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WILDLIFE HABITAT REQUIREMENTS AND RECLAMATION TECHNIQUES FOR THE MOUNTAINS AND FOOTHILLS OF ALBERTA

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and

The Reclamation Research Technical Advisory Committee

of

The Land Conservation and Reclamation Council

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STATEMENT OF OBJECTIVE

The recommendations and conclusions in this report are those of the authors and not those of the Alberta Government or its representatives.

This report is intended to provide Government and Industry staff with up to date technical information to assist in the development of guidelines and operating procedures. The report is also available to the Public so that interested individuals similarly have access to the best available information on land reclamation topics.

ALBERTA'S RECLAMATION RESEARCH PROGRAM

The regulation of surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council Executive consists of a Chairman from the Department of the Environment and two deputy Chairmen from the Department of Energy. Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The reclamation research program was established to provide answers to the many practical questions which arise in reclamation. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund.

To assist in technical matters related to the development and administration of the research program the Council appointed the Reclamation Research Technical Advisory Committee (RRTAC). The Committee first met in March, 1978 and consists of eight members representing the Alberta Departments of Agriculture, Energy, Environment and the Alberta Research Council. The Committee meets regularly to update research priorities, review solicited and unsolicited research proposals, arrange workshops and otherwise act as a referral and coordinating body for Reclamation Research.

This report contains the results of a study jointly financed by The Coal Association of Canada and the Alberta Land Conservation and Reclamation Council. The project was managed by The Revegetation Subcommittee of the Industry/Government Mountains and Foothills Coal Reclamatmion Research Program.

Additional information on the Reclamation Research Program may be obtained by contacting:

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EXECUTIVE SUMMARY

The enhancement or creation of wildlife habitat is receiving increased attention as a viable reclamation alternative for disturbed sites as a result of better reclamation technology, increased government and public awareness of the importance of wildlife, the realization of the adaptability of wildlife habitat reclamation to a diverse range of conditions. the potential for reduced reclamation costs, and improved aesthetic qualities. There is a need, however. to consolidate information on known methods of reclaiming wildlife habitat and to develop methods of assessing reclamation success for certification. In response to these needs, a study of wildlife habitat reclamation in the mountain and foothills biomes was initiated by a joint government-industry study group (MFRRP). This study was to review current information on wildlife habitat in the mountain and foothills biomes, wildlife habitat reclamation techniques, potential problems in wildlife habitat reclamation, and potential assessment methodologies. Needs for further research also were to be identified.

WILDLIFE HABITAT REQUIREMENTS

In order to simplify the review of wildlife habitat requirements for this study and to expedite the application of this information to reclamation programs, "key" or indicator species of wildlife were selected for study. Key species were selected through a four-step process that first identified species with similar habitat requirements (i.e., guilds) and then selected the most important species within these guilds on the basis of political, socio-economic and ecological significance. The key wildlife species selected for the mountain and foothills biomes were snowshoe hare, beaver, muskrat, moose, elk, caribou, mountain goat, bighorn sheep, spruce grouse and white-tailed ptarmigan. Information was

reviewed on the important habitat requirements of these ten species as they relate to potential reclamation methodologies.

Major types of wildlife habitats within the mountain and foothills biomes are briefly described. In addition, their utilization by wildlife and rehabilitation potential are reviewed. The habitats considered are the alpine, subalpine, montane and boreal uplands ecoregions.

WILDLIFE HABITAT RECLAMATION TECHNIQUES

Currently-used or proposed reclamation techniques for wildlife habitat were reviewed, with particular emphasis on those techniques most applicable to mine reclamation in the mountain and foothills biomes. The review assumed that a workable soil base would be provided and that revegetation techniques are known. The techniques described primarily involve landscape design which encompasses the selection of appropriate physical and vegetation features and the juxtaposition of these features to maximize benefits to wildlife. Four major classes of reclamation methodologies were considered: topographic modification, watershed re-establishment, revegetation and special supplementary methods.

Topographic features can influence wildlife distributions directly, through the provision of special habitats such as cliffs, talus and south-facing aspects and indirectly through topographic influences on vegetation development. Because current mining projects often result in the loss of topographic diversity, landform reclamation is important in promoting future wildlife uses and vegetation community development. Methods of restoring topographic diversity that are discussed include surface contouring, the creation of surface depressions, surface roughening, specialized shaping of overburden, and development of special topographic features such as cliffs.

Watershed re-establishment is the next logical step in reclamation to ensure watershed protection and to provide important water-associated features for wildlife. Techniques described for watershed re-establishment include re-establishment of water courses, creation of lakes and ponds, creation of wetlands and creation of riparian zones. Artificial islands also are discussed as a method to enhance wildlife habitat.

Revegetation is the final and essential element in the successful reclamation of wildlife habitat. Revegetation plans must consider a wide variety of factors including the seasonal habitat requirements of the target wildlife species, the size of the reclamation area, the geoclimatic constraints of the reclamation site, the selection of palatable vs unpalatable species, successional patterns within the re-established communities, the spatial arrangement of plants within the communities, and the spatial arrangement of the community blocks. Problems in selecting appropriate plant species for both the reclamation site (e.g., the microsite conditions) and the target species are discussed including concerns for forage quality, palatability, and reclamation potential. Plant community reclamation is discussed from the perspective of developing certain types of communities such as grasslands, emergent aquatics, shrub meadows, shrublands, deciduous forest, mixed-wood forest, and coniferous forest in appropriate biophysical sites within the reclamation area and adapting these communities for specific wildlife use.

Special structures in wildlife reclamation are viewed as a means of rapidly providing some forms of cover and/or specialized habitats for wildlife. These structures generally help increase the structural and topographic diversity of a site at minimal expense and so offer a means of supplementary enhancement or habitat creation for existing or planned reclamation sites. Methods considered were highwall enhancement, talus creation, rock piles, brush piles, downfall/deadfall, snags and artificial nest structures.

WILDLIFE PROBLEMS IN RECLAMATION

Once wildlife are attracted to a site, they may create problems through overuse of vegetation on the site. Wildlife problems that have been encountered on reclamation areas in Alberta include overbrowsing of trees and shrubs, trampling, debarking, uprooting and girdling of trees and shrubs. Potential methods of controlling damage by large and small mammals are reviewed.

The protection of wildlife on reclamation sites from hunting may create a problem in that animals may become accustomed to the lack of hunting pressure and, hence, may be susceptible to overhunting once a reclamation area is opened to public access. Methods of minimizing this problem are discussed.

INTEGRATION OF FORESTRY AND WILDLIFE END USES

Although forestry may be a prime land use in some reclamation areas within the mountain and foothills biomes, there are opportunities to integrate wildlife habitat reclamation with commercial timber reclamation. Methods of integrating these land uses, such as interplanting of commercial and non-commercial (i.e., more palatable) tree species, or the enhancement of small areas of habitat within reforested blocks, are discussed. Recommendations to minimize conflicts between forestry and wildlife (e.g., wildlife damage to seedlings) also are proposed.

ASSESSMENT METHODOLOGIES

In order to assess wildlife habitat reclamation areas for certification, it will be necessary to evaluate habitat quality and quantity and compare the reclamation area to some standard. Two major methods for assessing habitat quality are reviewed:

population-based assessments and habitat-based assessments. The disadvantages and advantages of each approach are discussed. Based on the relative merits of each approach, it was concluded that habitat-based assessments are more suitable for evaluating reclamation success. The Habitat Evaluation Procedures (HEP) program of the U.S. Fish and Wildlife Service is recommended as the best technique for pre- and post-mine assessments of wildlife habitat.

CRITERIA FOR HABITAT RECLAMATION STANDARDS

In order for wildlife habitat reclamation to become an accepted reclamation alternative, it is necessary to establish standards or guidelines for evaluating reclamation success. Existing reclamation legislation, as it pertains to wildlife and wildlife habitat, is reviewed for Alberta, Saskatchewan, British Columbia and several States. Although the development of specific standards for wildlife habitat reclamation is beyond the scope of this report, desirable features for assessment criteria are discussed.

RECOMMENDATIONS FOR FUTURE RESEARCH

Based on this study, a number of data deficiencies became apparent. Topics for further consideration were recommended in the area of reclamation technology, wildlife habitat relationships and assessment techniques.

ACKNOWLEDGEMENTS

The compilation and synthesis of information in this report has involved the input and assistance of a large number of people. We would like to thank all of the individuals interviewed during this study for their time and cooperation. We would particularly like to thank the project managers, A.J. Kennedy and C.W.B. Stubbs for their continued support and direction. We also are grateful to T.R. Eccles, R. Ferster, A. Kennedy, C. Powter, M. Ross and B. Stubbs for their reviews of an earlier draft of this report. We would like to acknowledge C. Cooper for his assistance in compiling the report and A. Carriere and P. Murphy for preparation of the typescript. We also would like to thank K. Yonge for several enlightening discussions regarding the topic of wildlife habitat reclamation.

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1.0 INTRODUCTION

Four end uses are commonly recognized as potential land use objectives for reclaimed land in Alberta: forestry, agriculture, recreation and wildlife. Prior to the past decade, only forestry and agriculture were considered to be viable reclamation alternatives. Restoration of wildlife habitat has received increased attention in recent reclamation planning, however, as a result of better reclamation technology, increased government and public awareness of the importance of wildlife, the recognition of the adaptability of wildlife habitat reclamation to a diverse range of reclamation conditions, the potential for reduced reclamation costs, and improved aesthetic qualities (Green and Yonge 1984).

Some general criteria for forestry and agriculture have been defined in Alberta reclamation legislation (Marshall 1983) but specific guidelines or criteria for certification have not been developed for wildlife end uses. Although a considerable amount of research on enhancement of wildlife habitat has been conducted in the United States, and several reviews of enhancement techniques for wildlife have been compiled, few attempts have been made to consolidate and define enhancement methodologies for wildlife habitat on severely disturbed sites. Of particular concern, no syntheses of wildlife habitat reclamation procedures are available to industry or government in Canada.

Within the foothills and mountain biomes of Alberta, the combined exploratory and extractive activities of the forest, petroleum and mining industries have resulted in removal of forest cover and/or the disturbance of a moderate amount of land (Thirgood and Ziemkiewicz 1978; Marshall 1983). Although the removal of forest cover can improve wildlife habitat in some cases through creation of new ecotone habitats, physical disturbance of the land surface can reduce the local availability and quality of wildlife habitat. Because demands for renewable and nonrenewable resources in the mountain and foothills biomes are increasing and are not always compatible with wildlife habitat (AENR 1984), there is a need to consolidate information on wildlife habitat reclamation and enhancement and to determine the applicability of this technology to the biophysical conditions of these biomes. It is also necessary to develop criteria for evaluating the success of these reclamation programs.

In response to these research needs, the Mountain and Foothills Reclamation Research Program (MFRRP)1 initiated a study of wildlife habitat reclamation. This study focuses on the synthesis of current information on habitat requirements of key wildlife species in the mountain and foothills biomes, an evaluation and collation of information on reclamation procedures for wildlife habitat, the applicability of these methods to Alberta, and the development of criteria for assessment of wildlife habitat reclamation procedures for land certification purposes. Subsequent studies of the wildlife program may involve research that addresses some of the information gaps identified during this study.

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1 The Mountain Foothills Reclamation Research Program (MFRRP) is jointly sponsored by the Coal Association of Canada and Alberta Energy and Natural Resources and is administered by the Coal Association, the Reclamation Research Technical Advisory Committee (RRTAC) and the Research Management Division of Alberta Environment.

2.0 STUDY OBJECTIVES

The objectives for the MFRRP Wildlife Study, as described in the Terms of Reference, are to:

1. "review habitat requirements of key wildlife species in the mountain and foothills biomes of Alberta;

2. review the mechanics and methods involved in reclamation to wildlife habitat;

3. summarize information on important aspects of vegetation community development and succession in reclaimed areas;

4. evaluate methods for evaluation of wildlife habitat reclamation procedures, and

5. develop rationale for assessment of wildlife habitat reclamation procedures for certification purposes."

These objectives were to be fulfilled through completion of the following specific tasks:

1. "Search all literature sources on reclamation to wildlife end land use, utilizing currently available computer data search techniques;

2. Conduct interviews with reclamation/wildlife experts in government agencies (Federal and Provincial Government) and the private sector and obtain all available unpublished literature pertaining to wildlife habitat reclamation;

3. Synthesize published and unpublished information that relates to wildlife habitat reclamation in the mountain/foothills;

4. Prepare a report describing the existing information on wildlife habitat reclamation in the mountain/foothills; and

5. Identify data deficiencies and provide recommendations on further research that may be required to investigate the basic questions identified."

3.0 METHODS

3.1 LITERATURE REVIEW

3.1.1 Wildlife Habitat Requirements

Our information review on wildlife habitat requirements was directed toward 10 key wildlife species: snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse and white-tailed ptarmigan. Each key species was chosen to represent a guild or group of species exhibiting similar habitat needs (Section 4.1 and Appendix 1).

