select **PROJECT DEFINITION** then...

...select **SET UNIQUE PROJECT CODE.**



The project code input form will then appear. Key a valid 3 character code into the form then hit the **RETURN** or **ENTER** key.

Key a 3 character code in this space then hit the **RETURN** or **ENTER** key

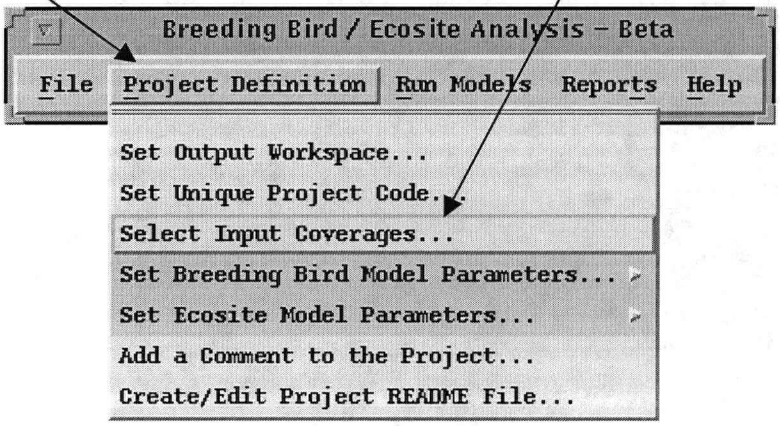


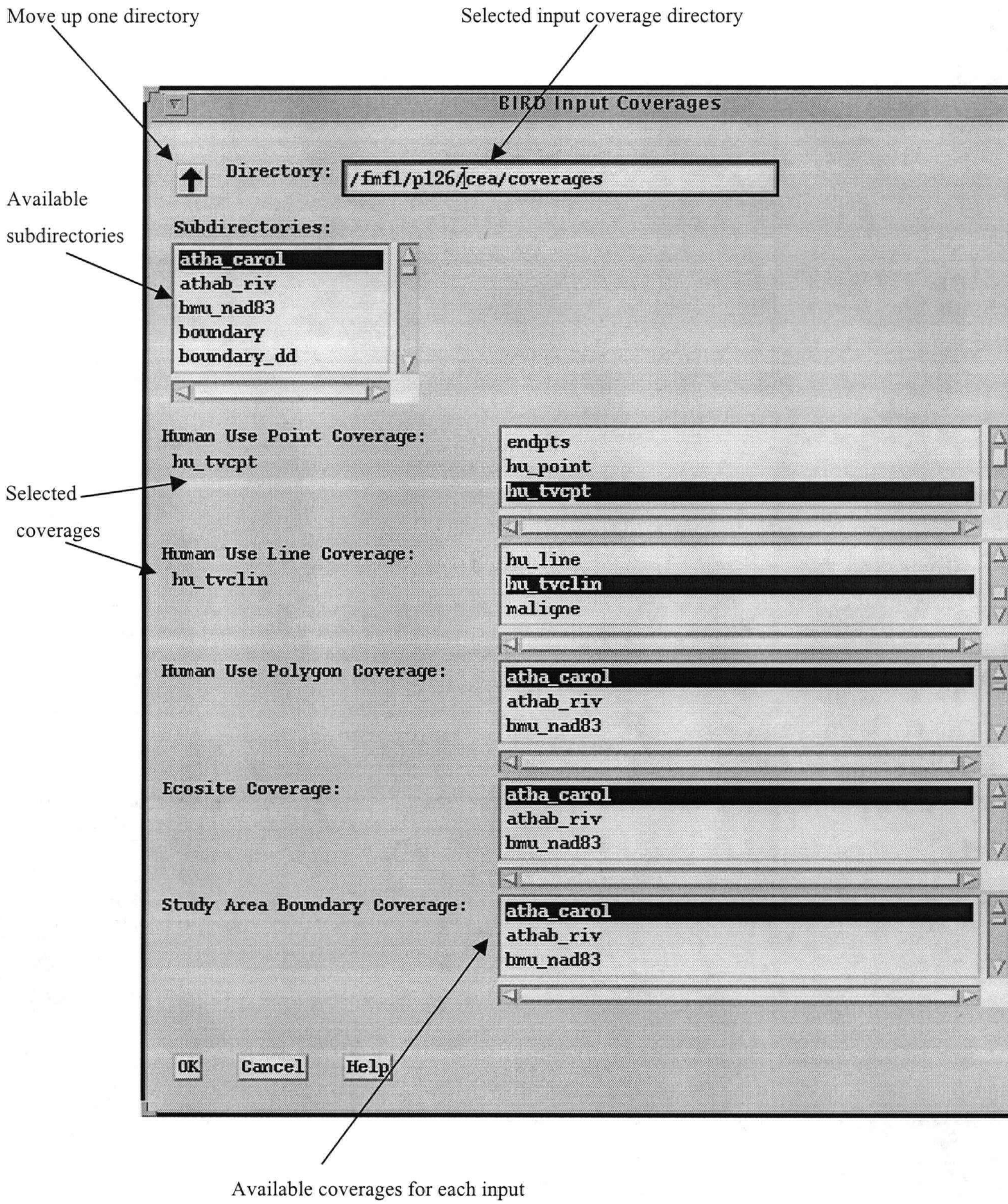
4.4 Selecting Input Spatial Layers

The coverages selected from these menus will be used for both models. First select **PROJECT DEFINITION** from the main menu, followed by **SELECT INPUT COVERAGES** in the submenu.

Select **PROJECT DEFINITION** then...

...Select **INPUT COVERAGES**.





See Appendix 2 for information regarding system specific coverages to use.

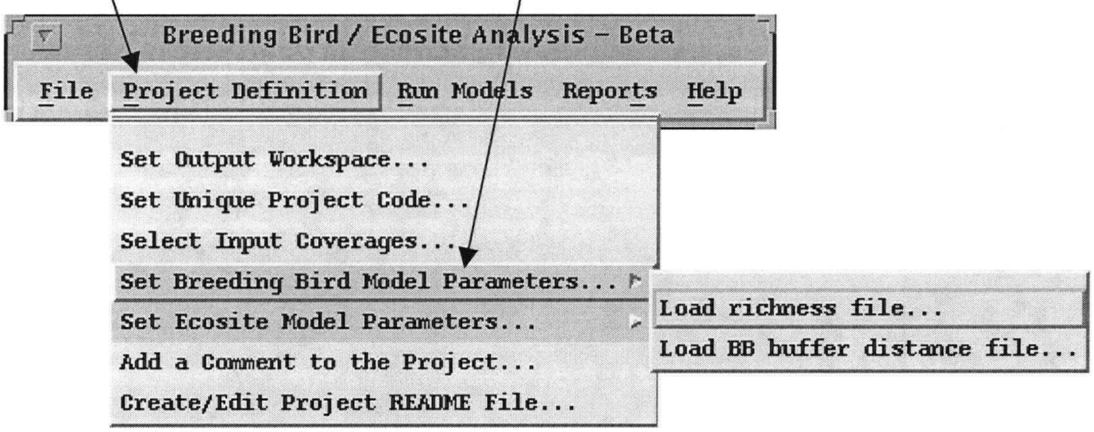
4.5 Setting the Breeding Bird Model Parameters

Following is a sample of how to select the richness file input form. Begin by selecting the **PROJECT DEFINITION** option from the main menu followed by **SET BREEDING BIRD MODEL PARAMETERS** from the first submenu and **LOAD RICHNESS FILE** from the second submenu. Then select the appropriate file from the richness file menu. The buffer distances file is selected in the same manner except that **LOAD BB BUFFER DISTANCE FILE** is selected from the second submenu. An example of the buffer file selection menu is also included below.

Select **PROJECT DEFINITION** then...

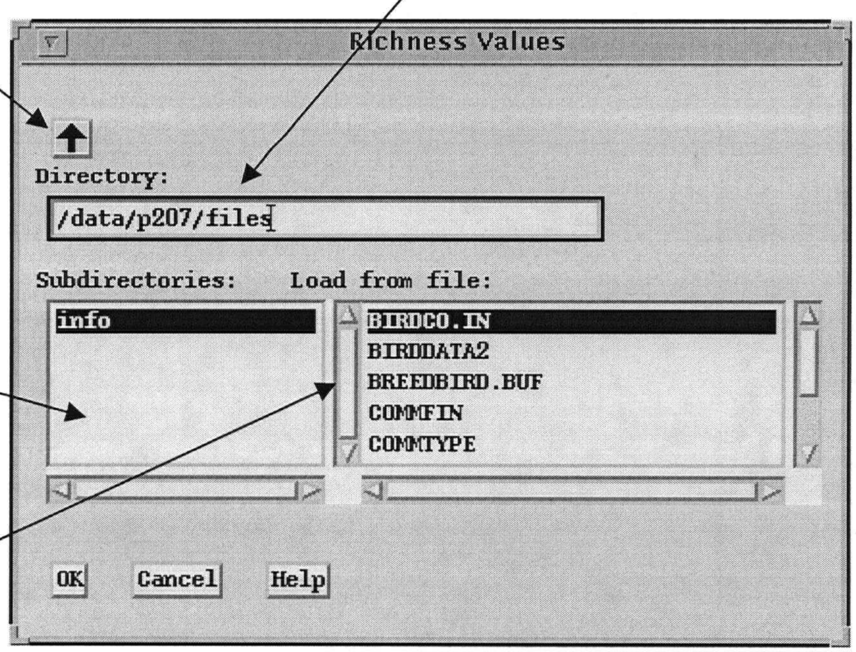
select **SET BREEDING BIRD MODEL PARAMETERS** then...

select **LOAD RICHNESS FILE**.