A computer literature search of biological and ecological data bases was conducted using the key words food, diet, ecology, behaviour, and wildlife habitat in combination with both the scientific and common names of the ten key wildlife species. Initially we searched a large number of data bases including SCISEARCH, NTIS, ENVIROLINE, Environmental Bibliography, Dissertation Abstracts on Line, CAB Abstracts, and Biosis Previews. However, as there was considerable redundancy in the references produced, these subsequently were narrowed down to NTIS, Dissertation Abstracts on Line, and Biosis Previews. We also manually searched the Canadian Wildlife Service (Western Region) Library, the Alberta Energy and Natural Resources Library, the Fish and Wildlife Division Library, and the thesis collection at the University of Alberta for relevant unpublished reports on the 10 key species. Additional unpublished information was obtained from the LGL Limited library and personal libraries of LGL Limited biologists, and from persons consulted during interviews.

3.1.2 Reclamation Techniques

Current published information on wildlife habitat reclamation techniques was obtained through use of a computer literature search of the RECLAIM data base and review of several recent bibliographies on reclamation (Sims and Powter 1982; Sims et al.

1984). As a considerable amount of literature had been assembled prior to the start of this study, we also obtained a number of publications through cross-checking of the literature cited in these publications. Additional references were obtained during interviews with reclamation specialists.

3.2 INTERVIEWS

Because interest in wildlife habitat reclamation in Alberta has developed only recently, a considerable amount of information on reclamation and revegetation techniques, wildlife requirements and reclamation standards was available only through interviews with reclamation and wildlife experts. Interviews were conducted with a wide variety of industry, government and consulting reclamation specialists in Alberta, British Columbia, Saskatchewan, Washington State, Idaho, Montana and Wyoming. With the exception of people contacted in Edmonton and Calgary, most of the interviews were conducted by telephone. A list of the persons contacted, their affiliation and date of contact(s) is provided in Appendix 2.

3.3 SCIENTIFIC NOMENCLATURE

To improve the readability of this report, we have attempted to utilize common names of plants and animals as much as possible. Plant, mammal and avian nomenclature follows Moss (1983), Banfield (1974) and Salt and Salt (1976), respectively. If no common names were listed for a species, we have used the scientific name as described in the references cited above. A list of common names and scientific equivalents is provided in Appendix 3.

4.0 WILDLIFE HABITAT REQUIREMENTS

4.1 SELECTION OF KEY WILDLIFE SPECIES

To effectively review and synthesize information on habitat requirements of all bird and mammal species in the mountains and foothills biomes would be a very labour intensive and costly exercise; moreover, much of the information would be redundant as many of the species have similar or overlapping habitat requirements. An initial step in this review consequently was to select "key" or indicator wildlife species toward which we directed the habitat requirements review. The key species concept is based on the premise that reclamation or enhancement of habitat for a key species also will benefit other sectors of the wildlife community, even though reclamation methods are not aimed specifically at all of the wildlife species in the habitat. The key species approach therefore offers a means of simplifying the planning and implementation of wildlife habitat reclamation.

As a general guideline, key species should be of socio-economic and ecological significance and should represent the habitat requirements of several other species of wildlife (e.g., a guild representative). Key species for the MFRRP were selected based on a four-step system (Green et al. 1984):

1. Identification of resident and seasonal wildlife species with strong affiliations with the mountains and foothills biomes of Alberta;

2. Identification of groups or associations of species that have similar habitat requirements;

3. Evaluation of the political, socio-economic and ecological significance of the species in each of the species associations; and

4. Selection of key representative species from each of the associations based on numeric scores for each of the above evaluations.

Details of this selection process are described in Appendix 1.

4.2 INFORMATION REVIEW

Literature reviews of habitat requirements and formal, generalized habitat models already exist for many of the key species. Rather than repeat the information contained in these, we focused our review on data developed directly within the geographic boundaries of the mountain and foothills biomes. Data on habitat requirements of key species were culled from a number of sources, ranging from annotated lists of birds and mammals found in the national and provincial parks, to single- and multiple-species studies undertaken by university and federal or provincial government researchers. Information from other parts of Alberta, and occasionally from other parts of western North America, was also reviewed and incorporated in the species accounts when data specific to the mountain and foothills areas of the province were lacking.

Our approach to synthesizing the available information on habitat requirements has been to describe the range of conditions presently occupied by each key species, with the aim of identifying, where possible, the optimal values of various habitat features. Because reclamation is a structuring or building process, habitat requirements of each key species have been summarized largely in structural terms (i.e., general landform type, slope and aspect of terrain; vegetation community structure and composition; and size, shape and juxtaposition of habitat units). Functional determinants of habitat use (food species selection, use of space, use of cover/shelter, response to human/mechanical disturbance) also were reviewed in order to provide an understanding of how each species uses available habitat.

4.3 IMPORTANT HABITAT REQUIREMENTS OF KEY SPECIES

Detailed accounts of forage selection and use of cover, terrain, space and special habitat features by each of the ten key species of wildlife are provided in Appendices 4 - 13. Existing literature reviews and habitat models relevant to each of these species also are identified.

Tables 1 to 10 summarize the major habitat requirements of the key species as they relate to the reclamation considerations for topography and contouring, watershed re-establishment, revegetation and special features. These summaries are intended to illustrate the range of habitat features potentially required as an end product of reclamation or enhancement of wildlife habitat in the study area. Other details of habitat reclamation will depend on the specific site conditions (Sections 5 and 6).

Table 1. Important habitat requirements of snowshoe hare.

Topographic Features	- in natural areas, snowshoe hares make greatest use of valleys and lower slopes, but distribution is probably controlled by vegetation cover rather than by topography *per se*.
Watershed Features	- no special requirements, but riparian shrublands provide favored habitat.
Vegetation Features	- require dense shrub growth and closed forest for food, and for hiding, reproductive and thermal cover; use both deciduous and conifer cover. Deadfall increases cover availability.
	- an interspersion of open herbaceous areas within 200 m of forest and dense shrub growth improves habitat suitability.
	- food consists of grasses, forbs, and deciduous and coniferous browse. No quantitative data are available from the mountain or foothills biomes.
	- require forage within 60 cm of ground or snow level, and with browse twig diameters of 4 mm or less.
	- home range sizes are in the order of 7-14 ha but data on optimal habitat area are lacking.
Special Features	- no specific requirements.

Table 2. Important habitat requirements of beaver.

Topographic Features	- valley bottoms with broad, mesic floodplains (>45 m) and oriented east-west permit optimal vegetation development. - gentle to moderate slopes (<25%) adjacent to waterbodies facilitate foraging.
Watershed Features	- require permanent, stable (or dammable) waterbodies. - stream gradients of <13% and minimum water depths of 0.9-1.5 m are required. - meandering streams or lakes with highly irregular shorelines are optimal. - a minimum habitat area of 0.8 km of stream channel or 1.3 km^2 of lake/marshland habitat is required. - clay soils provide the best substrate.
Vegetation Features	- stands of willow and aspen within 30 m of shore provide an optimal source of food and building materials. - additional forage species include balsam poplar, alder, paper birch, dwarf birch, rose, red osier dogwood, silverberry and saskatoon. Herbaceous terrestrial vegetation and aquatic macrophytes are used to some extent. - beavers generally use stems <5 cm basal diameter but stems >25 cm diameter also are cut.
Special Features	- no specific requirements.

Table 3. Important habitat requirements of muskrat.

Topographic Features	- habitat is restricted largely to valley bottoms due to waterbody requirements.
Watershed Features	- standing irregular waterbodies and slow-moving streams, with depths of 0.9-1.8 m, provide optimum conditions.
	- periodic flooding and drawdowns are required to maintain suitable plant communities.
	- clay soils provide the best substrate.
	- home ranges are generally 200 m or less in diameter; minimum habitat area has not been documented.
Vegetation Features	- extensive stands of emergents (e.g., cattail, bulrush, sedge, grasses) provide both food and cover; submergents (e.g., water milfoil, pondweed) also are used for food.
	- percent of area covered by emergents may vary from 10 to 60+%.
	- seasonally flooded shrublands (willow, dwarf birch, shrubby cinquefoil) also provide suitable habitat.
Special Features	- no specific requirements.

Table 4. Important habitat requirements of elk.

Topographic Features	- valley bottoms and adjacent slopes and benches, with slopes primarily 30% or less, provide major habitat. - west to south-facing exposures are required during winter.
Watershed Features	- no specific requirements.
Vegetation Features	- open and sparsely treed grasslands provide the major foraging habitat; fescues and sedges are the most important forage species but willows are seasonally important. - other locally or seasonally important forages include hairy wild rye, horsetail, pine, spruce, silverberry, buffaloberry and aspen. - also feed on seeded grasslands and other reclaimed areas. - forest cover is used for escape and shelter; optimal habitat consists of 60-70% foraging area with the remainder in forest cover. - undertake seasonal altitudinal movements related to floral phenology, traveling one-way distances of up to 69 km. May remain sedentary in areas of high vegetational heterogeneity. - elk are sensitive to human and vehicular disturbance when hunted and require forest and/or geomorphic escape cover. Most use occurs within 250 m of cover, depending on disturbance factors.
Special Features	- use natural mineral licks and artificial mineral sources.

Table 5. Important habitat requirements of moose.

Topographic Features	- valley bottoms and other flat to gently sloping areas provide major habitat.
Watershed Features	- waterbodies are used for feeding and for refuge from insects and high temperatures, and riparian areas provide excellent habitat; however waterbodies are not an essential habitat feature.
Vegetation Features	- dense early successional and alluvial shrublands provide optimum habitat.
	- willows are the major forage species, although other browse species, graminoids, forbs and aquatic macrophytes also are used.
	- annual home range sizes have been estimated as <1-121.6 km^2.
	- moose habituate to disturbance to some extent but require forest cover for escape in areas of intensive human use and hunter activity. Open (shrubland) areas 400 m or more in width with adjacent 100 m wide forest strips provide suitable habitat in relatively undisturbed areas.
Special Features	- use natural mineral licks, probably for sodium; also use artificial mineral sources.

Table 6. Important habitat requirements of caribou.

Topographic Features	- use flat or rolling terrain with moderate slopes and a variety of exposures, including south-facing.
Watershed Features	- delta/shoreline alluvial communities are used for foraging.
	- snowfields are important for thermoregulation and escape from insects during summer.
Vegetation Features	- rely primarily on climax plant communities.
	- important habitats are alpine tundra, low elevation meadows and shrublands, and mature, lichen-bearing conifer forests.
	- diet includes a wide variety of graminoids, forbs and shrubs, and both terrestrial and arboreal lichens, with no single species or group predominating.
	- habitat use varies seasonally with floral phenology. An interspersion of closed forests, open forests and non-forested areas provides optimal habitat, but relative percentage figures are not available.
	- annual home range sizes have been estimated at 630-1205 km^2.
	- caribou are sensitive to disturbance and require forest and/or geomorphic escape cover. Stands of protective cover should be at least 400 m wide.
Special Features	- use natural mineral licks and artificial mineral sources.

Table 7. Important habitat requirements of mountain goat.

Topographic Features	- broken, steep, predominantly west to south-facing slopes (>45°) and cliffs, with adjacent moderate slopes, provide year-round habitat.
	- require steep escape terrain within 400 m (preferably 200 m) of foraging areas.
Watershed Features	- no specific requirements.
Vegetation Features	- mosaics of grass/forb meadows and tundra and low shrublands provide foraging habitat. Make limited use of forest edges.
	- diet consists of alpine forbs, grasses and deciduous browse, but percent composition is poorly documented.
	- locally or seasonally important browse species include silverberry, saskatoon, aspen, rose, alder and willow; gramineous species include rough fescue, wheatgrasses, bromes, hairy wild rye, june grass and sedges.
	- undertake seasonal altitudinal shifts related to floral phenology, but home ranges are small (probably <25 km^2).
Special Features	- use natural mineral licks, probably as a source of sodium.

Table 8. Important habitat requirements of bighorn sheep.

Topographic Features	- open valley bottoms, slopes and steep broken terrain with a variety of exposures provide major habitat. - south and west-facing slopes are required during winter. - bighorn sheep are sensitive to disturbance when hunted and require escape terrain preferably within .8 km (not more than 1.6 km) of foraging areas.
Watershed Features	- no specific requirements.
Vegetation Features	- grasslands and grass/forb meadows are the major foraging habitats; forest edges are used for feeding and thermal cover. Some feeding also occurs on seeded grasslands. - grasses (fescues, wheatgrasses, june grass) and sedges provide the bulk of the diet, but forbs and to some extent shrubs also are used. - undertake seasonal altitudinal movements related to floral phenology. Seasonal ranges are separated by up to 40 km.
Special Features	- use natural mineral licks and artificial mineral sources.

Table 9. Important habitat requirements of spruce grouse.

Topographic Features	- prefer flat to gentle slopes.
Watershed Features	- no specific requirements.
Vegetation Features	- prefer lodgepole pine forests, but will also use white spruce and other conifer-dominated forests.
	- shrub cover in occupied areas generally is <25%, but pockets of dense shrub understory provide cover for moulting birds, for nests and for broods. Open canopy areas are required for male display flights.
	- lodgepole pine needles are the major winter food; during the snow-free period *Vaccinium* spp. provide a major part of the diet.
	- scattered white spruce appears to be important to incubating hens.
	- uniformly spaced, aggregated territories of up to 3.9 ha/territory are occupied during the breeding season; large blocks of habitat are preferred.
Special Features	- no specific requirements.

Table 10. Important habitat requirements of white-tailed ptarmigan.

Topographic Features	- open rocky slopes and alpine cirques provide summer and some winter habitat; valley bottoms 2.5-7.5 km downslope of summer habitat are used during deep-snow years.
	- rocks >30 cm diameter provide the major hiding and thermal cover in alpine areas.
Watershed Features	- proximity to snowfields or rocky alpine stream courses (usually within 25 m) appears to be an important feature of summer habitat.
	- stream courses also are used during winter, but this is probably related to vegetation cover.
Vegetation Features	- moist rocky alpine tundra is used during summer; large expanses of dry tundra are avoided.
	- shrublands and open conifer forests are important winter habitats. Stands of willow 2-3 m in height are used during severe winters.
	- summer diet consists of leaves and fruits of a variety of alpine plants (e.g., dryas, buttercup, willow, Smelowskia spp.). Willow buds are the major winter food.
Special Features	- no specific requirements.

5.0 EFFECTS OF DISTURBANCE AND POTENTIAL FOR HABITAT REHABILITATION

5.1 DISTURBANCES ASSOCIATED WITH MAJOR DEVELOPMENTS

Activities associated with renewable and nonrenewable resource development in the mountain/foothills biomes can influence habitat structure and may alter habitat use patterns of wildlife over the short or long-term. A detailed assessment of the impacts of development on wildlife is beyond the scope of this report (but see Geist 1975; McLaughlin 1979; Shank 1979; Sopuck et al. 1979 and Searing 1981 for detailed reviews and additional references); here we provide an overview of the types of disturbance presently occurring in the mountains and foothill biomes of the province, both as an adjunct to our discussion of wildlife habitat selection and as background for our subsequent assessment of various reclamation techniques. These disturbances can be divided into two major categories based on their effects on habitat:

1. those resulting in physical changes in habitat structure (e.g., clearing of vegetation, modification of drainage patterns, alteration of soil horizons, infrastructure development), and

2. those not causing habitat alteration, but resulting in increased levels of sensory stimuli (e.g. from human presence, vehicular traffic) that may result in changes in local wildlife distribution and habitat use.

Although our discussion focuses on disturbances associated with the resource extraction industries, it is also recognized that recreational activities can also have significant effects.

5.1.1 Habitat Alterations

Changes in habitat resulting from vegetation clearing within the foothills biome and, to a much lesser extent, the mountain biome, are associated primarily with logging but mine development, seismic exploration, oil and gas well drilling, and construction of roads, pipelines and power transmission corridors all require some degree of vegetation removal and soil disturbance. Removal of vegetation can elicit either positive or negative responses from wildlife, depending largely on the wildlife species, size and shape of cleared area, type of vegetation cleared and type of replacement vegetation (if any). For example, many ungulates are edge-adapted species (e.g., white-tailed deer, mule deer, elk, moose) that benefit from the creation of forest openings and subsequent increased growth of preferred forage species, provided that sufficient forest remains for escape and thermal cover requirements. Other ungulates (e.g., caribou) are associated with large tracts of mature undisturbed forest, the removal of which results in net habitat loss. Of particular concern in the mountain biome is disturbance to alpine/subalpine tundra and grassland ranges used by ungulates in winter.

Development activities requiring physical alteration of the landscape often also result in changes in drainage patterns. Apart from the obvious example of dam construction for irrigation and hydroelectric projects, such activities include surface mining and road construction. As with removal of vegetation, drainage or alteration of water levels in existing waterbodies (and creation of new waterbodies) can have both positive and negative effects, depending on wildlife species concerned and a number of site specific factors such as vegetation type, waterbody area, depth and shoreline complexity, and existing local interspersion of waterbodies. Thus increases in water levels or creation of new waterbodies can result in loss of emergent or terrestrial habitat, but increases in availability of wetland habitat. Permanent decreases in existing water levels generally are negative, resulting in loss of emergent cover for species such as waterfowl and muskrat and in increased over winter mortality of beaver and muskrat as a result of reduced water depth. However, temporary fluctuations are necessary for maintaining emergent and riparian communities.

Some infrastructure developments (e.g., buildings, roads, railways) result in permanent or at least long-term habitat loss; these developments along with others such as pipelines and power transmission corridors may also act as barriers to wildlife movement. Effects range from habituation by the animal, to actual physical obstruction of movement, to avoidance as a result of accompanying human/mechanical disturbance or in response to altered habitat. In the latter sense large cleared or flooded areas may also act as barriers. Development of transportation corridors also results in direct wildlife mortality through road kills and increased hunter access.

5.1.2 Perceived (Sensory) Disturbance

Development and recreational activities result in increased human presence and often are accompanied by noise from machinery and other sources (e.g., mine-blasting). Such activities may cause no or only very minor changes in habitat structure, but nevertheless elicit alarm or avoidance reactions from wildlife that can result in short-term spatial redistribution and changes in habitat use. This consideration is particularly germane to reclamation planning, as even structurally optimum habitat may not be occupied if wildlife use is prevented by perceived disturbance factors. Although some wildlife species acclimate to constant or predictable disturbance sources, physiological stress from disturbance, overcrowding in "safe" areas and displacement into marginal habitat can all result in decreased fecundity and survivorship.

5.2 WILDLIFE HABITATS IN THE MOUNTAIN AND FOOTHILL BIOMES

In the following section, we briefly discuss the major vegetation communities in the mountain and foothills biomes of

Alberta, their use by wildlife (i.e., the ten key species) and their rehabilitation potential. The major communities are described according to the wildlife habitat ecoregions outlined by Russell et al. (1984)

5.2.1 Alpine Ecoregion

5.2.1.1 Vegetation Types. The Alpine ecoregion (Russell et al. 1984) comprises mountain slopes above treeline varying in elevation from 1880 m on north-facing slopes at 54° 20' N to 2280 m on south-facing slopes at 49° N. Russell et al. (1984) describe 13 natural vegetation types according to moisture regime, landform, and soil type. Very little research has been completed concerning plant succession in this ecoregion and community development sequences are not known.

5.2.1.2 Key Wildlife Species. The region is an important year-round source of forage for mountain goat and white-tailed ptarmigan, both remaining at high elevations except when forced down by deep snow. The region is also utilized seasonally for forage by bighorn sheep, elk, and caribou. Xeric, graminoid vegetation types (or windswept ridges, south-facing slopes, and avalanche chutes) and forb and dwarf shrubland vegetation types all are major food sources.

5.2.1.3 Habitat Rehabilitation. Research results to date indicate that commercially available grass or legume species are not long-lived on alpine disturbances. The lack of commercially available adapted plant materials is a serious limitation to rehabilitation of alpine regions. "Little is known about plant succession on alpine disturbances and how it might be used advantageously in rehabilitation" (Brown et al. 1978).

Rehabilitation of disturbed alpine areas in Alberta is presently restricted almost entirely to the National Parks. Parks

Canada currently uses seed of native alpine grasses produced by a contract grower, and transplants of native shrubs produced under contract from locally-collected cuttings (G. Harrison, pers. comm.). Notable initial success has been achieved with this method on Whistlers Mountain (el. 2256-2465 m) near Jasper. Seven species of alpine grass were used: Agropyron latiglume, Poa alpina, Poa interior, Trisetum spicatum, Deschampsia caespitosa, Festuca saximontana, and Phleum alpinum (Harrison 1981). Skiing Lake Louise Ltd., a private company which operates the Lake Louise ski area, also contracts seed production of native grasses and shrub transplant production, both from plant material collected locally (D. Walker, pers. ob.). The Whistlers Mountain disturbance was created by trampling from park visitors, and differs significantly from the ski area disturbance which resulted from land reshaping with heavy machinery. Very little topsoil was lost from the former area and it will probably not require maintenance fertilization. The latter disturbance, where topsoil was lost, has required fertilization to maintain even modest plant growth thus far.

Successful rehabilitation of an alpine area has been reported forthe Panther River Coal Site west of Sundre (Tomm 1981). The disturbances consisted of a network of exploration trails and drill sites made during the period 1967-1971. Reclamation of the trails by Fording Coal and later by the AFS included recontouring, seeding, and fertilization. Maintenance fertilization was not reported. It is assumed that at least some of the original topsoil was replaced during reshaping of the roadbed into the original land contours. Of the species initially used for revegetation, two commercially available species, creeping red fescue and Kentucky bluegrass, were most successful. In 1983, several small sections of the trails were examined by W. Russell (pers. comm.). Most of the vegetative cover was dominated by a native invader, latiglume wheatgrass (Agropyron latiglume) indicating that early plant succession had occurred.

Commercial seed production of non-graminoid species from the Alpine ecoregion has not been reported, but vegetative propagation of several alpine species has been investigated by R.H. Hillson (pers. comm.) during a three year study at the University of Alberta (Table 11). Some cautious optimism has been expressed with regard to revegetation of the Alpine ecoregion both in Alberta and elsewhere (Brown and Johnson 1979). On the other hand, a documented, long-term example of successful revegetation was not found and restoration of plant productivity in the alpine is expected to be very difficult.

Extrapolation from successful alpine revegetation to successful development of alpine wildlife habitat is highly speculative. Development of alpine habitat for some species such as for white-tailed ptarmigan, is probably possible and economically feasible using existing techniques; both cover and forage could be created with transplants of woody species, reseeding with alpine graminoids and a modest amount of land reshaping. Development of alpine habitat for other species, such as grazing ungulates, is more problematic and is likely to require an extremely long period of time (e.g., 50-100 years).

In an alpine meadow in northeast British Columbia, a hairy wild rye/rough fescue community on a 45% S slope at 1623 m yielded 941 kg/ha (Brink et al. 1972). Plant production of an undisturbed alpine grassland in Colorado was approximately 1000 kg/ha; assuming annual utilization of 20-30% of total herbage, 200-300 kg of forage/ha should be available on an average grazeable alpine turf (Thilenius 1975). In order to restore equal or better productivity to alpine wildlife range, revegetation would have to match that level and ensure long-term maintenance. Even limited utilization (e.g., elk require a daily food intake of 4.4 kg of dry matter, and may destroy an equivalent amount by trampling) (Hudson and Nietfeld 1985) may result in overgrazing and rapid depletion of carrying capacity without intensive management of the range until plant

Table 11. Native alpine species successfully produced and evaluated in container out-plantings. (Source: R.H. Hillson, pers. comm.)

By vegetative cutting	
aline bearberry	*Arctostaphylos rubra*
Arctic willow	*Salix arctica*
crowberry	*Empetrum nigrum*
everlasting, woolly	*Antennaria lanata*
mountain laurel	*Kalmia polifolia*
moss campion	*Silene acaulis*
rock willow	*Salix vestita*
snow willow	*Salix nivalis*
stonecrop	*Sedum lanceolatum*
purple saxifrage	*Saxifraga oppositifolia*
white mountain avens	*Dryas octopetala*
By wild seed collection	
alpine sweet-broom	*Hedysarum alpinum*
white mountain avens	*Dryas octopetala*

succession reaches an advanced, highly diversified stage. In addition, the nutritional quality of alpine plants is higher than native species found at lower elevations (Johnston et al. 1968) and may be difficult to match.

5.2.2 Subalpine Ecoregion

5.2.2.1 Vegetation Types. The Subalpine ecoregion (Russell et al. 1984) is divided elevationally into the upper subalpine and lower subalpine region based on floristic composition and physiognomy with open coniferous forests occurring in the upper region and closed conifer forest in the lower. Forests are dominated by alpine fir and Engelmann spruce with recently burned areas in the lower subalpine occupied by lodgepole pine. The lower limit of the subalpine is 1700 m in the south, the most common upper limit of Douglas fir.

Russell et al. (1984) further divide the Subalpine Ecoregion latitudinally into three subdivisions: (1) Southern, from the Canadian - U.S. border to Crowsnest Pass, (2) Central, from Crowsnest Pass to Bow Pass, and (3) Northern, from Bow Pass to the upper region of the Wapiti River drainage. Bow Pass is the northern limit of white bark pine and larch.