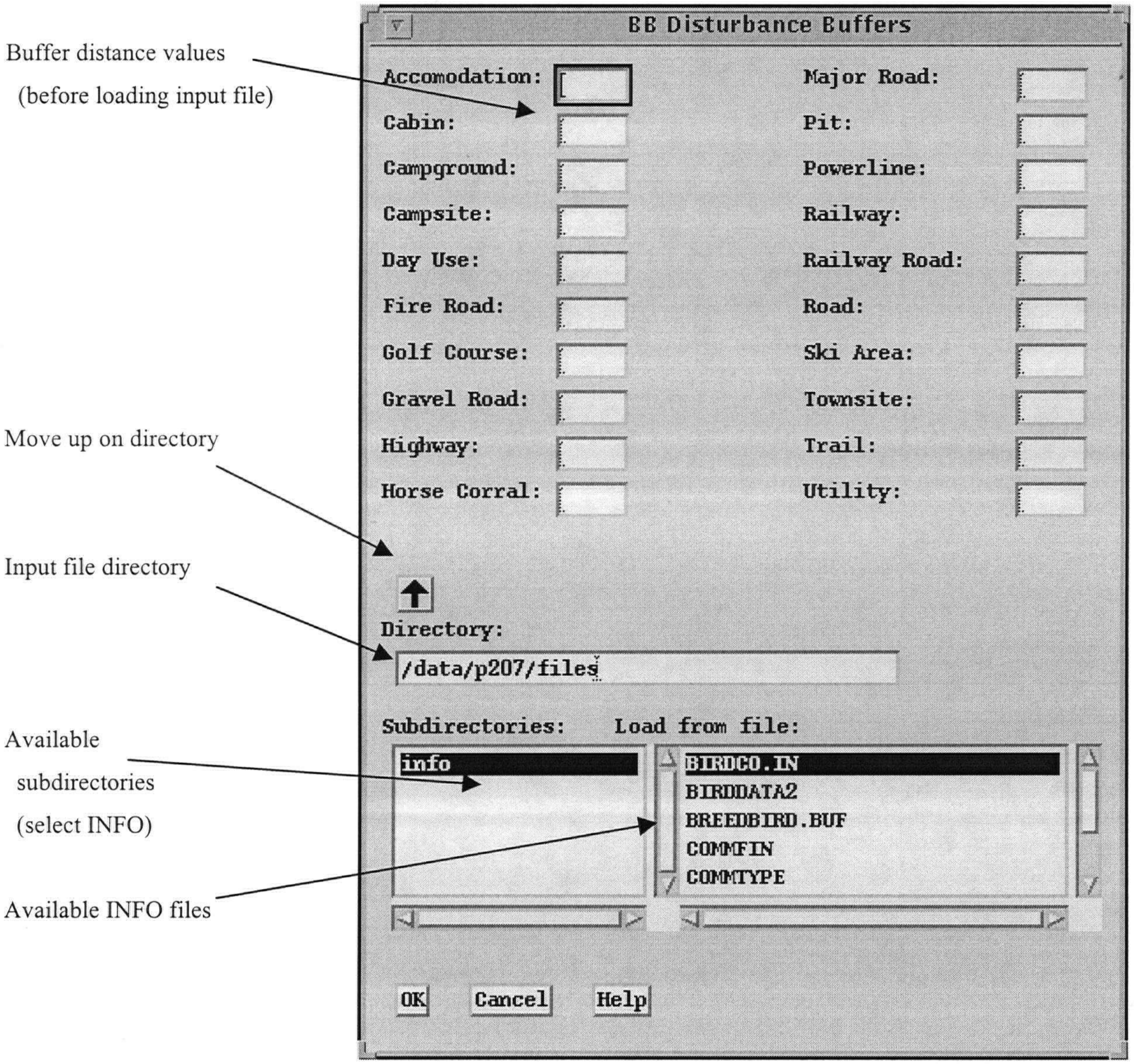
Move up one directory

Selected input file directory

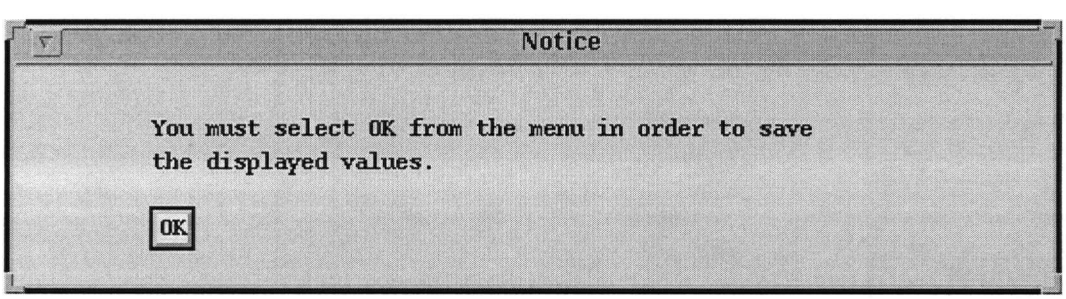


Available subdirectories (select INFO)

Available INFO files



Note that the buffer distances can be keyed manually rather than selected from a file. Or, the distances can first be populated by selecting a file then manually edited if required. Also, when loading from a file the notice box below will be displayed to remind the user to select the **OK** button in order to save the displayed buffer values.



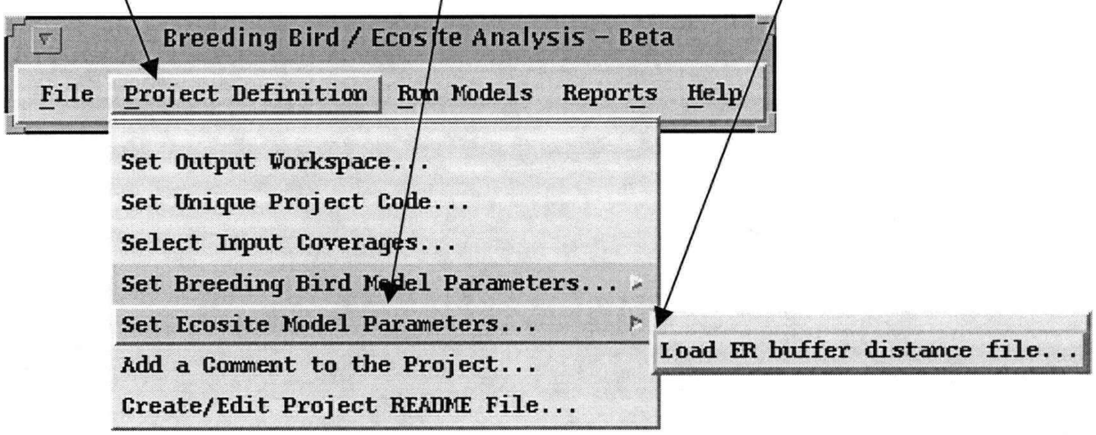
4.6 Setting the Ecosite Representivity Parameters

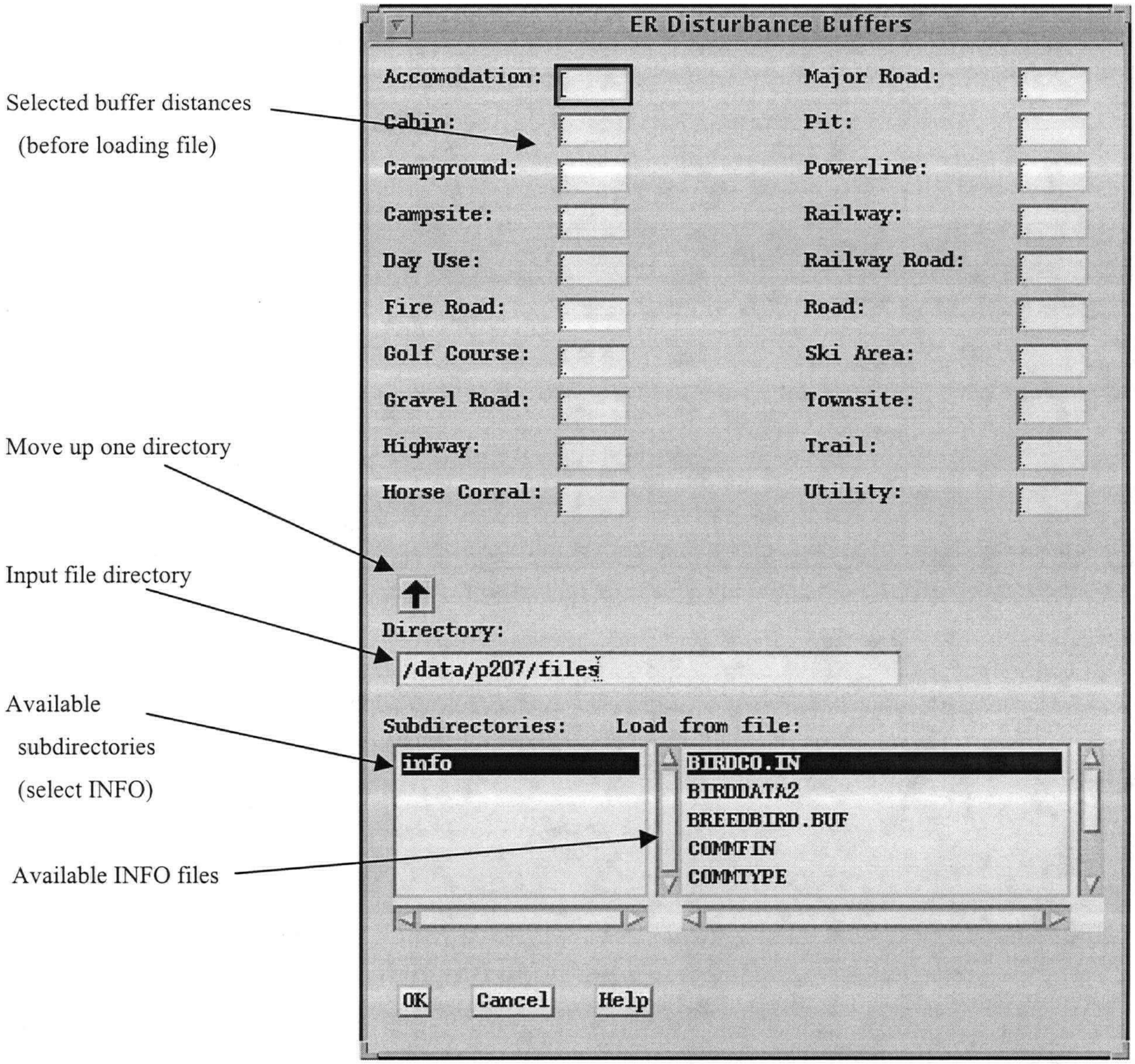
There is only one option available in the ecosite model parameters submenu: load the buffer distances file. Select the **PROJECT DEFINITION** option from the main menu then the **SET ECOSITE MODEL PARAMETERS** option from the first submenu and **LOAD ER BUFFER DISTANCE FILE** from the second submenu. This will open the buffer file selection menu shown on the following page.

Select **Project Definition** then...