Plant succession on natural disturbances in the subalpine begins with yellow mountain avens followed by a willow stage, and culminates in a spruce or spruce/fir forest. An important feature of the subalpine is grassy, south-facing slopes dominated by rough fescue in the southern and central subdivisions and hairy wild rye in the northern subdivision.

5.2.2.2 Key Wildlife Species. Vegetation types in the Subalpine ecoregion are important to many of the key wildlife species. The steep grassy slopes and avalanche paths are important forage areas for elk, bighorn sheep and mountain goat and graminoid/forb-dominated habitats are widely used by caribou. Snowshoe hare and moose utilize subalpine shrublands, as do ptarmigan during winters of heavy snow accumulation. Coniferous forests also are used by snowshoe hare and ptarmigan during severe winters. Spruce grouse range extends to treeline in coniferous forest types, mainly lodgepole pine but also white spruce and larch.

5.2.2.3 Habitat Rehabilitation. A considerable body of literature exists on research trials, observations, and operational procedures for revegetation in the Subalpine ecoregion. Early works include Peterson and Etter (1970), Etter (1971, 1973), Lesko et al. (1975) and information summaries by Hubbard and Bell (1977) and Peterson and Peterson (1977). More recent research works by the AFS include extensive species selection trials in the southern region (Selner et al. 1977), the Cadomin Trials (Russell and Takyi 1979; Takyi and Russell 1980; Islam and Takyi 1984), native grass and grass-legume trials (Tomm and Russell 1981), and plant establishment trials (Takyi and Leitch 1981, Takyi 1981). Several coal companies also are conducting in-house trials to augment operational revegetation programs (Berdusco and Milligan 1977, Quarrin 1982; G. Acott, pers. comm.).

Forage productivity of both herbaceous and woody species is difficult to categorize. Temperature and the frost-free period decrease while precipitation and the precipitation/evaporation (P/E) ratio increase with higher elevation (Spilsbury and Tisdale 1944). At lower elevations, especially in the southern and central sub-divisions, the P/E ratio is more important for plant growth and is affected by slope, aspect and exposure to wind. At higher elevations, temperature and the frost-free period are the dominant influences (Spilsbury and Tisdale 1944). Dodd et al. (1972) found a close relationship between herbage production and crown cover in coniferous stands in British Columbia. McLean and Smith (1973) found that dry summers in British Columbia produced superior yields in forested rangelands if the preceding year had been wet.

The forest and shrubland vegetation types in the Subalpine ecoregion have not been specifically investigated for browse production but several productivity estimates are available for gramineous communities. Native rough fescue grassland yielded 1424 and 1718 kg/ha in two consecutive years in the southern foothills of Alberta (Bezeau et al. 1967); similarly annual herbage production on a native rough fescue grassland in the southern foothills near Stavely ranged from 1497 to 2869 kg/ha (Smoliak et al. 1979) Forage production of 1345 kg/ha is considered excellent range condition for the rough fescue community and 810 kg/ha is excellent for the western porcupine grass/wheatgrass community (Wroe et al. 1979).

Potential for habitat rehabilitation in the Subalpine ecoregion varies widely among the key species, being highest for those species adapted to successional communities, such as snowshoe hare and moose (shrublands) and spruce grouse (lodgepole pine forest). Conversely, the winter habitat of caribou consists of overmature, closed, coniferous forests dominated by Engelmann spruce, alpine fir and sometimes lodgepole pine and white spruce; development of this late successional or mature vegetation type may require 100-130 years.

5.2.3 Montane Ecoregion

5.2.3.1 Vegetation Types. Russell et al. (1984) define the Montane ecoregion as occurring below the Subalpine ecoregion and above the Aspen Parkland ecoregion (range 1000 to 1600 m). Douglas fir and limber pine communities differentiate the Montane from other regions. The Montane region occurs in the foothills and into the mountains along low-elevation passes.

5.2.3.2 Key Wildlife Species. Vegetation types associated with valley bottoms in the Montane ecoregion are important habitat for moose, muskrat and beaver. Moose will browse year-round in the mesic and hydric tall shrublands dominated by willows and in mesic deciduous forest. Additional summer food sources are provided by the hydric graminoid and sedge fen types. Coniferous forest is important for thermal cover and escape cover. Previously this mosaic of habitat types was perpetuated by uncontrolled forest fires but, as a result of fire suppression, logging has recently become an important factor in the creation of moose habitat. Muskrat habitat is provided by sedge fen, hydric graminoid, and hydric shrubland vegetation, while the deciduous groveland (trembling aspen) vegetation type provides ideal beaver habitat when adjacent to hydric shrub and graminoid types. Elk and, to some extent bighorn sheep, are associated with the xeric Douglas fir woodland, rough fescue grassland, and Junegrass grassland vegetation types.

5.2.3.3 Habitat Rehabilitation. Rehabilitation of moose, muskrat and beaver habitat requires the impoundment or regulated control of water. Land reshaping and a reliable source of fresh water are the first requirements, but once met the introduction of cover and food species is relatively easy. Most willow species are easy to propagate from seed and cuttings (Watson et al. 1980). Aspen and balsam poplar necessary for beaver habitat also are easily propagated and established (Watson et al. 1980) and propagation techniques exist for other species associated with the deciduous forest vegetation type (see Section 6.3). Reviews on methods of establishment of woody species are contained in Monenco (1983) and Medin and Ferguson (1971). Elk food requirements can be met in part with the establishment of a productive sward of grass.

5.2.4 Boreal Uplands Ecoregion

5.2.4.1 Vegetation Types. The Boreal Uplands Ecoregion is subdivided into a northern region from Rocky Mountain House north to the Grande Prairie area and a southern region from Sundre south to the Canada - U.S. border (Russell et al. 1984). The northern subdivision includes the major coal-bearing formations in the foothills west of Edmonton. The coniferous forest vegetation types characteristic of this region are dominated by lodgepole pine, white spruce and black spruce, which are distributed along moisture and nutrient gradients (Russell et al. 1984). Estimated forage production in the major habitats of the Boreal Forest is outlined in Table 12.

5.2.4.2 Key Wildlife Species. The key wildlife species found in the Boreal Uplands ecoregion are muskrat, beaver, snowshoe hare, moose, elk,spruce grouse, and to a lesser extent, caribou. Muskrat utilize willow/birch shrubland vegetation types adjacent to waterbodies; these and deciduous forest types near streams also are important beaver habitat. Moose habitat and snowshoe hare habitat includes a mosaic of coniferous forest, deciduous forest, tall shrublands and wetlands. Open coniferous forests with grasses and sedges in the understory are the major elk habitat, while spruce grouse are associated primarily with lodgepole pine and white spruce forests. Caribou are strongly associated with mature conifer forests and to some extent with muskegs.

5.2.4.3 Habitat Rehabilitation. There is wide scope for habitat rehabilitation in this region. Initial establishment of primary successional species (grass/legume) along with localized plantings of secondary successional vegetation types (low shrubs, aspen, pine) are feasible with existing technologies, but research is required to determine successful management procedures during the early stages of establishment of the woody species. Bartos (1978) developed a plant succession model for simulating the aspen-conifer succession in the western U.S., incorporating five major vegetation components (aspen, conifer, shrubs, annuals and perennials) with respect to numbers of plants and biomass production. Such a model could be developed specifically for the boreal uplands forest in order to account for climatic and edaphic factors.

Table 12. Representative forage production in major habitats of the boreal forest (Source: Hudson 1981).

Habitat	Grasses/Herbs (kg/ha)	Shrubs (kg/ha)
Grassland	200-2500	<10
Sedge meadow	4000	<10
Shrubland	1500	75-200
Aspen forest	250	25- 50
Spruce forest	<100	25

6.0 WILDLIFE HABITAT RECLAMATION TECHNIQUES

The review of currently-used or proposed reclamation techniques for wildlife was aimed primarily at resource industries which are legally required to reclaim disturbed land. However, because of the study emphasis on coal mine reclamation, we specifically have addressed those methods most applicable to the operational conditions of coal mines.

Current practices for coal mining generally necessitate large scale movement of topsoil and overburden to expose the underlying coal deposits (Marshall 1983). As a result, the post-mining soils in reclamation areas may consist of varying proportions of exposed spoil materials, overburden or regolith materials and organic topsoil. Although the resulting soil composition and textures affect the success of revegetation on these sites (Pedocan, in prep.), methods of reconstructing or enhancing mine soils will not be reviewed in this study. In compiling this review, we have assumed that a soil medium has or will be provided on the reclaimed area and that:

1. the soil is suitable for self-sustaining plant growth (i.e., fertilizer applications will not be necessary after an initial establishment period).

2. several species of trees, shrubs and ground covers are capable of surviving in the soil medium; and

3. the soil medium is relatively stable and not prone to significant erosion problems.

We also have assumed that the propagation, planting and maintenance methodologies to establish self-sustaining tree, shrub, and ground covers are known. The techniques described in this review involve methods of landscape design for wildlife use which encompass the selection of appropriate physical and vegetative features and the juxtaposition of these features to maximize benefits to wildlife.

Successful enhancement of disturbed areas for wildlife must provide the basic requirements for food, water, cover, and range. Consequently reclamation for wildlife should consider factors such as topography, soil water regimes, surface water availability, plant diversity, habitat dispersion and habitat edge. In some cases, isolation from human disturbance may also be an important consideration. Generally, an area with a diversity of habitats is capable of supporting a greater variety of wildlife than areas with a limited number of plant communities (Thomas 1979a). Diversity is the key to successful reclamation for wildlife, and reclamation programs for wildlife habitat should maximize the diversity of habitat, topography and vegetation within the local area of the mine development. Once these communities are established, natural ecological processes should be allowed to direct successional trends in the plant community. If a mine occurs in an area of relatively homogeneous vegetation cover, reclamation of the post mine landscape can provide a number of opportunities to develop different and more diverse vegetation communities of value to wildlife.

To be successful, wildlife reclamation programs must pre-plan andintegrate post-mining topography, surface and ground hydrology, and revegetation. Programs which incorporate an holistic community approach to reclamation are much more likely to benefit wildlife in the long-term than are piece-meal approaches to reclamation. Community development must not only involve the selection of suitable plant species and planting configurations but also the placement of these communities in appropriate microsites that meet that community's requirements for features such as slope and aspect, ground and surface water hydrology, wind exposure, and elevation.

Wildlife ecology and habitat use can involve a complex array of interspecific and intraspecific plant and animal relationships and, as a result, methodologies for enhancement of wildlife habitat can also become complex. To simplify the objective of establishing a diversity of self-sustaining plant communities, we believe that reclamation of terrestrial wildlife habitat should be initially directed towards the rapid establishment of early seral plant communities that are of benefit, in the short term, to wildlife species adapted to these communities (Green and Yonge 1984). There are several advantages to this approach:

1. Plant associations in early seral communities are more simple than in mid-successional or some climax communities and, as a result, reclamation requirements for re-establishing these communities are less complex;

2. The establishment of early seral communities is a realistic and attainable goal for reclamation and, within a relatively short term, provides a means of evaluating the wildlife habitat enhancement program. In contrast, a program to develop a mature plant community would involve a complex array of enhancement methodologies and, because the results may not be evident for 50-100 years or more, it will be extremely difficult to evaluate the success of the program;

3. Early successional wildlife species will respond to and are most likely to benefit sooner from the re-establishment of plant communities in reclamation areas than wildlife species that are adapted to more mature plant communities; and

4. Because results of the program will be evident in a relatively short period (<15 years), there is positive psychological feedback to industry which will

likely encourage continued or increased participation by industry in enhancement of wildlife habitat.

Although the major focus of this review will be the establishment of early seral communities, we also have considered, where appropriate, methods which may promote a later stage of plant maturity. This is particularly true for watershed and wetland re-establishment, where edaphic climaxes such as emergent or riparian communities are a desired vegetative end product. Reclamation of some mature communities may require decades and reclamation programs for these habitats must be prepared for long-term management of these sites.

The following review of reclamation techniques for wildlife habitat examines four major classes of methodologies: topographic modification, watershed re-establishment, revegetation, and special supplementary methods To encourage a more holistic approach to the reclamation of vegetation communities, we have provided some cross referencing among these four major categories of reclamation techniques.

6.1 TOPOGRAPHY AND CONTOURING

Natural landforms generally contain a variety of topographic features that directly or indirectly affect wildlife. Slope steepness, aspect, shape and geological stability are several of the topographic features that influence habitat edge and, consequently, are important in determining habitat diversity and interspersion of vegetation communities (Thomas et al. 1979a; Maser et al. 1979a). Landforms can directly influence wildlife distributions through provision of escape terrain, protective cover from climatic extremes, visual protection, burrow/nest sites, or specialized habitats such as rock talus or highwalls (Thomas et al. 1979a; Tessman 1982; Proctor et al. 1983). Perhaps more importantly from a reclamation perspective, landforms also affect wildlife through their control of the movement of soil and water and the subsequent effects on the rates and success of vegetation re-establishment.

During reclamation, materials handling and regrading often result in the loss of most abrupt topographic relief. Reclamation standards in many western provinces and states (see Section 8.2) have required smooth contouring and resloping of overburden and spoil materials. The resulting terrain is often homogeneous with respect to slope steepness and aspect, soil type, soil moisture regimes, and microclimate, offering little visual protection and few special terrain features for wildlife. The loss of topographic diversity also reduces habitat edge and, as a result of the loss of microsite diversity, may hamper the re-establishment of vegetation.

In the following section, we examine some of the methods that have been used or proposed to increase or maintain landform diversity in reclaimed areas. Additional information on landform diversity is discussed in Section 6.4 in relation to special habitat features such as rock talus, highwalls and rock piles.

6.1.1 Surface Contouring of Above-ground Mine Features

6.1.1.1 Concept. The use of minor undulations in reclamation or enhancement of surface topography has been suggested by several authors (Tessman 1982; Proctor et al. 1983) and is currently employed or planned in reclamation programs by Cardinal River Coal (G. Acott, pers. comm.), Coal Valley (C. Brinker, pers. comm.), Westar Mining (1983) and TransAlta Utilities (P. Lulman, pers. comm.). The creation of rolling surface undulations on reclamation slopes or flatlands provides a greater diversity of microsites in terms of exposures to climatic factors, aspect, water/snow accumulation, and soil moisture regimes, which in turn can benefit wildlife through increased topographic variability, vegetation diversity and improved vegetation re-establishment. For example, surface undulations have been used in areas prone to desiccation to improve shrub and herb establishment (Institute for Land Rehabilitation 1978; Sindelar et al. 1973; WECO 1983). In areas of relatively flat terrain or on smooth open slopes, surface undulations may help to reduce the line of sight visibility of wildlife. This may be particularly important during the first five to ten years after reclamation when vegetation growth is minimal and is not able to provide adequate hiding cover for wildlife. Surface undulations are not appropriate, however, in areas intended for use as ungulate winter range. In these areas, smooth contouring of the slope is necessary to aid in snow removal by wind erosion and sublimation. Whenever possible, vegetation planting should be integrated with the contouring design to maximize the benefits to habitat diversity (Section 6.3.3).

6.1.1.2 Technique. Two methods have been suggested to create surface undulations:

6.1.1.2.1 Free Dumping of Overburden. Overburden is dumped in a relatively random fashion to create a rough rolling terrain. This technique has been used in flatland areas by Westar Mining (1983) and could also be used to increase surface topography on flat dump tops or wide terraces.

6.1.1.2.2 Recontouring. Spoil and overburden piles can be regraded leaving small depressions and hills along the slopes (Tessman 1982). Some depressions can be enclosed to create areas for water accumulation, whereas others can be graded to provide broad vegetated waterways that drain downward along gently-graded slopes. Both of these methods should be integrated with watershed re-establishment techniques (Section 6.2). If depressions are created on slopes, particularly steep slopes, care must obviously be taken to prevent erosion.

6.1.2 Surface Depressions

6.1.2.1 Concept. Surface depressions were suggested as a reclamation tool by Tessman (1982) and have been successfully implemented in at least one mine site in Montana (WECO 1983). Surface depressions can involve the enhancement of existing depressional features in a mine site (e.g., a sub-grade haul road) or the excavation of new depressions. The functions of depressions are similar to those already described for surface undulations; they promote snow/water accumulation, enhance soil moisture, increase surface topography with resultant benefits to vegetation edge and diversity, and provide some hiding cover for wildlife.

6.1.2.2 Techniques. The following two approaches have been recommended to create suitable surface depressions for wildlife:

6.1.2.2.1 Excavation. Tessman (1982) suggested that depressions be excavated along shallow slopes or on flat terrain, be round to elongate, and not retain standing water (to avoid potential erosion problems but, more importantly, to provide mesic to hydric sites for riparian shrub development). Recommended specifications include a width of 5-15 m, a length of 10-20 m and depths of at least 1-2 m (Tessman 1982). Care should be taken to not locate depressions in areas where overflow could result in erosion problems. Scrapers may be a more practical alternative to bulldozers or graders in creating depressions (Erickson 1981, cited in Tessman 1982). Surface depressions might also be created using shallow blast charges.

6.1.2.2.2 Enhancement of Mine Features. WECO (1983) undertook the re-establishment of a coulee bottom habitat in an abandoned sub-grade access road. The road was first recontoured to approximate a more natural (sinuous) coulee form. Areas with convergent landscapes and north - northeast exposures were considered the best sites for coulee reclamation. In the mountain and foothills biomes, haul roads might better be converted to drainage channels (Section 6.2), riparian zones or draws.

6.1.3 Surface Roughening

6.1.3.1 Concept. Surface roughening has been used successfully to improve microsite diversity and plant re-establishment on reclamation sites (Sindelar et al. 1973, Institute of Land Rehabilitation 1978; Tessman 1982; Westar Mining 1983). The resulting surface helps to retain surface run-off, reduce wind erosion and avoid soil compaction with subsequent benefits to plant growth. Rough surfaces also provide some shelter for small mammals and some passerine birds.

6.1.3.2 Techniques. Discs and harrows can be used to roughen or scarify the land surface (Hardy Associates 1978; Westar 1983). Some specialized equipment also has been developed to gouge or dimple the land surface (Sindelar et al. 1973).

6.1.4 Shaping of Overburden and Spoil Material

6.1.4.1 Concept. Kerr (MS, cited in Proctor et al. 1983) described an option for shaping spoil and overburden material to provide topographic diversity in uniformly-shaped or flatland reclamation areas. To be economically acceptable, however, such large-scale reshaping of mine materials must be incorporated into the pre-mining plan.

6.1.4.2 Technique. Kerr (MS) suggested that spoil or overburden piles be developed in a crescent-like shape that he referred to as a "poppy seed roll" (Figure 1). The advantage of this form is that it provides a wide variety of aspects, varied air currents and wind exposures, a diverse soil moisture regime, different elevations and varied topography which, in turn, promote plant interspersion and

Figure 1. Contouring of overburden storage areas for wildlife habitat. Such a form provides a variety of slopes and aspects and, in turn, provides an increased diversity of wildlife habitats. (Source: Proctor et al. 1983).

diversity. The revegetation program should be planned to maximize the benefits of topographic diversity to wildlife.

6.1.5 Special Topographic Features

Although special features such as highwalls, rock talus, rock piles and caves will be discussed in more detail later in this report (Section 6.5), they are important supplemental methods of increasing topographic diversity in a reclamation site. Because construction materials and opportunities for creating special features are usually most commonly available during the late pre-mining, mining and early post-mining stages of a development, it is important that plans for special features be implemented early in the pre-mine planning phase. For example, loose rock/rubble that becomes available during mine operations can be used to create rockpiles throughout appropriate sections of the reclamation area. Similarly, if a highwall was to become available during the mining process, the highwall could be enhanced for wildlife use by developing escape terrain and nesting sites on the highwall and talus area at the highwall base.

6.2 WATERSHED RE-ESTABLISHMENT

Water is an essential component for the survival and success of wildlife. If reclamation areas are to provide adequate habitats for wildlife, it is necessary that self-sustaining water supplies be provided on or in close proximity to the reclamation site.

An additional benefit of watershed re-establishment for wildlife is the ability of many of the techniques to integrate with and improve watershed protection measures. Watershed protection is being considered as part of another MFRRP project (Pedocan Limited, in prep.) and will not be considered in detail here. The rehabilitation of watershed basins, watercourses, waterbodies and riparian zones will help reduce erosion, maintain water quality and improve ground water supplies in the mine site as well as improving water quality in areas receiving run-off from the mine.

Several techniques for the re-establishment of watershed features on a reclamation site are examined below including re-establishment of watercourses, lakes/ponds, wetlands, and riparian zones and the construction of artificial islands. All of these methods involve the major physical attributes of watershed features; vegetation features and other special techniques are discussed later in this report (Sections 6.3 and 6.4, respectively). In addition, because several of these methods may improve fish habitat, piscivorous wildlife and recreation may also benefit.

An exceptionally useful manual concerning fish and wildlife habitat improvements for reservoirs and streams was developed by Nelson et al. (1978). The handbook details proven designs for aquatic and riparian enhancement, well beyond the scope of this report and study. The major techniques, applicable to reclamation areas in the mountain and foothills biomes, have been incorporated in the following review together with more recent information from other studies.

6.2.1 Watercourse Reconstruction

6.2.1.1. Concept. Minesite drainage structures are designed primarily to transport water away from the site or to consolidate the water in retaining or sedimentation ponds. Because of design efficiency, these drainage systems are not always attractive to wildlife. However, properly enhanced drainage systems are capable of supporting dense vegetation cover, provide an easily-accessible source of water and nutritional forage, create favourable sites for tree and shrub growth (particularly riparian species), modify the microclimate in the immediate vicinity, and, in some cases, may provide temporary water supplies during periods of low water (Tessman 1982). Watercourse re-establishment also can promote plant species diversity with obvious benefits to wildlife. Reclamation of watercourses has only recently been implemented in Alberta. Gulf Resources has undertaken several stream reclamation projects in the Hanlan- Robb area (Wright 1984), Parks Canada has successfully moved a portion of a stream adjacent to the Trans-Canada highway expansion (Leeson 1984), Coal Valley diverted a portion of the Lovell River (R. Ferster, pers. comm), and the Alberta Fish and Wildlife Division in cooperation with Alberta Transportation reconstructed a section of the Crowsnest River (B. Stubbs, pers. comm.).

6.2.1.2 Techniques. Watercourse reconstruction should involve at least three components: watercourse location and design, watercourse and streambank stabilization, and streambank enhancement.

6.2.1.2.1 Watercourse Design. Although the routing of watercourses is determined primarily by the post-mine topography, the routing can be modified within these topographic constraints to improve the value of watercourses to wildlife. It generally is not desirable to completely route surface drainage off the reclaimed site. Drainageways for wildlife should be convoluted to slow the water velocity and to provide a variety of bank heights and shapes as a result of erosional and depositional processes (Nelson et al. 1978; Tessman 1982). Pools can be constructed on the bends to provide deeper water areas for fish and some species of wildlife. Bends in the watercourse can be extended, particularly in areas with very gentle slopes, to create oxbow lakes and associated aquatic and riparian communities (Nelson et al. 1978).

Watercourse widths must be adapted to the specific conditions of the site including the drainage area of the watercourse, the resulting discharge volume and the discharge velocity. Bends and loops should occur at intervals of approximately five to seven times the stream width (Wyoming Fish and Game 1976, cited in Tessman 1982). Pools with depths of 0.5-1.5 m below the channel elevation should be constructed by scooping depressions in the major bends of the channel.

6.2.1.2.2 Streambank Stabilization. Newly-created streambanks are generally prone to erosion and should be stabilized through a combined program of revegetation and erosion control. Keown et al. (1977, cited in Nelson et al. 1978) have comprehensively reviewed most current techniques for streambank stabilization.

In intermittent, gently-sloping channels, reseeding with grasses can reduce stream velocity with subsequent reduction in erosion potential (Nelson et al. 1978; Tessman 1982). Species of grasses, forbs and shrubs that are adapted to hydric conditions should be emphasized in the revegetation of draw bottoms.

Rip-rap, gabion matting and wood cribbing can be used to temporarily stabilize streambanks in areas prone to erosion (Nelson et al. 1978; Proctor et al. 1983; Wright 1984). In general, these structures provide only limited cover for fish and tend to locally increase water velocities. Revegetation of banks with riparian trees, shrubs and ground cover should be used with these methods to provide a long-term solution to bank stabilization (Section 6.2.4).

6.2.1.2.3 Bank Cover. Re-establishment of riparian cover is important in increasing both fish and wildlife habitat values along watercourses. Riparian vegetation binds the streambank, offers protection against erosion and provides direct and indirect cover for fish and wildlife (Nelson et al. 1978). Well-vegetated streambanks are able to withstand some undercutting, which produces direct cover for fish and, to a lesser extent, aquatic and semi-aquatic mammals (e.g., muskrat and mink).