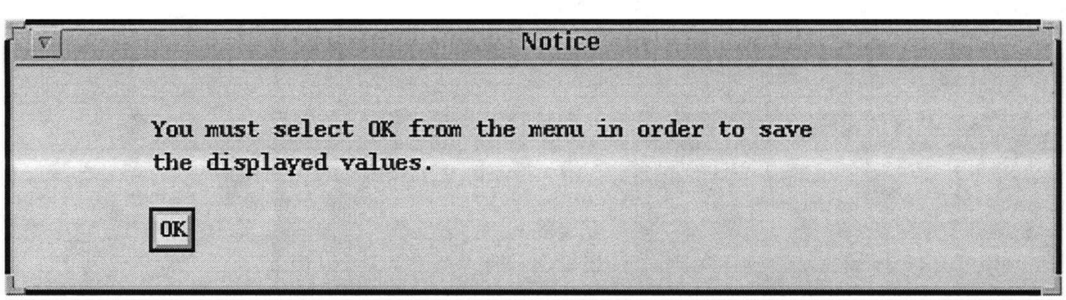
select **Set Ecosite Model Parameters** then...

select the only available option.





Note that the buffer distances can be keyed manually rather than selected from a file. Or, the distances can first be populated by selecting a file then manually edited if required. Also, when loading from a file the notice box below will be displayed to remind the user to select the **OK** button in order to save the displayed buffer values.

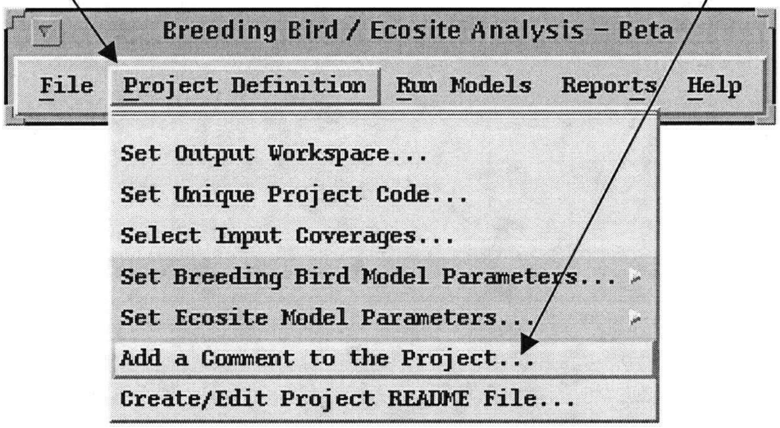


4.8 Entering a Project Comment

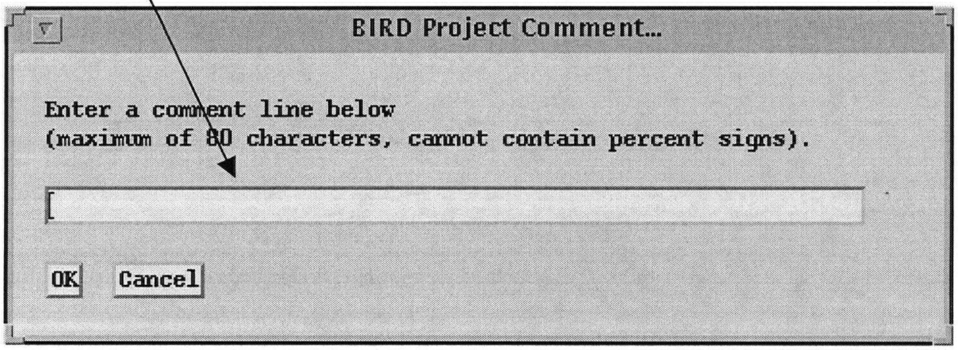
A comment can be entered which applies to the entire project and which will appear on all reports generated. To add a comment simply select the **PROJECT DEFINITION** option from the main menu followed by the **ADD A COMMENT TO THE PROJECT** option from the submenu. Fill the comment box in on the comment form which appears. Note that the comment cannot exceed 80 characters (it will be truncated at that length) and that it must not contain the '%' character.

Select **PROJECT DEFINITION** then...

select **ADD A COMMENT TO THE PROJECT**.



Key the desired project comment here (no special characters allowed)

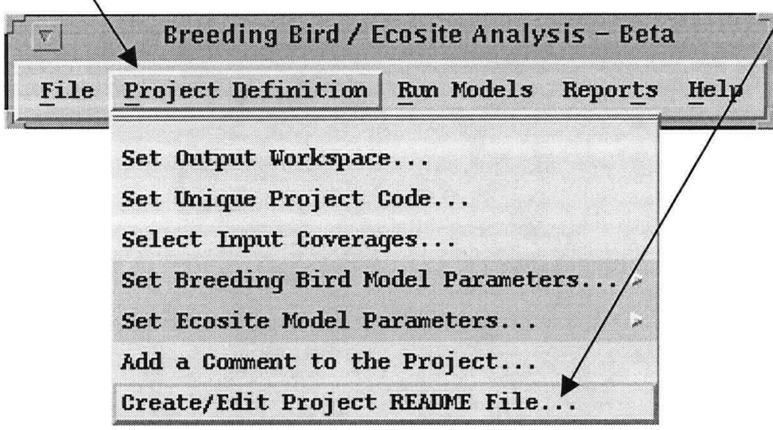


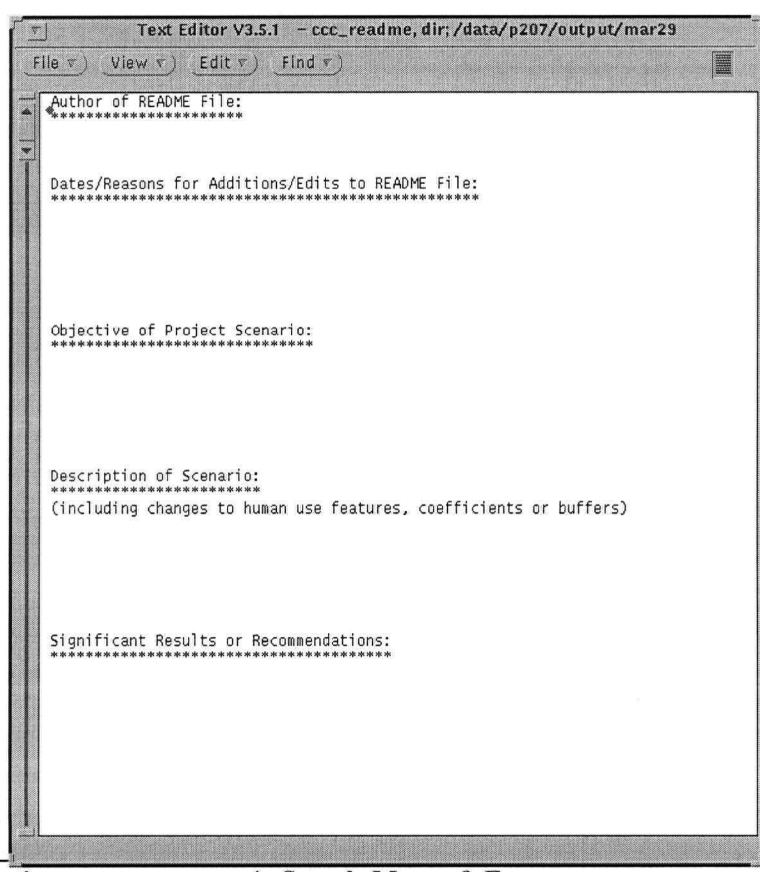
4.9 Creating/Editing the Project README File

To create or edit the project README file simply select **PROJECT DEFINITION** from the main menu followed by **CREATE/EDIT PROJECT README FILE** from the submenu. This will pop up a texteditor window open to the project file which can remain open and active throughout the application session. When the file is first created it will contain some default headings as shown below. The user simply keys the required information anywhere within the texteditor window. To save the file at any time use the right mouse button to select **File** from the upper left corner of the window then select the **Save** option from the submenu. To exit the texteditor window use the right mouse button on the top bar of the window then select **QUIT** from the submenu.

Select **PROJECT DEFINITION** then...

select **CREATE/EDIT PROJECT README FILE.**





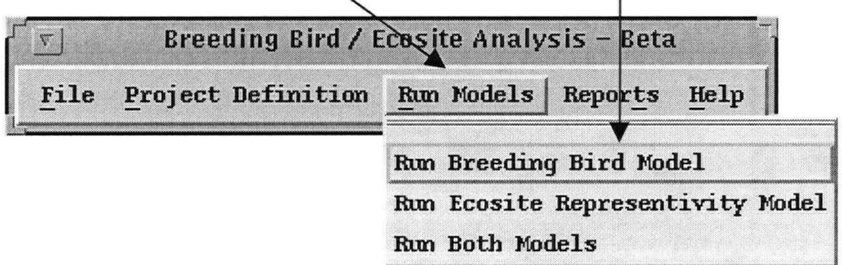
4.10 Running the Models

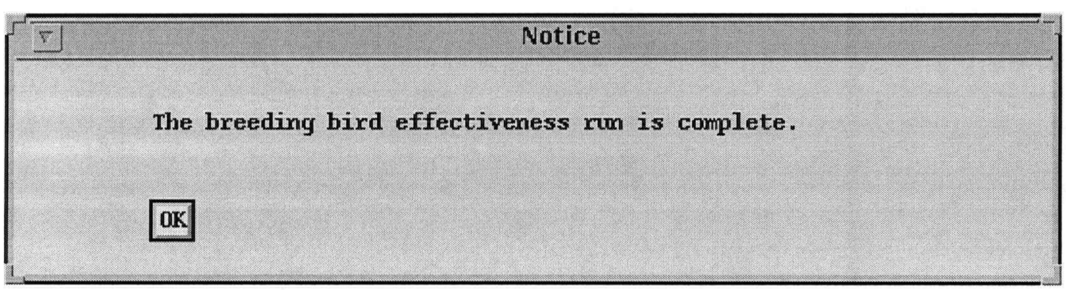
The two models, breeding bird (BB) and ecosite representivity (ER) can be run in either order. Each model is run by simply selecting **RUN MODELS** from the main menu then selecting the appropriate model from the submenu. A message box will appear to inform the user of progress throughout the run as well as to notify once the run is complete. Both models can be run consecutively by selecting **RUN BOTH MODELS** from the submenu.

Select **RUN MODELS** then...

select the appropriate model option

(e.g. **RUN BREEDING BIRD MODEL**).