Artificial overhanging streambanks can be reconstructed on the outside bends of stream channels (Figure 2) (Wright 1984). A platform of planks or logs supported on rock rip-rap, gabions or log

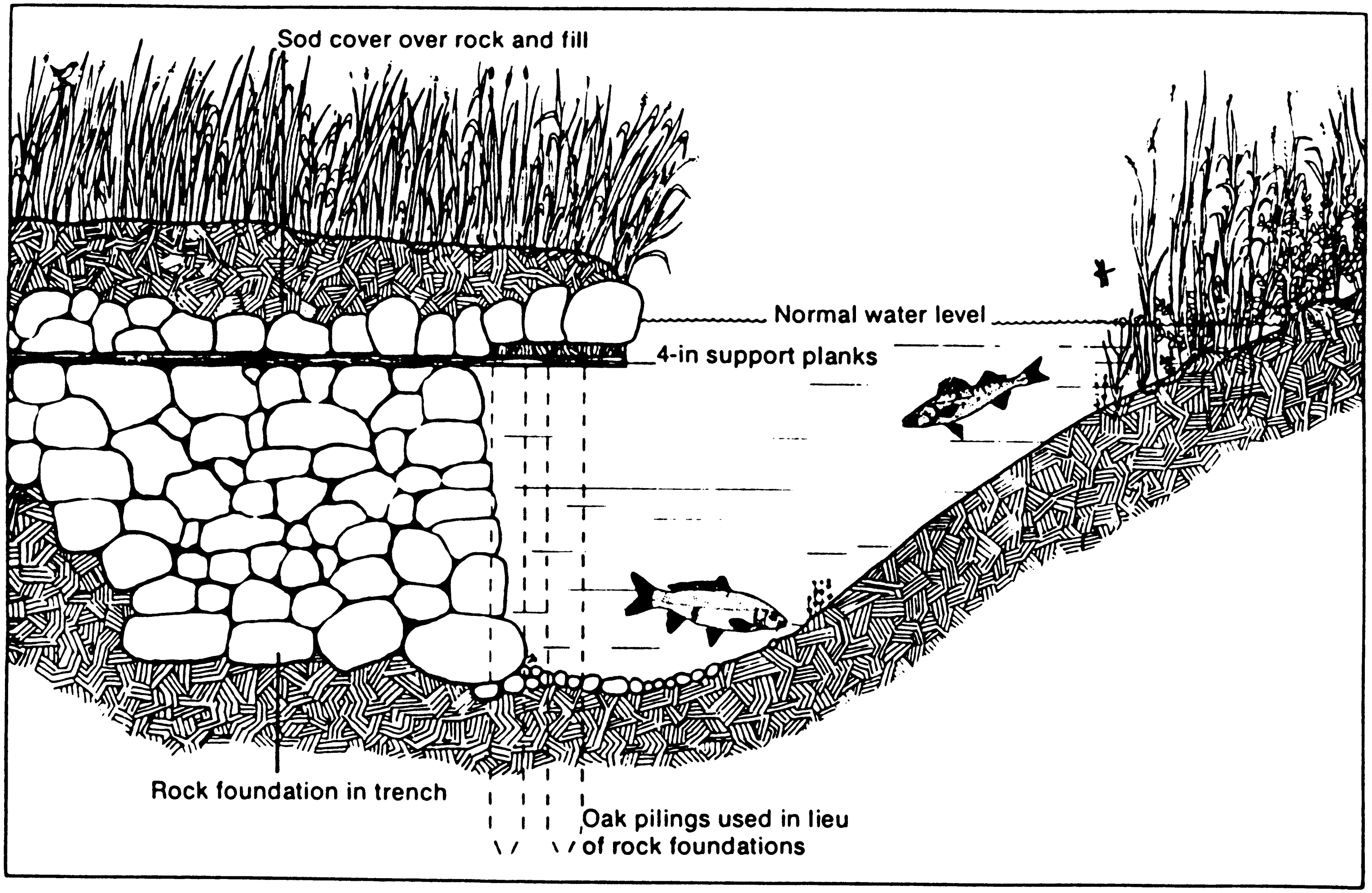

Figure 2. Reclamation of overhanging bank habitat in watercourses. (Source: Nelson et al. 1978).

cribbing (to prevent further back cutting of the bank) can be used to provide an overhanging ledge which, in turn, is covered with a layer of rock and a layer of soil or sod. Vegetation can then be established on the platform using direct seeding or transplanting techniques. Wright (1984) found that revegetation of these banks proceeded rapidly with a good establishment of willows by the end of the third growing season.

In the event that overhanging banks are not required or are not appropriate, a soil cap should be provided on the rip-rap, gabions or wood cribbing. The soil cap will provide a suitable medium for revegetation and, eventually, the restabilization of the bank. In depositional areas along a watercourse (e.g., the inside bank), seeding and transplants of riparian vegetation also can be used to stabilize the watercourse.

6.2.2 Creation of Lakes and Ponds

For the purpose of this review, we have considered lakes and ponds to be those waterbodies which at completion will be moderately to very deep (i.e., average depths greater than 3 m) and consist of a large open water area and a small littoral zone (i.e., less than 20% of the surface area).

6.2.2.1 Concept. During mining operations, a variety of waterbodies or potential waterbodies such as sedimentation ponds, end pits, or stockdams are formed. Most of these waterbodies are characterized by steep approaches, sharp banks, few littoral areas, sterile substrates, and restricted water level fluctuations. Consequently, riparian, emergent, and submergent vegetation is often poorly developed and the resulting waterbodies are of only limited value to wildlife (Olson 1981). However, modification to these waterbodies during construction or reclamation can greatly increase their value (Olson 1981; Herricks 1982; Szafoni 1982; Tessman 1982; Proctor et al. 1983). These mine forms should only be enhanced for wildlife if water quality can be maintained at an acceptable standard in the waterbody.

Large impoundments provide a number of benefits to wildlife: a readily available and permanent source of water; subirrigation of shoreline areas and recharge of the ground water aquifer, with subsequent benefits to the establishment of dense, riparian vegetation; potential year-round habitat for fish and hence a potential food source for piscivorous mammals and birds; increased habitat diversity and quality for semi-aquatic mammals, small mammals, waterbirds and amphibians; and improved hunting and roosting areas for some raptors (Tessman 1982). If the primary end use of an area is ungulate winter range, a year-round water source should not be provided because it may encourage overuse of winter range during other seasons (Tessman 1982).

No examples of lake creation are known for the foothills and mountain biomes. However, a final cut at the Forestburg Diplomat mine near Red Deer, Alberta has been converted to a 2.5 ha, 7 m deep lake suitable for stocking and overwintering of rainbow trout (B. Logan, pers. comm.). At completion, the final cut was recontoured to 10% slopes, although several steep cuts were left intact. Topsoil was then added to the disturbed slopes surrounding the pond down to a level below the anticipated highwater mark and was reseeded with a forage crop seed mix. Part of this area is now under water. Inflow is primarily runoff from surrounding agricultural land. An overflow outlet was constructed but the lake levels have not yet been sufficient to discharge through this structure. The lake has now reverted to control by the County of Red Deer.

Lake/pond enhancement is planned at the Cardinal River (G. Acott,pers. comm.), Obed (T. Adamson, pers. comm.) and Coal Valley (C. Brinker, pers. comm.) mines. At the Cardinal River site, one of the end pits will be used to create a 20 ha lake. Overburden material will be backfilled at the pit edge to provide a littoral zone up to 150 m wide and 6 m deep. The littoral area will also be amended with topsoil. The remainder of the pit will provide a deep water area with potential for stocking with rainbow trout. Inflow from several natural streams and outflow along a drainage channel will ensure recharge and flushing. At the Obed site, existing borrow pits will be converted for waterfowl use, primarily through construction of shallow littoral zones and nesting islands and transplants of emergent vegetation. Several settling ponds along the west flank of the mine site may also be converted for wildlife use. One of the final cuts at the Coal Valley site may be converted to a 6-7 m deep lake suitable for fish stocking if regulatory approval is obtained (R. Ferster, pers. comm.).

6.2.2.2 Techniques. Site topographic considerations are the first and, perhaps, crucial step in the development of a lake or pond for wildlife and fisheries use (Herricks 1982). Topographic parameters that should be considered include location, depth, size, bank slope, shoreline configuration, bottom contouring, and substrate.

6.2.2.2.1 Location. Lakes and ponds within a reclaimed area must be located in stable landforms and compliment the existing or planned topography and the resulting surface hydrology. Assuming that the primary water source will be surface runoff and snowmelt, the watershed should provide sufficient water to replenish the reservoir annually. It is also preferable to have at least one or more inflow streams and at least one outflow for the waterbody in order to maintain water levels and recycle water and nutrients. The overall watershed plan for the postmine landscape should attempt to integrate watercourse reconstruction with waterbody development.

6.2.2.2.2 Substrates. The bottom substrate of a basin must be sufficiently impervious to hold water. It is generally recommended that a minimum of 20% of the bottom substrate consist of clay or other non-porous materials. Prior to flooding, the bottom substrates of the basin may require compaction to reduce permeability and erosion potential. Highly-porous substrates may necessitate the addition of a bentonite clay substrate as a sealer (Nelson et al. 1978).

6.2.2.2.3 Depth. At least 25-75% of the basin should have depths greater than 3-5 m and, if possible, greater depths, should be provided (Herricks 1982; Proctor et al. 1983). Deep areas prevent sold freezing of the basin and choking by aquatic vegetation. To ensure bottom diversity (see Bottom Contours below), depths should be variable throughout the basin.

6.2.2.2.4 Bottom Contours. Several aspects of bottom contours are important to wildlife use of waterbodies: topographic diversity, shoreline slope, and littoral zone development. A fourth and related aspect, the development of artificial islands, is discussed later in this section (Section 6.2.5).

Irregular bottom contours provide a high diversity of microsites for fish and invertebrates with resulting benefits to some species of birds and mammals. Herricks (1982) suggests that irregular bottom contours with depth variations of at least 1 to 2 m are preferable for lakes and ponds.

Shoreline grading should also be variable to increase habitat diversity (Herricks 1982). Slopes of 1:3 to 1:20 appear to be most stable and are preferred in lake/pond reclamation (Nelson et al. 1978; Herricks 1982; Tessman 1982; Proctor et al. 1983). In littoral areas, narrow and wide shelves with gradual slopes (e.g., 1:10 to 1:20) and depths of 0.5 to 1.5 m help promote vegetation development and provide fisheries habitat. Some steep drop-offs also are desirable to provide areas where shoreline access is not restricted by emergent vegetation.

Littoral zones should always be developed as part of the reclaimed waterbody. They are generally the most productive waterbody areas, providing nesting cover for a wide variety of waterbirds and some passerines, protective cover for fish fingerlings and a variety of plant and invertebrate food sources. They also help reduce turbidity, siltation and shoreline erosion (Tessman 1982). Because the extent of emergent vegetation is dependent on the amount of littoral habitat, it is suggested that littoral areas comprise at least 20% of the lake surface area (Herricks 1982). If bottom substrates are sterile, it is recommended they be amended with topsoil and natural or domestic hay prior to flooding to promote establishment of a natural detritus chain and a suitable growth medium for aquatic plants (Crawford and Rossiter 1982). Innoculation of the littoral substrate with bottom ooze from nearby wetlands or lakes also would be beneficial in introducing seeds and rhizomes of aquatic plants, as well as invertebrates.

6.2.2.2.5 Shoreline Configuration. Waterbodies created for wildlife use should have irregular shorelines as opposed to simple circular shorelines (Figure 3). Shorelines with numerous peninsulas and bays provide increased edge, littoral areas and depth heterogeneity (Herrick 1982,; Proctor et al. 1983) which, in turn, provide the potential for increased habitat diversity and wildlife production.

Highly-convoluted shorelines and associated vegetation communities reduce exposure to wind and wave erosion, provide a good interspersion of feeding and loafing areas for waterbirds and muskrat (Crawford and Rossiter 1982) and create visual barriers between breeding pair of waterfowl, thereby increasing the potential waterfowl productivity (Tessman 1982).

6.2.3 Creation of Wetlands

For the purpose of this review, wetlands have been considered as small waterbodies with water depths of less than 1.5 m throughout most (80%) of the waterbody basin. Assuming that bottom substrates and water quality are suitable for plant growth, most of the wetland should be capable of supporting emergent plant growth.