4.11 Producing Output Reports

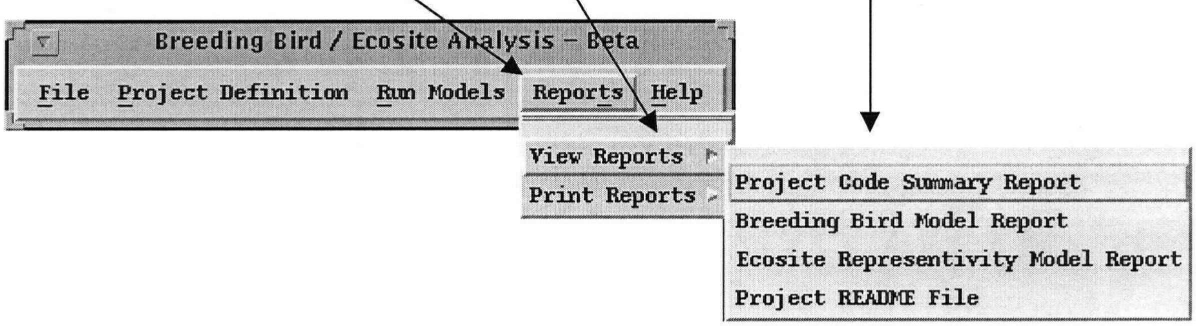
Model run reports are automatically generated during a model run but are not printed. Once the run is complete the user has the option to either view the reports on screen or send them to the printer. First select **REPORTS** from the main menu followed by the appropriate viewing option (e.g. **VIEW REPORTS**) and the desired report (e.g. **BREEDING BIRD MODEL REPORTS**). Selecting to view reports will display the reports on screen, selecting to print will produce hard copies of the reports at the default printer. Note that there is also an option to view a project code summary report which can be done at any time regardless of which models have been run. The project code summary report basically contains all information in the status box. The list of available reports is the same for both the view and print submenus.

Select **REPORTS** then...

select the viewing option (e.g. **VIEW REPORTS**) then...

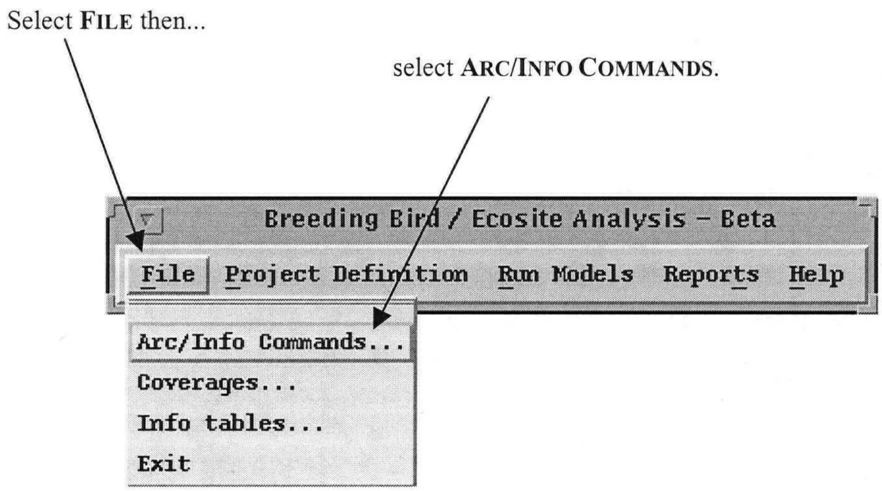
select the report type

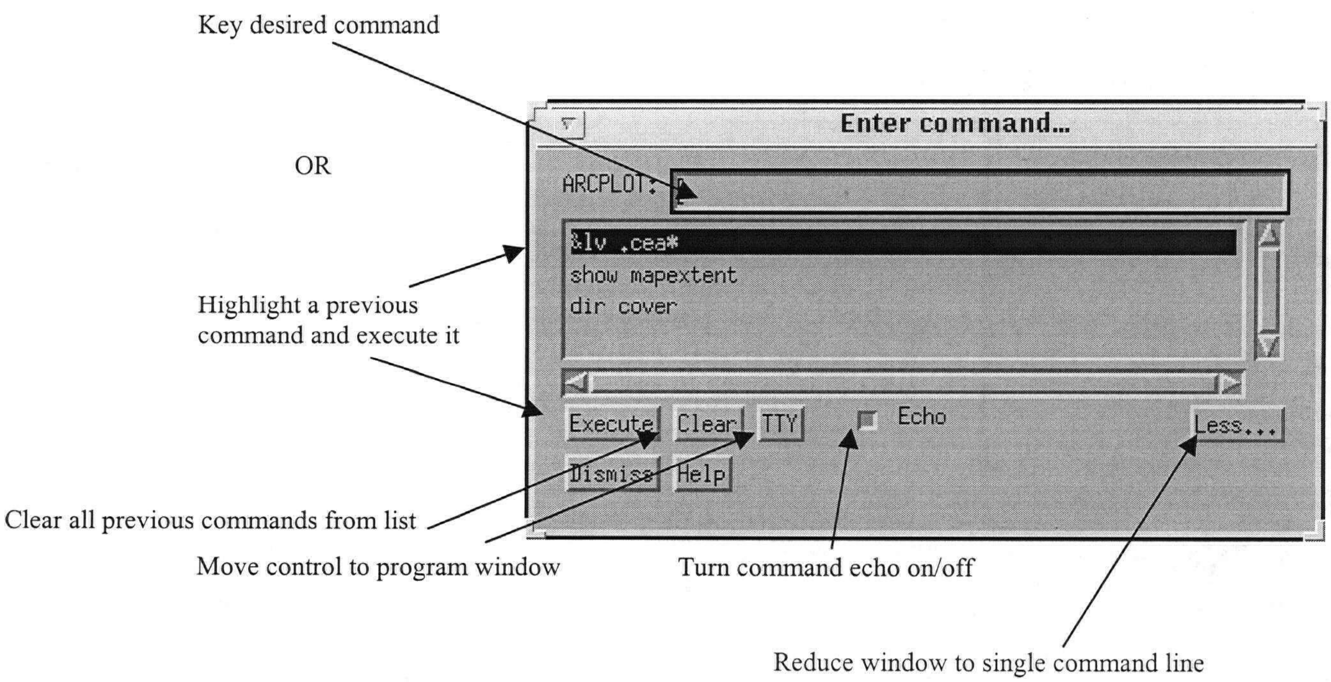
(e.g. **BREEDING BIRD MODEL REPORT**).



4.14 Using the Data Maintenance Tools

The main menu includes tools for entering arc/info commands interactively and for managing coverages and INFO files. To enter commands simply select **FILE** from the main menu followed by **ARC/INFO COMMANDS** from the submenu. This will open a commands input form. All commands keyed will be executed in the original program window. As long as input is entered from the form all other menus within the application will remain active. However, if **tty** is selected from the form then commands must be entered directly in the program window and all other menus are inactive until the command '&return' is entered.

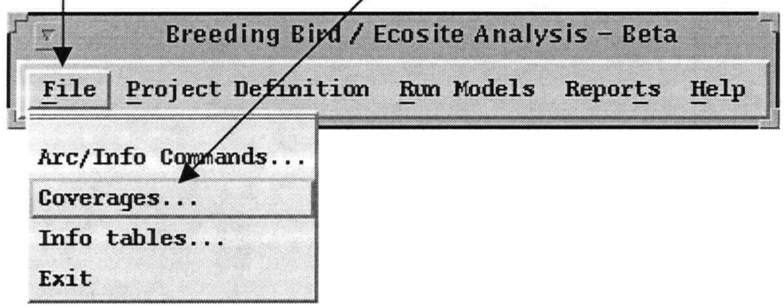




The coverages menu/form provides the user with some basic tools for coverage management such as renaming, copying and deleting. Select **FILE** from the main menu and **COVERAGES** from the submenu. A sample of the main coverage management form is on the next page. Below is a sample of the coverage subform for copying coverages.

Select **FILE** then...

select **COVERAGES**.



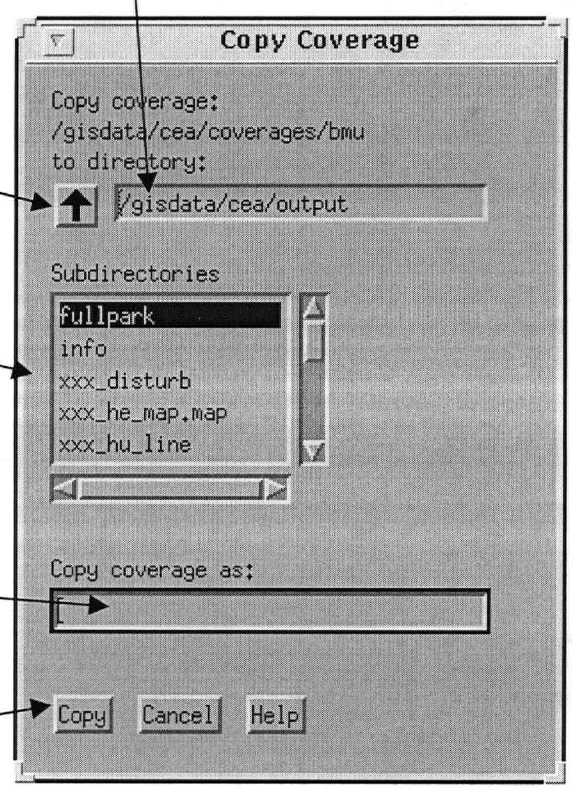
Current directory location

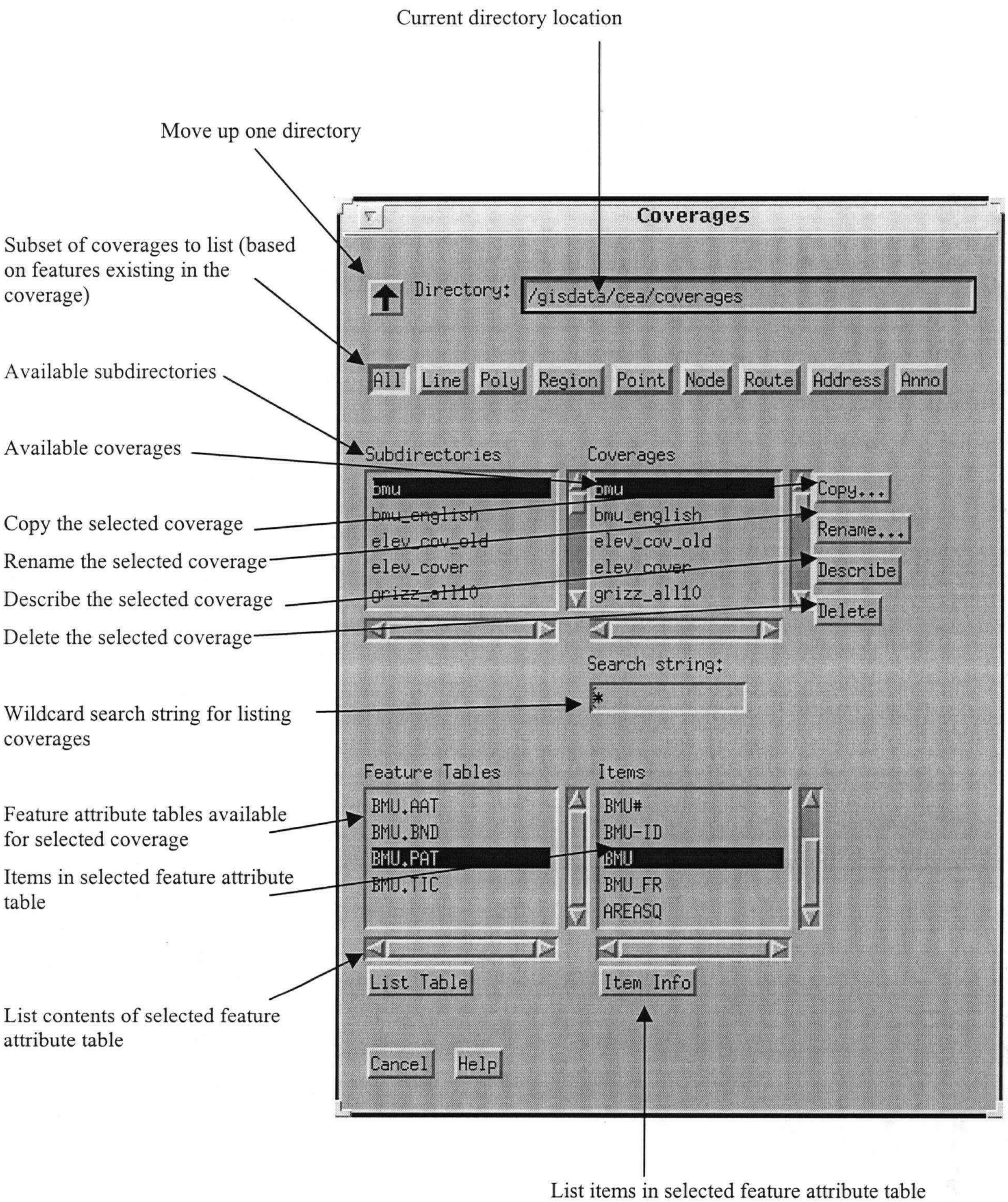
Move up on directory

Available subdirectories

Name for new coverage (13 characters maximum)

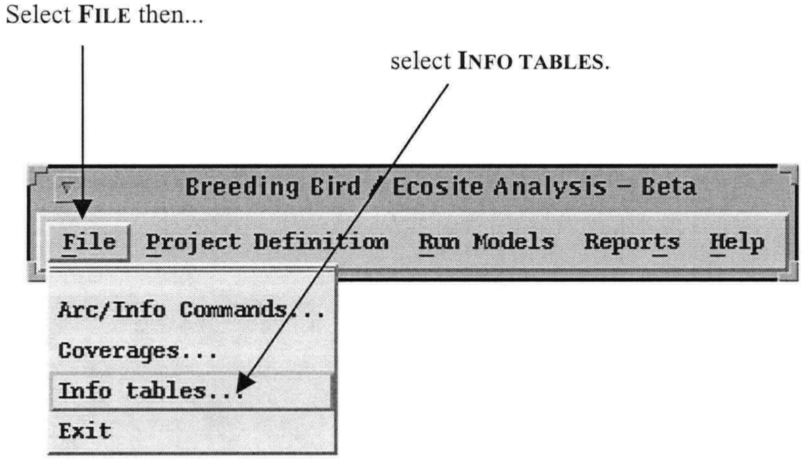
Perform the copy

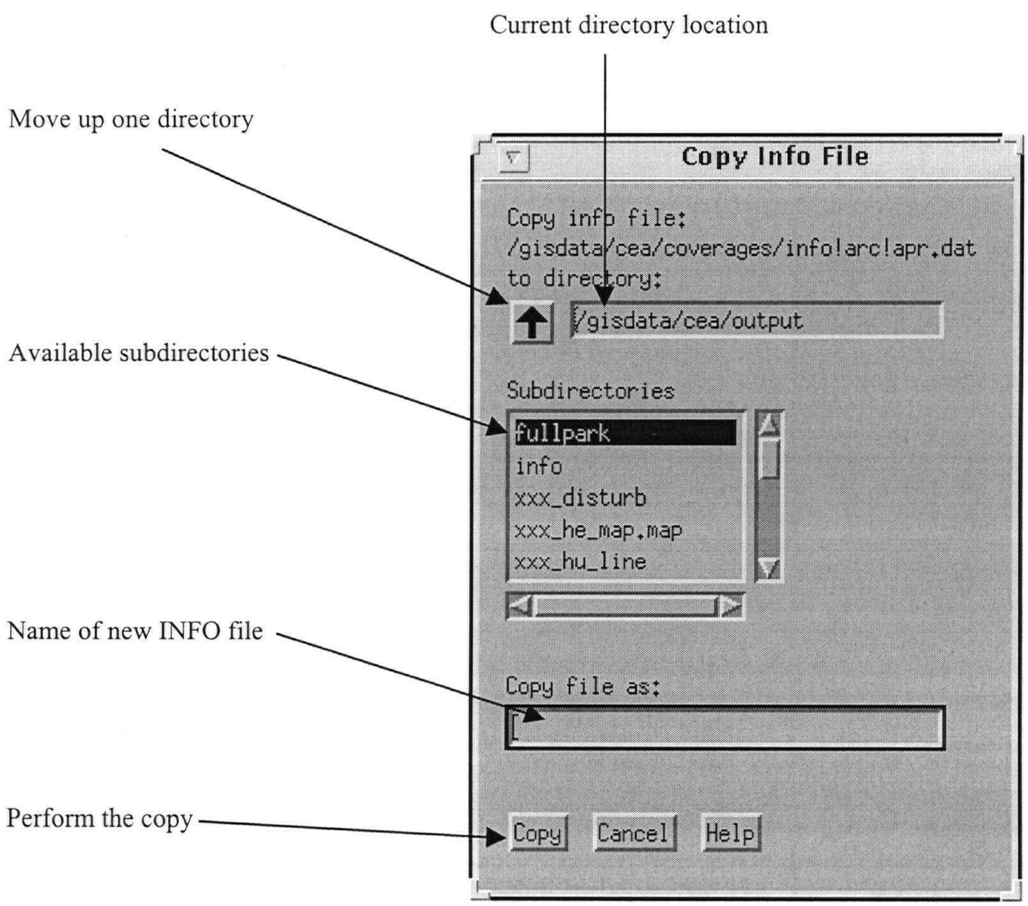


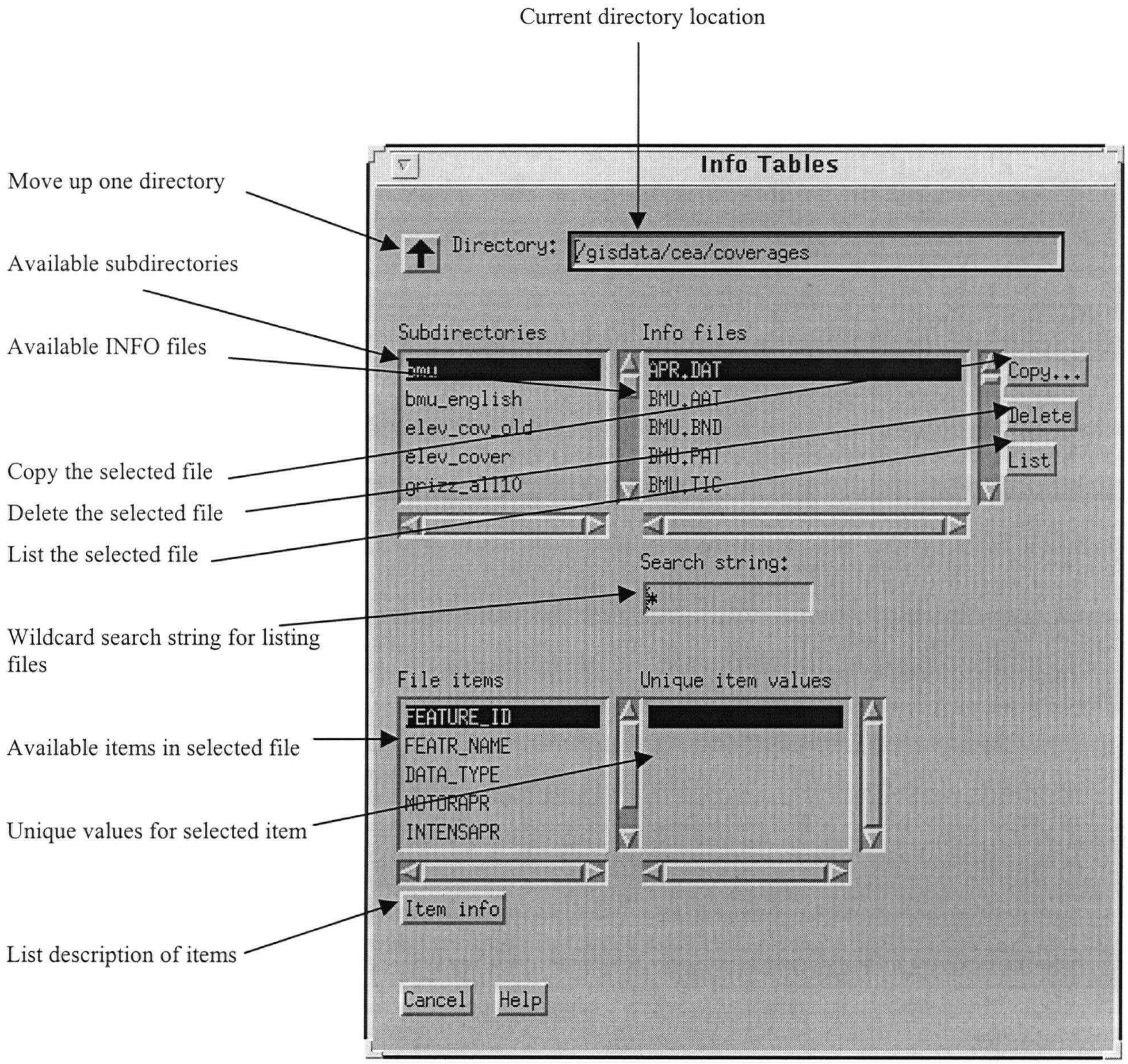


Note that some of the options in this menu will display a new window containing the requested information (e.g. **DESCRIBE**), others will request further input or confirmation (e.g. **DELETE**).

The INFO tables menu/forms provide basic INFO file management tools to the user. These tools can be used to copy and delete INFO files. To access these tools first select **FILE** from the main menu then select **INFO TABLES** from the submenu. A sample of the subform used to copy files is included below, the main INFO table management form is on the following page.