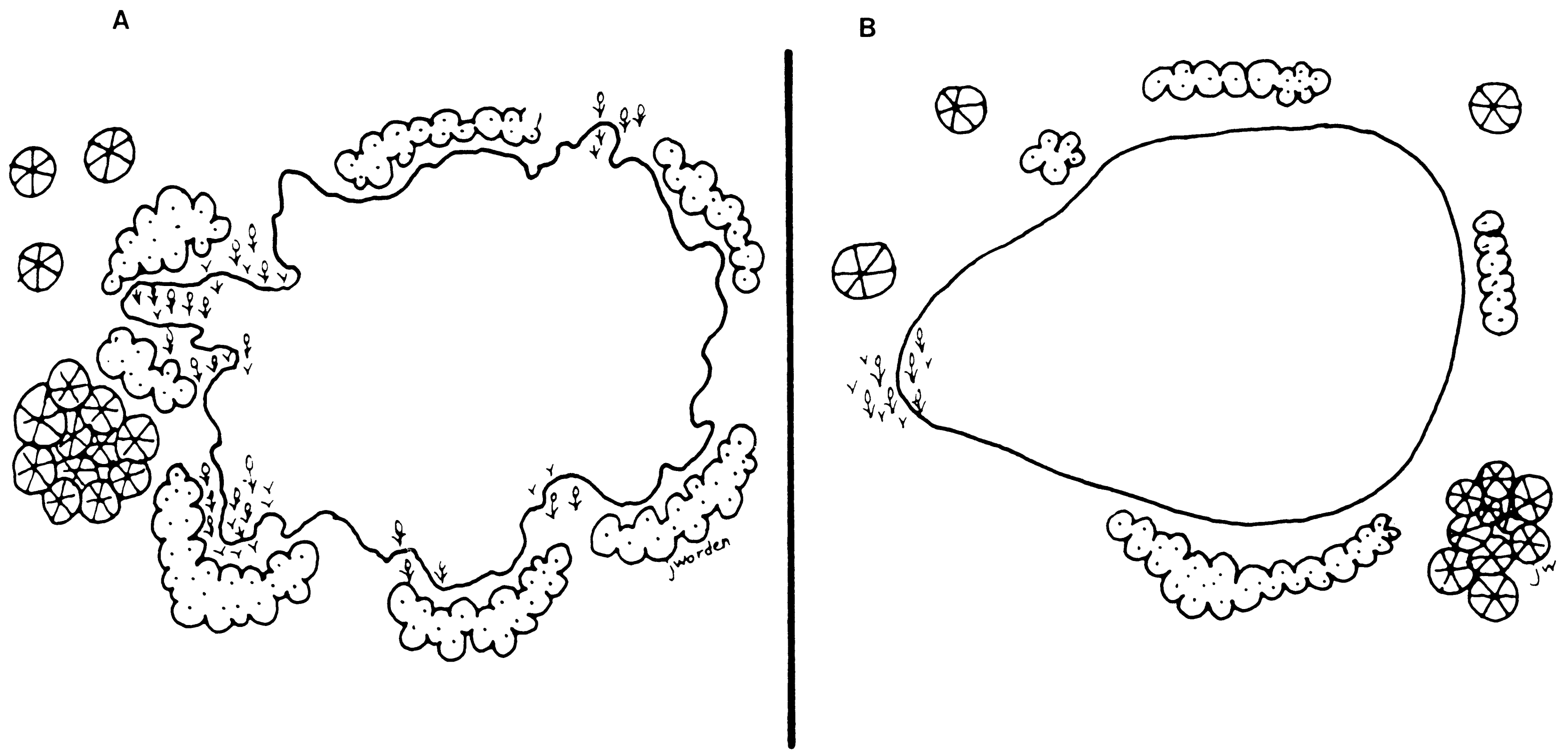

Figure 3. Wetland shape and shoreline complexity. Wetland A is an example of a wetland with a high shoreline complexity and is prefered over Wetland B for wildlife habitat enhancement. Irregular shorelines increase the amount of terrestrial and aquatic edge and, in turn, provide increased ecotone habitats for wildlife. (Source: Szafoni 1982)

6.2.3.1 Concept. Shallow basins within a mine drainage system, sedimentation ponds for watershed protection or sewage treatment lagoons offer opportunities to develop wetland areas. Wetlands can provide many of the benefits already described for lakes/ponds -- provision of a water source, subirrigation of adjacent land, recharge of the groundwater aquifer, increased habitat edge, and increased potential for development of riparian zones -- as well as the provision of a potentially valuable habitat for waterfowl, shorebirds, some passerines, aquatic mammals (particularly muskrats) and amphibians and the potential for treatment of some water pollutants and sedimentation (Kadlec 1981).

Wetland basins have been created as part of the wildlife enhancement program at the Widco site in southeast Washington (Clausing 1981). Gravel borrow pits were converted to wetlands and a disturbed creek bottom area was rehabilitated as riparian habitat with small wetlands. Settling ponds may be converted to wetlands as part of the reclamation plan at the Obed site (T. Adamson, pers. comm.). Saline retention ponds at the Sherness mine site may eventually be enhanced for use by waterfowl (K. Natsukoshi, pers. comm.).

6.2.3.2 Techniques. Design specifications for reclaimed wetlands include substrate, area, depth, bottom contours, shoreline configuration and littoral zone development.

6.2.3.2.1 Substrate. Substrate requirements for wetlands are almost identical to those already described for lakes/ponds, with the exception that most of the bottom substrates should be suitable for plant growth (see Section 6.2.2.2.1).

6.2.3.2.2 Size. Wetlands size can generally be adapted to the needs of the mine plan. Proctor et al. (1983) suggest, however, that wetlands be 0.4 to 4.0 ha in size with wetlands in the 0.4 to 2.0 ha range being optimal for waterfowl production. Wetlands smaller than

0.1 ha are of little use to wildlife and should be consolidated to form larger wetland areas.

6.2.3.2.3 Depth. The extent of shallow (0.5 - 1.5 m) water areas is probably the most important determinant of wetland suitability for wildlife. The amount of shallow water largely determines the amount of emergent aquatic vegetation and, in turn, significantly influences the use of wetlands by wildlife such as waterbirds and aquatic mammals. However, because very dense stands of aquatic vegetation can inhibit wildlife use, the hemi-marsh -- a wetland complex with a 50:50 composition of vegetation and open water areas -- appears to be most productive for wildlife (Weller and Fredrickson 1974). Depths should therefore be variable with at least 50% of the basin occupied by shallow water areas no more than 1.5 m in depth.

6.2.3.2.4 Bottom Contours. Uneven bottom contours are preferred for reclaimed wetlands (Crawford and Rossiter 1982; Herricks 1982; Proctor et al. 1983). Irregular contours provide a variety of water depths and microsites and allow for a good interspersion of emergent vegetation and open water. If the pre-flooding basin is smoothly contoured, the topographic diversity of the bottom substrate could be increased by excavating deeper pools and constructing shallow platforms with the excavated material.

Shoreline slopes should be variable to increase the interspersion of littoral and deep water zones. Slopes in littoral areas should be 10:1 - 20:1 (Crawford and Rossiter 1982; Herricks 1982) whereas slopes in deep water areas can be as steep as 3:1 if the substrate material is stable. Bottom contouring in wetlands should also consider the construction of artificial islands for wildlife use (Section 6.2.5).

6.2.3.2.5 Shoreline Configuration: As described for lake/ponds, wetland shorelines should be convoluted to promote wildlife use (see Section 6.2.2.2.5).

6.2.4 Riparian Zones

6.2.4.1 Concept. Riparian zones generally support a greater number and diversity of wildlife and sustain higher levels of productivity than most other terrestrial or aquatic habitats (Odum 1971). They also have a significant influence on the physical, chemical and biological properties of the associated terrestrial and aquatic communities (Szafoni 1982). Riparian vegetation helps slow overland drainage, increases percolation, reduces sheet erosion, stabilizes streambanks and helps to trap sediments and nutrients (Szafoni 1982). Riparian areas are not only beneficial to wildlife but also provide some watershed protection.

Moist to wet areas and seeps frequently develop as part of the drainage system within a mine site, and because water is readily available, trees and shrubs establish easily in these areas. Subsurface irrigation in the areas around wetlands, lakes and ponds also offers excellent opportunities for reclamation of riparian habitats. Riparian development has been incorporated into reclamation plans for the Cardinal River Mine (G. Acott, pers. comm.), Gregg River Mine (Hardy Associates 1982; M. Murphy, pers. comm.), McLeod Mine (McLeod River Coal Ltd. 1982) and the Widco Site in Washington (Clausing 1981) and is presently being implemented at the Westmoreland Mine in Montana (Westmoreland, n.d.).

6.2.4.2 Techniques. Riparian areas should be developed in moist to wet areas that result from mine drainage and waterbody/watercourse creation and enhancement. Areas that remain moist throughout most of the growing season are most preferable. Revegetation in riparian areas should include an interspersion of trees, shrubs and ground cover adapted to mesic and hydric conditions (see Section 6.3.3.3).

6.2.5 Island Development

6.2.5.1 Concept. Small islands in lakes, ponds and wetlands can provide additional terrestrial - aquatic edge and littoral areas while also providing an aesthetic landscape element in the waterbody. They are also an effective method of improving waterfowl nesting success because of reductions in terrestrial mammal predation (Stoecker 1982). Development of islands in conjunction with mud flats and shoals can also improve feeding and loafing areas for some waterbirds (Stoecker 1982). Islands can often be easily created during the construction of ponds, lakes and wetlands, particularly if recontouring or resloping of the basin is required.

6.2.5.2 Techniques. Artificial islands have frequently been constructed as part of marsh enhancement programs (e.g., Ducks Unlimited projects) and can easily be incorporated into the site reclamation plans for most waterbodies. Front-end loaders and bulldozers have been used effectively to construct artificial islands prior to flooding (Nelson et al. 1978; Stoecker 1982; Proctor et al. 1983). Cardinal River Coal may include artificial islands in their pit-lake reclamation program (G. Acott, pers. comm.). Specifications for construction of artificial islands include location, size, substrate, elevation and shape.

6.2.5.2.1 Location. Waterfowl nesting/loafing islands should be separated from the mainland by water at least 9.0 m wide and 0.5-0.6 m deep (Keith 1966). Where several islands are to be constructed in a waterbody, they should be well dispersed to reduce territorial strife during the breeding and nesting periods. Hook (1973) suggested that islands be separated by a minimum of 33 m to minimize territorial strife and encourage nesting by Canada geese.

Shelter from prevailing winds is an important consideration in reducing wave erosion of the island and encouraging wildlife use (Stoecker 1982). Preferred locations include the upwind side of the waterbody, and coves protected areas behind larger peninsulas. Tree and shrub plantings on the mainland, upwind from the island, can also be used to protect the island.

6.2.5.2.2 Size. Island sizes of 1 to 200 m^2 or larger have been employed successfully in a number of lake/marsh enhancement programs (Hammond and Mann 1956; Nelson et al. 1978; Giroux 1981; Stoecker 1982; Proctor et al. 1983). Although size is not critical to wildlife use of islands, those larger than 200 m^2 probably are more cost-effective to build than smaller islands (Proctor et al. 1983). In large waterbodies, several well-spaced smaller islands are preferable to one large island.

6.2.5.2.3 Substrate. Islands may be constructed of overburden, rock or any other relatively stable fill material. Where wave action may erode the structure, rock rip-rap, gabions or wood cribbing can be used for short-term stabilization. Because vegetation enhances the value of islands to wildlife, the island should be capped with top soil to provide a suitable substrate for plant growth (Stoecker 1982; Proctor et al. 1983). Straw mulch can also be applied as a short-term stabilizing cover. Vegetation established on the island should be appropriate for its size and intended use. On small islands or islands intended primarily for waterfowl use, plantings of grasses, forbs and emergent aquatic plants are preferred. On larger islands, areas of riparian shrubs and trees can be established to increase habitat diversity, to stabilize the island banks and to provide some protection from wind exposure.

6.2.5.2.4 Elevation. The tops of artificial islands should be at least 1 m above the high water mark to avoid nest destruction during flooding or severe wave action (Proctor et al. 1983).

6.2.5.2.5 Shape. Shape is not an important design criterion for small islands but becomes increasingly more important as the island size increases. On larger islands, irregular shorelines provide the best wildlife habitat (see Section 6.2.2.2.5). Small peninsulas and bays offer protected areas for waterfowl feeding and loafing whereas crescent shaped islands, oriented away from the prevailing winds, provide larger protected areas (Stoecker 1982). Mud bars, shoals, exposed cobble areas and snags can also be incorporated into the island design (Figure 4) to provide additional habitat diversity for some species of birds and mammals (Stoecker 1982).

6.3 REVEGETATION

Following development of post-mining topography and watershed re-establishment, revegetation is the final and essential element in successful reclamation. Until recently, few attempts had been made to reclaim vegetation communities on mine areas. Consequently, our knowledge of community reclamation and plant community dynamics on reclaimed land is minimal. Reclamation research to address community development is presently underway at Cardinal River Coal (G. Acott, pers. comm.), Coal Valley (R. Ferster, pers. comm.), Westar Mining (1983), and Whitewood Mine (P. Lulman, pers. comm.).

The revegetation component of wildlife habitat reclamation must consider a wide variety of factors including seasonal habitat requirements of the key species, size of the reclamation area, site geoclimatic constraints, the selection of palatable and unpalatable plant species appropriate for the key species and probable microsite conditions, successional patterns within the re-established communities, spatial arrangement of plants within the communities and spatial arrangements of community blocks.