Note that some of the options in this menu will display a new window containing the requested information (e.g. **LIST**), others will request further input or confirmation (e.g. **DELETE**).

References

Dobson, Brenda. In Progress. A Planning Approach to Cumulative Effects Assessment: Developing and Testing Ecological Indicators Using Alternative Scenario Modeling in Jasper National Park. M. Sc. Thesis, Univ. of British Columbia.

Parks Canada. 1998. Cumulative Effects Assessment (CEA) Application for Grizzly Bears. User Guide. Rep. prep. for Parks Canada by The Forestry Corp. 59pp.

Parks Canada. 1998. Cumulative Effects Assessment (CEA) Application for Grizzly Bears. System Guide. Rep. prep. for Parks Canada by The Forestry Corp. 15pp.

Purves, H. and C. Doering. 1998. Grizzly Bear Habitat Effectiveness: Assessing cumulative effects of human use in Jasper National Park. 13pp.

APPENDIX IV CALCULATION FOR THE COEFFICIENTS OF DISTURBANCE FOR THE BREEDING BIRD HABITAT EFFECTIVENESS MODEL.

Table 22. Coefficients of Disturbance for the Breeding Bird Habitat Effectiveness Model

Ecosite	Bird Sensitive to Human Use (A)	Birds Tolerant of Human Use (B)	Breeding Bird Richness by Ecosite (C)	Coefficient of Disturbance (B / C)
AL1	11	16	27	0.59
AL2	8	21	29	0.72
AT1	6	13	19	0.68
AT2	3	11	14	0.79
AT3	3	18	21	0.86
BK1	13	22	35	0.63
BK2	5	10	15	0.67
BK4	12	25	37	0.68
BK6	7	14	21	0.67
BP1	2	6	8	0.75
BP2	3	5	8	0.63
BS1	0	4	4	1.00
BV1	6	21	27	0.78
BV2	6	6	12	0.50
BV3	4	3	7	0.43
BY1	11	31	42	0.74
BY2	11	21	32	0.66
BY4	11	10	21	0.48
BY6	3	4	7	0.57
BZ1	1	5	6	0.83
BZ2	2	7	9	0.78
CA1	8	18	26	0.69
CA2	11	11	22	0.50
CA4	6	6	12	0.50
CN1	5	19	24	0.79
CP1	1	14	15	0.93
CV1	11	17	28	0.61
DV1	0	10	10	1.00
DV2	4	13	17	0.76
EG1	9	25	34	0.74
EG3	5	15	20	0.75
EG4	4	18	22	0.82
EN2	3	17	20	0.85
EN3	0	4	4	1.00
FR1	8	21	29	0.72
FV1	10	17	27	0.63
FV2	8	5	13	0.38
GA1	9	18	27	0.67
GT1	4	12	16	0.75
GT2	3	18	21	0.86

Ecosite	Bird Sensitive to Human Use (A)	Birds Tolerant of Human Use (B)	Breeding Bird Richness by Ecosite (C)	Coefficient of Disturbance (B / C)
HC1	11	23	34	0.68
HC2	3	20	23	0.87
HC4	13	47	60	0.78
HD1	15	45	60	0.75
HD2	11	22	33	0.67
HD3	8	13	21	0.62
HD4	3	22	25	0.88
HE1	0	8	8	1.00
HE2	0	6	6	1.00
IB1	0	10	10	1.00
IB2	4	8	12	0.67
IB3	6	9	15	0.60
JN1	1	14	15	0.93
KA1	0	1	1	1.00
LV2	3	10	13	0.77
LV3	5	19	24	0.79
MC1	6	14	20	0.70
ML1	10	17	27	0.63
ML2	8	17	25	0.68
ML3	6	10	16	0.63
MP1	2	11	13	0.85
MQ1	4	11	15	0.73
NG1	2	8	10	0.80
NT2	2	12	14	0.86
NT3	0	10	10	1.00
NY1	2	13	15	0.87
NY3	18	38	56	0.68
PL1	10	23	33	0.70
PL4	6	17	23	0.74
PL5	5	24	29	0.83
PP1	6	14	20	0.70
PP3	11	16	27	0.59
PP4	3	15	18	0.83
PP6	9	19	28	0.68
PP7	4	19	23	0.83
PR1	6	16	22	0.73
PR2	17	32	49	0.65
PR3	10	12	22	0.55
PR4	6	15	21	0.71
PR6	8	12	20	0.60
PT1	10	26	36	0.72
PT3	7	24	31	0.77
PT4	6	23	29	0.79
PT5	12	32	44	0.73
RD1	1	8	9	0.89
SB1	12	26	38	0.68
SB2	9	11	20	0.55

Ecosite	Bird Sensitive to Human Use (A)	Birds Tolerant of Human Use (B)	Breeding Bird Richness by Ecosite (C)	Coefficient of Disturbance (B / C)
SB3	6	4	10	0.40
SB4	6	15	21	0.71
SB5	1	10	11	0.91
SF1	4	11	15	0.73
SP1	4	7	11	0.64
SX1	4	23	27	0.85
SX2	10	20	30	0.67
SX3	3	19	22	0.86
TA2	2	15	17	0.88
TA3	11	22	33	0.67
TR1	3	22	25	0.88
TR2	0	15	15	1.00
TZ1	3	6	9	0.67
TZ2	5	7	12	0.58
TZ3	1	2	3	0.67
VD1	4	5	9	0.56
VD2	8	11	19	0.58
VL1	19	52	71	0.73
VL3	16	37	53	0.70
VL4	8	22	30	0.73
VL5	7	20	27	0.74
WF1	8	12	20	0.60
WF2	4	19	23	0.83
WF3	0	7	7	1.00
WF4	1	10	11	0.91
WF7	0	22	22	1.00
WH2	5	11	16	0.69
WH3	0	11	11	1.00
WH5	4	16	20	0.80
WW1	0	2	2	1.00

APPENDIX V CUMULATIVE EFFECTS ASSESSMENT RESULTS FOR THE PRESENT LEVEL OF LAND USE USING THE DEFAULT PARAMETERS

Table 23. Breeding bird habitat effectiveness at the present level of land use in Three Valley Confluence.

Ecosite Type	# of Polygons	Potential Habitat Value	Realized Habitat Value	Breeding Bird Habitat Effectiveness (%) (present level of land use)
AL1	5	2851.94	2822.67	98.97
AL2	2	304.29	304.29	100
AT1	146	62915.07	40362.49	64.15
AT3	22	10187.18	8185.55	80.35
BK6	2	3505.78	3505.78	100
BP1	10	2619.67	2558.1	97.65
BS1	1	331.74	331.74	100
BY1	14	25827.61	25827.61	100
BY2	13	13148.35	13108	99.69
BY4	1	510.1	510.1	100
CA1	13	24389.52	23453.95	96.16
CA2	19	47621.2	47541.37	99.83
CA4	31	36688.71	36590.07	99.73
CN1	5	2888.24	2888.24	100
CV1	14	29568.79	29547.51	99.93
EG1	45	71996.78	68412.6	95.02
EG3	10	9062.75	9034.93	99.69
EG4	21	25421.11	23544.22	92.62
EN2	12	10441.64	10441.64	100
EN3	5	2049.63	2049.63	100
FR1	58	18315.8	15158.73	82.76
FV1	6	4834.77	4834.77	100
FV2	2	1327.86	1327.86	100
GA1	2	2326.05	2326.05	100
GT1	2	3060.54	3060.54	100
HC1	2	2147.36	2147.36	100
HC4	2	630.97	616.54	97.71
HD1	40	51564.9	45446.19	88.13
HD2	10	7402.28	7035.4	95.04
HD3	25	7390.74	6808.72	92.13
HD4	24	6996.51	5405.66	77.26
HE1	16	6484.39	6448.99	99.45
HE2	1	426.6	426.6	100
IB2	3	1403.95	1403.95	100
IB3	1	311.4	311.4	100
JN1	17	12972.12	12200.49	94.05
KA1	1	10.96	10.96	100
LV2	9	3836.06	3835.49	99.99
LV3	10	10232.96	10232.96	100
ML1	7	7529.94	7529.94	100

Ecosite Type	# of Polygons	Potential Habitat Value	Realized Habitat Value	Breeding Bird Habitat Effectiveness (%) (present level of land use)
MP1	3	1219.99	1219.99	100
NT2	1	589.43	589.43	100
NT3	2	276.11	276.11	100
NY1	10	17702.97	17264.2	97.52
NY3	83	164134.8	154240.2	93.97
PL1	20	21466.44	21440.53	99.88
PL4	10	5710.22	5710.22	100
PL5	4	3954.76	3942.41	99.69
PP3	5	3711.16	3711.16	100
PP6	2	1207.91	1207.91	100
PR1	10	7595.37	7592.66	99.96
PR2	56	142015.8	139967.7	98.56
PR3	34	29217.64	27292.49	93.41
PR4	10	8921.18	8673.59	97.22
PT1	102	163612.8	158636.4	96.96
PT3	62	183765.5	182032.3	99.06
PT4	23	21354.85	20253.68	94.84
PT5	34	122260.6	120817.4	98.82
RD1	10	5339.39	5339.39	100
SB1	9	7342.52	7342.52	100
SB2	13	9050.95	9050.95	100
SB3	6	3802.21	3802.21	100
SB4	15	22220.33	22220.33	100
SX1	4	3127.95	3127.95	100
SX2	10	11906.55	11818.8	99.26
SX3	1	1184.95	1184.95	100
TA2	1	13.05	13.05	100
TZ1	2	100.95	99.36	98.42
VD2	2	1748.59	1748.59	100
VL1	34	38056.17	35848	94.2
VL3	77	46993.26	38426.44	81.77
VL5	16	7034.29	6787.96	96.5
WF1	12	7493.7	7493.7	100
WF2	12	7948.39	7948.39	100
WF3	21	5066.66	5066.66	100
WF7	4	1921.76	1921.76	100
WH2	5	860.1	543.81	63.23
WH3	7	3012.41	3012.41	100
WH5	15	13591.1	13377.93	98.43

Table 24 . Ecosite representation at the present level of land use in Three Valley Confluence. JNP and BNP are Jasper and Banff National Parks.repectively.

ecosite	# Individual patches of ecosite	Ave. potential polygon size km^2	standard deviation*	Ave. realized polygon size km^2	standard deviation*	Habitat Effectiveness %	Representation Contribution in JNP %	Representation contribution in BNP/JNP %	Realized contribution to JNP %	Realized contribution to BNP/JNP %
AL1	3	0.352	0.286	0.146	0.155	96.98	3.21	3.11	1.79	1.73
AL2	2	0.052	0.052	0.035	0.047	99.17	0.21	0.21	0.13	0.13
AT1	21	1.577	1.814	0.127	0.245	56.37	48.13	27.13	38.56	21.73
AT3	3	1.617	2.064	0.104	0.241	55.55	84.5	46.94	84.5	46.94
BK6	2	0.835	0.503	0.835	0.503	100	2.99	2.99	1.51	1.51
BP1	8	0.409	0.160	0.398	0.172	97.14	8.71	8.46	6.69	6.5
BS1	1	0.829	0.000	0.829	0.000	100	0.99	0.99	0.41	0.41
BY1	14	0.439	0.173	0.439	0.173	100	6.14	6.14	2.41	2.41
BY2	11	0.374	0.269	0.314	0.255	99.45	1.36	1.36	1.06	1.06
BY4	1	0.243	0.000	0.243	0.000	100	0.85	0.85	0.33	0.33
CA1	9	1.042	1.452	0.641	1.223	95.67	11.29	10.8	8.34	7.98
CA2	13	1.665	1.902	1.028	1.633	99.75	13.63	13.6	11.55	11.52
CA4	26	1.176	1.767	0.846	1.562	99.62	22.11	22.03	20.88	20.8
CL	9	0.248	0.128	0.223	0.138	99.72	5.29	5.27	3.22	3.21
CN1	5	0.241	0.117	0.241	0.117	100	4.01	4.01	2.6	2.6
CR	17	1.412	1.745	1.020	1.561	97.67	6.28	6.13	3.79	3.7
CV1	9	1.173	2.302	0.811	1.933	99.87	7.87	7.86	4.64	4.63
EF1	10	0.306	0.283	0.306	0.283	100	4.14	4.14	3.46	3.46
EG1	34	0.623	0.474	0.466	0.473	94.71	10.77	10.2	7.33	6.94
EG3	6	0.755	0.464	0.499	0.340	99.19	5.47	5.42	3.29	3.27
EG4	20	0.578	0.441	0.411	0.432	92.46	9.69	8.96	8.76	8.1
EN2	12	0.435	0.620	0.348	0.556	99.84	4.22	4.21	3.4	3.39
EN3	5	1.025	1.084	1.025	1.084	100	7.75	7.75	5.47	5.47
FR1	13	0.486	0.314	0.086	0.181	74.98	26.19	19.64	16.22	12.16
FV1	6	0.298	0.172	0.298	0.172	100	1.93	1.93	1.73	1.73
FV2	2	0.511	0.212	0.511	0.212	100	2.38	2.38	2.16	2.16
GA1	2	0.431	0.198	0.286	0.255	99.66	100.04	99.7	15.36	15.31
GL	4	0.191	0.046	0.191	0.046	100	0.15	0.15	0.07	0.07
GT1	2	0.956	0.800	0.956	0.800	100	8.69	8.69	3.26	3.26
HC1	2	0.316	0.192	0.316	0.192	100	0.9	0.9	0.55	0.55
HC4	1	0.105	0.000	0.049	0.064	92.93	0.13	0.12	0.08	0.08
HD1	16	0.537	0.291	0.146	0.245	81.63	36.54	29.82	25.41	20.74
HD2	3	0.748	0.707	0.352	0.546	94.14	15.93	15	7.47	7.03

* Standard deviation represents the average amount by which the data differ from the mean or average.

ecosite	# Individual patches of ecosite	Ave. potential polygon size km^2	standard deviation	Ave. realized polygon size km^2	standard deviation	Habitat Effectiveness %	Representation Contribution in JNP %	Representation contribution in BNP/JNP %	Realized contribution to JNP %	Realized contribution to BNP/JNP %
HD3	9	0.391	0.222	0.098	0.171	89.19	10.04	8.95	8.49	7.57
HD4	6	0.466	0.529	0.038	0.062	46.23	33.91	15.68	28.1	12.99
HE1	13	0.623	0.873	0.574	0.820	99.12	17.8	17.64	11.52	11.41
HE2	1	0.711	0.000	0.711	0.000	100	1.15	1.15	0.6	0.6
IB2	3	0.390	0.376	0.390	0.376	100	4.28	4.28	3.21	3.21
IB3	1	0.208	0.000	0.208	0.000	100	0.97	0.97	0.88	0.88
JN1	16	0.541	0.786	0.406	0.684	93.85	5.93	5.57	5.34	5.01
KA1	1	0.110	0.000	0.110	0.000	100	1.82	1.82	1.15	1.15
LV2	8	0.369	0.328	0.294	0.243	99.73	3.43	3.42	2.94	2.93
LV3	10	0.426	0.354	0.426	0.354	100	4.4	4.4	3.24	3.24
M	5	0.416	0.233	0.416	0.233	100	1.2	1.2	0.8	0.8
M+GL	5	0.336	0.110	0.336	0.110	100	1.76	1.76	1.07	1.07
ML1	7	0.398	0.453	0.230	0.230	99.07	2.66	2.64	2.21	2.19
ML2	4	0.545	0.353	0.545	0.353	100	1.97	1.97	1.92	1.92
ML3	1	0.491	0.000	0.491	0.000	100	9.92	9.92	9.92	9.92
MP1	3	0.313	0.208	0.313	0.208	100	1	1	0.51	0.51
NT2	1	0.421	0.000	0.421	0.000	100	2.24	2.24	1.21	1.21
NT3	2	0.138	0.024	0.068	0.038	98.34	3.05	2.99	2.73	2.69
NY1	6	1.967	2.357	0.851	1.600	93.74	35.46	33.23	24.92	23.36
NY3	27	1.086	1.599	0.215	0.587	91.14	28.04	25.55	24.05	21.92
PL1	18	0.361	0.267	0.342	0.242	99.79	2.98	2.98	1.48	1.47
PL4	10	0.248	0.233	0.248	0.232	99.78	3.28	3.27	1.57	1.57
PL5	3	0.455	0.093	0.449	0.101	98.72	4.03	3.98	0.98	0.97
PP3	5	0.275	0.104	0.275	0.104	100	2.77	2.77	1.41	1.41
PP6	2	0.216	0.156	0.216	0.156	100	1.49	1.49	0.77	0.77
PR1	8	0.432	0.575	0.383	0.555	99.93	3.22	3.22	1.73	1.73
PR2	36	0.805	0.748	0.490	0.671	98.1	8.33	8.17	5.42	5.32
PR3	12	1.107	0.917	0.460	0.623	93.45	24.63	23.02	13.41	12.53
PR4	6	0.708	0.552	0.315	0.498	96.35	7.3	7.04	3.77	3.63
PT1	41	1.108	1.184	0.312	0.544	94.79	30.74	29.14	24.61	23.33
PT3	35	1.694	1.972	0.578	0.943	98.41	73.18	72.02	70.74	69.62
PT4	7	1.052	0.830	0.130	0.210	88.52	59.56	52.72	59.56	52.72
PT5	20	1.389	1.387	0.486	0.779	97.93	35.27	34.53	30.49	29.86
R	6	1.310	1.031	1.123	1.063	99.99	3.24	3.24	2.26	2.26
R+CR	24	2.155	2.433	2.143	2.440	99.44	3.39	3.37	2.32	2.3
R+GL	3	1.718	2.567	1.718	2.567	100	1.96	1.96	1.08	1.08

ecosite	# Individual patches of ecosite	Ave. potential polygon size km^2	standard deviation	Ave. realized polygon size km^2	standard deviation	Habitat Effectiveness %	Representation Contribution in JNP %	Representation contribution in BNP/JNP %	Realized contribution to JNP %	Realized contribution to BNP/JNP %
R+T	4	0.636	0.292	0.636	0.292	100	0.8	0.8	0.32	0.32
RD1	10	0.593	0.317	0.593	0.317	100	8.88	8.88	5.71	5.71
RG	18	0.397	0.487	0.353	0.475	98.8	6.14	6.07	4.37	4.32
SB1	9	0.215	0.074	0.215	0.074	100	2.21	2.21	1.3	1.3
SB2	13	0.348	0.293	0.348	0.293	100	4.29	4.29	2.37	2.37
SB3	6	0.634	0.283	0.634	0.283	100	8.07	8.07	3.56	3.56
SB4	15	0.705	0.541	0.661	0.480	99.89	5.82	5.81	3.56	3.55
SC	3	0.096	0.046	0.096	0.046	100	2.84	2.84	1.97	1.97
SX1	4	0.290	0.114	0.290	0.114	100	1.03	1.03	0.76	0.76
SX2	7	0.567	0.621	0.391	0.501	98.5	6.86	6.75	4.27	4.21
SX3	1	0.539	0.000	0.539	0.000	100	6.16	6.16	1.86	1.86
T	37	0.405	0.399	0.405	0.399	100	5.97	5.97	4.38	4.38
T+GL	1	0.146	0.000	0.146	0.000	100	0.9	0.9	0.28	0.28
T+M	2	0.260	0.019	0.260	0.019	100	2.02	2.02	0.95	0.95
T+RG	10	0.713	0.454	0.750	0.466	94.64	4.62	4.37	2.89	2.73
TA2	1	0.008	0.000	0.008	0.000	100	0.03	0.03	0.03	0.03
TK1	6	0.506	0.580	0.434	0.561	99.96	5.41	5.41	3.32	3.32
TZ1	1	0.112	0.000	0.110	0.000	98.22	0.36	0.36	0.36	0.36
VD2	2	0.460	0.403	0.460	0.403	100	4.38	4.38	3.87	3.87
VL1	15	0.357	0.253	0.175	0.218	94.78	26.84	25.44	17.37	16.46
VL3	26	0.341	0.884	0.117	0.326	79.29	35.28	27.97	21.92	17.38
VL5	10	0.261	0.165	0.130	0.131	94.95	27.83	26.42	27.83	26.42
WF1	12	0.312	0.173	0.312	0.173	100	15.05	15.05	2.93	2.93
WF2	12	0.288	0.227	0.288	0.227	100	2.21	2.21	0.96	0.96
WF3	20	0.362	0.274	0.362	0.274	99.96	4.74	4.74	1.92	1.92
WF4	1	0.156	0.000	0.156	0.000	100	1.18	1.18	0.45	0.45
WF7	4	0.218	0.120	0.218	0.120	100	0.77	0.77	0.38	0.38
WH2	2	0.269	0.054	0.167	0.198	62.03	3.03	1.88	2.66	1.65
WH3	7	0.391	0.172	0.391	0.172	100	3.82	3.82	3.35	3.35
WH5	11	0.618	0.424	0.557	0.411	98.28	19.36	19.03	12.44	12.22
ZZ	70	0.175	0.696	0.118	0.307	88.87	10.33	9.18	6.35	5.64

APPENDIX VI DEFAULT AND TEST PARAMETER VALUES FOR THE SENSITIVITY ANALYSIS FOR THE ECOSITE REPRESENTATION AND BREEDING BIRD MODELS

Table 25. Sensitivity analysis disturbance buffers for the Ecosite Representation Model.

Feature Category	Default Disturbance Buffers	Disturbance buffer + ½	Zones of Influence - ½
trail	3 m	5	2
fire road	9 m	14	5
highway	80 m	120	40
major road	65 m	98	33
road	50 m	75	25
gravel road	30 m	45	15
railway road	27 m	41	14
railway	40 m	60	20
powerline (include. Pipeline, telus, etc.)	14 m	21	7
day use	80 m	120	40
campsite	90 m	135	45
utility (include sewage lagoon, power stations)	50 m	75	25
cabin (include portal, acc huts, warden cabins)	80 m	120	40
campground	80 m	120	40
accommodation	80 m	120	40
townsite	80 m	120	40
horse corral	80 m	120	40
golf course	50 m	75	25
pits	50 m	75	25
ski area	50 m	75	25

Table 26. Sensitivity analysis disturbance buffers for the Breeding Bird Model.

Feature Category	Default Disturbance Buffers	Disturbance Buffer + ½	Disturbance Buffer - ½
trail	0 m	0*	0
fire road	17 m	26	9
highway	260 m	390	130
major road	145 m	218	73
road	130 m	195	65
gravel road	110 m	165	55
railway road	19 m	29	9
railway	130 m	195	65
powerline (include. Pipeline, telus, etc.)	34 m	51	17
day use	100 m	150	50
campsite	110 m	165	55
utility (include sewage lagoon, power stations)	100 m	150	50
cabin (include portal, acc huts, warden cabins)	100 m	150	50
campground	100 m	150	50
accommodation	100 m	150	50
townsite	100 m	150	50
horse corral	100 m	150	50
golf course	100 m	150	50
pits	100 m	150	50
ski area	100 m	150	50

Table 27. Default and test coefficients of disturbance for the sensitivity analysis for the Breeding Bird Habitat Effectiveness Model.

Ecosite	Bird Sensitive to Human Use	Increase # of sensitive birds by (+) 50 %	Decrease # of sensitive birds by (-) 50 %	Richness by Ecosite	Default Coefficient	Coefficient + 50%	Coefficient - 50%
AL1	11	16.5	5.5	27	0.59	0.39	0.80
AL2	8	12	4	29	0.72	0.59	0.86
AT1	6	9	3	19	0.68	0.53	0.84
AT2	3	4.5	1.5	14	0.79	0.68	0.89
AT3	3	4.5	1.5	21	0.86	0.79	0.93
BK1	13	19.5	6.5	35	0.63	0.44	0.81
BK2	5	7.5	2.5	15	0.67	0.50	0.83
BK4	12	18	6	37	0.68	0.51	0.84
BK6	7	10.5	3.5	21	0.67	0.50	0.83
BP1	2	3	1	8	0.75	0.63	0.88
BP2	3	4.5	1.5	8	0.63	0.44	0.81
BS1	0	2	0	4	1.00	0.50	1.00
BV1	6	9	3	27	0.78	0.67	0.89
BV2	6	9	3	12	0.50	0.25	0.75
BV3	4	6	2	7	0.43	0.14	0.71
BY1	11	16.5	5.5	42	0.74	0.61	0.87
BY2	11	16.5	5.5	32	0.66	0.48	0.83
BY4	11	16.5	5.5	21	0.48	0.21	0.74
BY6	3	4.5	1.5	7	0.57	0.36	0.79
BZ1	1	1.5	0.5	6	0.83	0.75	0.92
BZ2	2	3	1	9	0.78	0.67	0.89
CA1	8	12	4	26	0.69	0.54	0.85
CA2	11	16.5	5.5	22	0.50	0.25	0.75
CA4	6	9	3	12	0.50	0.25	0.75
CN1	5	7.5	2.5	24	0.79	0.69	0.90
CP1	1	1.5	0.5	15	0.93	0.90	0.97
CV1	11	16.5	5.5	28	0.61	0.41	0.80
DV1	0	5	0	10	1.00	0.50	1.00
DV2	4	6	2	17	0.76	0.65	0.88
EG1	9	13.5	4.5	34	0.74	0.60	0.87

Ecosite	Bird Sensitive to Human Use	Increase # of sensitive birds by (+) 50 %	Decrease # of sensitive birds by (-) 50 %	Richness by Ecosite	Default Coefficient	Coefficient + 50%	Coefficient - 50%
EG3	5	7.5	2.5	20	0.75	0.63	0.88
EG4	4	6	2	22	0.82	0.73	0.91
EN2	3	4.5	1.5	20	0.85	0.78	0.93
EN3	0	2	0	4	1.00	0.50	1.00
FR1	8	12	4	29	0.72	0.59	0.86
FV1	10	15	5	27	0.63	0.44	0.81
FV2	8	12	4	13	0.38	0.08	0.69
GA1	9	13.5	4.5	27	0.67	0.50	0.83
GT1	4	6	2	16	0.75	0.63	0.88
GT2	3	4.5	1.5	21	0.86	0.79	0.93
HC1	11	16.5	5.5	34	0.68	0.51	0.84
HC2	3	4.5	1.5	23	0.87	0.80	0.93
HC4	13	19.5	6.5	60	0.78	0.68	0.89
HD1	15	22.5	7.5	60	0.75	0.63	0.88
HD2	11	16.5	5.5	33	0.67	0.50	0.83
HD3	8	12	4	21	0.62	0.43	0.81
HD4	3	4.5	1.5	25	0.88	0.82	0.94
HE1	0	4	0	8	1.00	0.50	1.00
HE2	0	3	0	6	1.00	0.50	1.00
IB1	0	5	0	10	1.00	0.50	1.00
IB2	4	6	2	12	0.67	0.50	0.83
IB3	6	9	3	15	0.60	0.40	0.80
JN1	1	1.5	0.5	15	0.93	0.90	0.97
KA1	0	1	0	1	1.00	0.00	1.00
LV2	3	4.5	1.5	13	0.77	0.65	0.88
LV3	5	7.5	2.5	24	0.79	0.69	0.90
MC1	6	9	3	20	0.70	0.55	0.85
ML1	10	15	5	27	0.63	0.44	0.81
ML2	8	12	4	25	0.68	0.52	0.84
ML3	6	9	3	16	0.63	0.44	0.81
MP1	2	3	1	13	0.85	0.77	0.92

Ecosite	Bird Sensitive to Human Use	Increase # of sensitive birds by (+) 50 %	Decrease # of sensitive birds by (-) 50 %	Richness by Ecosite	Default Coefficient	Coefficient + 50%	Coefficient - 50%
MQ1	4	6	2	15	0.73	0.60	0.87
NG1	2	3	1	10	0.80	0.70	0.90
NT2	2	3	1	14	0.86	0.79	0.93
NT3	0	5	0	10	1.00	0.50	1.00
NY1	2	3	1	15	0.87	0.80	0.93
NY3	18	27	9	56	0.68	0.52	0.84
PL1	10	15	5	33	0.70	0.55	0.85
PL4	6	9	3	23	0.74	0.61	0.87
PL5	5	7.5	2.5	29	0.83	0.74	0.91
PP1	6	9	3	20	0.70	0.55	0.85
PP3	11	16.5	5.5	27	0.59	0.39	0.80
PP4	3	4.5	1.5	18	0.83	0.75	0.92
PP6	9	13.5	4.5	28	0.68	0.52	0.84
PP7	4	6	2	23	0.83	0.74	0.91
PR1	6	9	3	22	0.73	0.59	0.86
PR2	17	25.5	8.5	49	0.65	0.48	0.83
PR3	10	15	5	22	0.55	0.32	0.77
PR4	6	9	3	21	0.71	0.57	0.86
PR6	8	12	4	20	0.60	0.40	0.80
PT1	10	15	5	36	0.72	0.58	0.86
PT3	7	10.5	3.5	31	0.77	0.66	0.89
PT4	6	9	3	29	0.79	0.69	0.90
PT5	12	18	6	44	0.73	0.59	0.86
RD1	1	1.5	0.5	9	0.89	0.83	0.94
SB1	12	18	6	38	0.68	0.53	0.84
SB2	9	13.5	4.5	20	0.55	0.33	0.78
SB3	6	9	3	10	0.40	0.10	0.70
SB4	6	9	3	21	0.71	0.57	0.86
SB5	1	1.5	0.5	11	0.91	0.86	0.95
SF1	4	6	2	15	0.73	0.60	0.87
SP1	4	6	2	11	0.64	0.45	0.82

Ecosite	Bird Sensitive to Human Use	Increase # of sensitive birds by (+) 50 %	Decrease # of sensitive birds by (-) 50 %	Richness by Ecosite	Default Coefficient	Coefficient + 50%	Coefficient - 50%
SX1	4	6	2	27	0.85	0.78	0.93
SX2	10	15	5	30	0.67	0.50	0.83
SX3	3	4.5	1.5	22	0.86	0.80	0.93
TA2	2	3	1	17	0.88	0.82	0.94
TA3	11	16.5	5.5	33	0.67	0.50	0.83
TR1	3	4.5	1.5	25	0.88	0.82	0.94
TR2	0	7.5	0	15	1.00	0.50	1.00
TZ1	3	4.5	1.5	9	0.67	0.50	0.83
TZ2	5	7.5	2.5	12	0.58	0.38	0.79
TZ3	1	1.5	0.5	3	0.67	0.50	0.83
VD1	4	6	2	9	0.56	0.33	0.78
VD2	8	12	4	19	0.58	0.37	0.79
VL1	19	28.5	9.5	71	0.73	0.60	0.87
VL3	16	24	8	53	0.70	0.55	0.85
VL4	8	12	4	30	0.73	0.60	0.87
VL5	7	10.5	3.5	27	0.74	0.61	0.87
WF1	8	12	4	20	0.60	0.40	0.80
WF2	4	6	2	23	0.83	0.74	0.91
WF3	0	3.5	0	7	1.00	0.50	1.00
WF4	1	1.5	0.5	11	0.91	0.86	0.95
WF7	0	11	0	22	1.00	0.50	1.00
WH2	5	7.5	2.5	16	0.69	0.53	0.84
WH3	0	5.5	0	11	1.00	0.50	1.00
WH5	4	6	2	20	0.80	0.70	0.90
WW1	0	1	0	2	1.00	0.50	1.00