6.3.1 Revegetation For Key Species

The main function of the revegetation plan, from a wildlife habitat perspective, is the integration of proposed vegetation communities with physical features of the site to fulfill the needs of the selected key species. Vegetation communities provide the essential elements of food and/or cover for most wildlife and

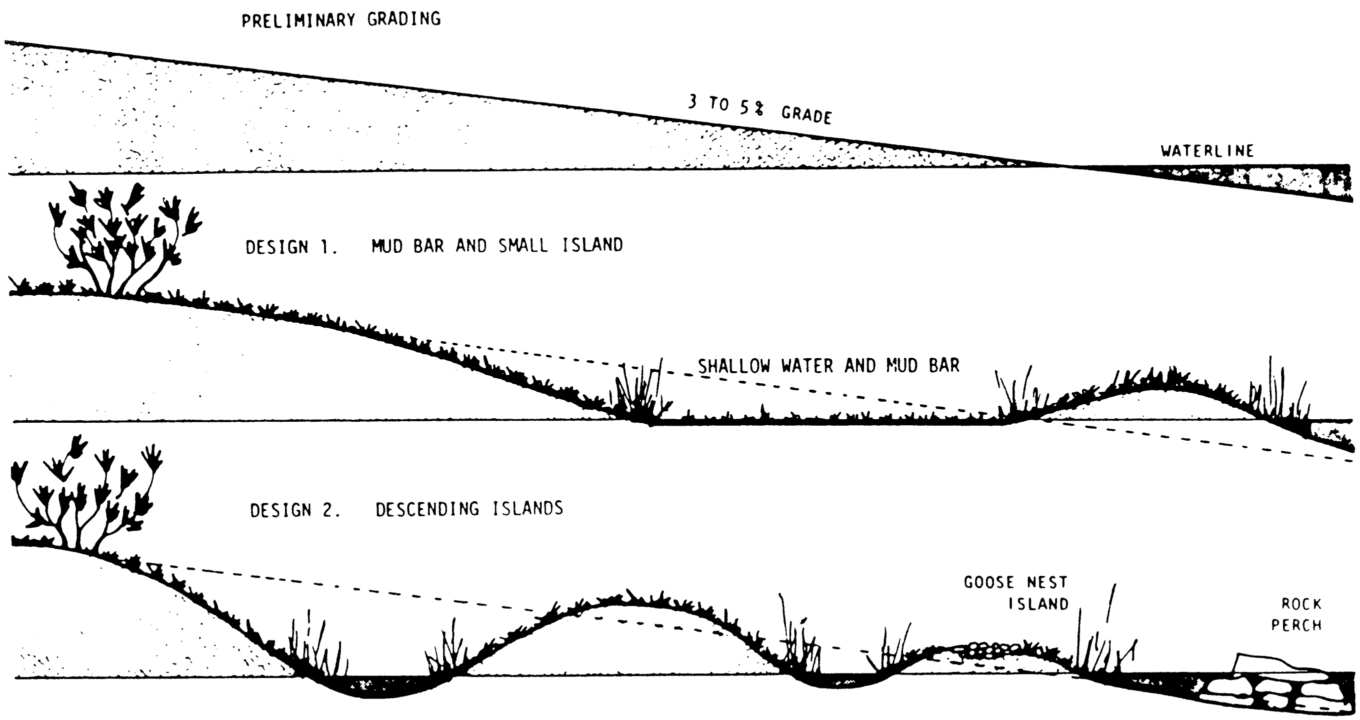

Figure 4. Construction of artificial isalnds. Recontouring of the shoreline slope can increase habitat diversity through the creation of islands, mud bars, shoals and littoral zones. (Source: Stocker 1982)

can provide or enhance access to the other essential element, water. Cover requirements can include thermal cover, reproductive cover, and/or hiding and escape cover.

In developing a conceptual approach for revegetation of wildlife habitat in the mountain and foothills biomes, we are faced with the reality that different plant communities are adapted to different biophysical conditions. Regardless of the perceived requirements of a key species for a particular habitat, we cannot provide that habitat unless the basic requirements of soil moisture, aspect, slope and exposure are present. For example, if no steep, south-to-southwest facing slopes with high wind exposures are available in a reclamation site, it is unlikely that we will be able to successfully re-create some types of elk and deer winter range. The success of the revegetation program in re-establishing wildlife habitat is dependent on the recognition of the physical constraints of the post-mine topography and hydrology on plant community development.

The spatial requirements of wildlife species in relation to the size of the reclamation area places additional constraints on a revegetation program. Each species exploits several habitat types during its lifetime to obtain an acceptable balance of food, cover, and water, and it may not be possible or desirable to provide all of these requirements in a single reclamation area if this will result in overcrowding. The size of a reclamation area, in relation to the spatial requirements of a key species, obviously will influence the number and types of habitats and special habitat features that can be realistically provided. However, space requirements for most wildlife species are poorly understood. In particular little information on the spatial requirements of the key species in relation to specific life and seasonal phases is available that is specific to the mountains and foothills biomes of Alberta.

The existing successional states of many of the major habitat ecoregions in the mountain and foothills biomes (Section 5.0) reflect a history of fire suppression. Seral habitats are less abundant today than in the past whereas mature, later-successional habitats are abundant. Most reclamation sites in the mountain and foothills biomes remove areas of homogeneous mature forest cover that are small in relation to the regional abundance of these forest communities. In many cases, forest communities adjacent to reclamation sites will provide ample thermal cover and, possibly, hiding cover for wildlife (Wallis and Wershler 1979; Millson and Bondy 1984). Therefore, it would seem most beneficial to wildlife if habitat reclamation focused initially on the provision of food, reproductive cover and hiding cover (to promote use of the new food sources). Although some provisions may be made to re-establish thermal cover over the long-term, the length of time required to restore thermal cover (e.g., 70 to 130 years or more) (Thomas et al. 1979c), precludes its consideration in programs aimed at restoring early successional communities (Section 6.0). Thermal cover also could be provided by minimizing the clearing of mature forest cover on a development site. Maintenance of these uncleared 'islands' would also provide some food and cover for wildlife and a seed source for natural revegetation.

6.3.2 Selection of Species

The relationship between vegetation communities, their species composition and utilization of these species by wildlife is complex and not well understood, yet plant species selection is an essential element in the rehabilitation of land for wildlife habitat. Animal preferences for plant species do not follow common methods of vegetation classification. Wildlife may use one group of plant species for food and another group of species for hiding or thermal cover; additional plant species may be important components of reproductive cover, or may provide a suitable source of moisture. Use of these vegetation groups also may be influenced by season or factors such as harassment by humans, natural predators and inter- and intraspecific competition.

In the following discussion, we examine several factors that will influence the choice of revegetation species for wildlife habitat: key species requirements, forage quality, palatability and revegetation potential.

6.3.2.1 Key Species Requirements. Trees, shrubs and/or ground cover must be selected to satisfy the seasonal requirements of the key species for food and cover. Dietary analyses of bighorn sheep and elk have been used to select plant species for use in the reclamation program at Crowsnest Resources (B. Densmore, pers. comm.). Plant species that are commonly consumed by elk and bighorn sheep will be included in the seed mix (if seed is available) as well as 3-4 species of plants known to survive well on the site. Reviews of the major dietary requirements of several large herbivorous mammals were compiled to provide lists of plant species for potential use in the reclamation program at the Cardinal River (Wallis and Wersher 1981) and Fording Coal (Norecol 1984) mine sites. Introduced and native plant species of known commercial propagation that are utilized by the ten key species are summarized in Table 13.

6.3.2.2 Forage Quality. Quality of forage should also be considered in species selection. Considerable controversy has arisen over the use of native species as opposed to commercial species in revegetation (see Sims et al. 1984 for a review). Native species are often suggested as preferred species for wildlife habitat reclamation because they are adapted to local conditions and are utilized by wildlife in natural areas. There is insufficient evidence, however, to suggest that introduced or agronomic species are inferior or superior to native species in terms of adaptability, wildlife preference, nutritional value and productivity (Institute of Land Rehabilitation 1968; Sims et al. 1984).

Table 13. Introduced and native plant species of known commerical produciton that are potentially suitable for wildlife habitat reclamation in the foothills and mountain biomes of Alberta. (Only those species that are preferred (t) or moderately utilized (o) by the key species and that are currently feasible to propagate are included.)

MAMMAL SPECIES	PLANT SPECIES: Grasses	Brome, Smooth	Fescue, Creeping Red	Timothy, Hay	Wheatgrass, Northern	Wheatgrass, Slender	Wheatgrass, Streambank	Introduced Legumes	Alfalfa (Falcata)	Alfalfa (Sativa)	Native Forbes	Anemone, Canada	Anemone, Long Fruited	Anemone, Cut-leaved	Aster Spp.	Bunchberry	Fleabane Spp.	Harebell	Indian Paint	Northern Bedstraw
Snowshoe Hare																				
Beaver																				
Muskrat																				
Elk		t	t	t	t	t	t		t	t										o
Moose																				o
Caribou																				
Mountain Goat																	o			
Bighorn Sheep				t	t	t						o	o	o	o			o	o	o
Spruce Grouse																o				
White-tailed Ptarmigan																				

Table 13 continued.....

.....Table 13 continued

MAMMAL SPECIES	Strawberry	Sweet-Broom	Three-Flowed Avens	Vetchling	Yarrow	Yellow Avens	Shrubs	Alder, Green	Alder, River	Avens, White	Avens, Yellow	Bearberry	Birch, Dwarf	Blueberry	Buffaloberry	Cherry, Choke	Cinque Foil Shrubby	Cranberry, Bog	Cranberry, Highbush	Cranberry, Lowbush
											PLANT SPECIES									
Snowshoe Hare								t	t				t					t	t	o
Beaver								o					o							
Muskrat																				
Elk			o			o												o		
Moose				o				o					o			o				t
Caribou										o	o	o	o				o			
Mountain Goat								o				o								o
Bighorn Sheep	o	o			o				o			o				o	o			
Spruce Grouse												o		o				t		
White-tailed Ptarmigan								t		t	t	t			t		t	t		

Table 13 continued.....

.....Table 13 continued

MAMMAL SPECIES	PLANT SPECIES: Crowberry	Dogwood, Red Osier	Elderberry, Black	Heather, Purple	Heather, Yellow	Honeysuckle, Bracted	Juniper, Common	Meadow Sweet, White	Raspberry, Red	Rose, Prickly/Wild	Saskatoon	Silverberry	Snowberry	Tea, Labrador	Willow, Arctic	Willow, Beaked	Willow, Grey	Willow, Snow	Willow, Spp.
Snowshoe Hare		t				o		t						o		t			t
Beaver		o										o							t
Muskrat																			
Elk							o		o			t							t
Moose		t				o	o		o	o	t						o		t
Caribou	o			o	o								o	o	o			o	
Mountain Goat						o			o			t	o						o
Bighorn Sheep		o	o									o							o
Spruce Grouse									o										
White-tailed Ptarmigan	t			t	t					t									t

Table 13 concluded.....

.....Table 13 concluded

PLANT SPECIES

Trees

MAMMAL SPECIES	Aspen, Trembling	Birch, Paper	Fir, Alpine	Fir, Douglas	Larch, Alpine	Mountain Ash, Green's	Pine, Lumber	Pine, Lodgepole	Poplar, Balsam	Spruce, Black	Spruce, White
Snowshoe Hare	t	t		t	t			t	t	o	t
Beaver	t	o							o		
Muskrat											
Elk	t			o			t	t			t
Moose		o	o			t		o	t		o
Caribou	t	o			t						
Mountain Goat	o		o					o			
Bighorn Sheep	o										o
Spruce Grouse		o						t			t
White-tailed Ptarmigan											

Several recent studies suggest that some agronomics may produce higher quality forage than native species. Kilcher and Looman (1983) demonstrated conclusively that introduced varieties of crested wheatgrass, Russian wild ryegrass, and Altai wild ryegrass outyielded and generally had higher crude protein and phosphorus levels than did 5 native grass species. A native cultivar of slender wheatgrass (cv. Revenue), however, performed better than most of the introduced varieties. The authors also note that the high-yielding introduced varieties did not allow between-row growth of other plants (weeds), a characteristic which may not be desirable if succession to a native plant community is to be encouraged. Troelsen and Campbell (1959) investigated the nutritive value of six grasses cut and cured as hay in early July. Rankings from best to worst were: (1) Russian wild ryegrass, (2) crested wheatgrass and streambank wheatgrass (equal native spp.), (3) intermediate wheatgrass, (4) tall wheatgrass, and (5) reed canary grass. Other studies have identified Russian wild ryegrass as the best winter forage variety available (Smoliak and Bezeau 1956; Lawrence 1977). Recent variety releases of Altai wild ryegrass (Prairieland) and a native species, northern wheatgrass (Elbee) may have value as winter forage (Agriculture Canada 1977, 1980). Elbee established well and was similar to Magna smooth brome in yield after one year in trials near Hinton but Altai wild ryegrass failed to establish an adequate stand (Smith and Walker, in prep.)

Several studies in the western United States have shown that although introduced species may be more productive than native species during the first several years after seeding, productivity of native species increases after the first few years and may exceed that of introduced species (see Sims et al. 1984 for a review). Mitchell (1973 cited in Sims et al. 1984) suggested that native grasses sacrifice seed production for vegetative growth and propagation during the initial establishment period. Once established, however, these native species require little maintenance as a result of their adaptations to the biogeoclimatic conditions and, hence, in the long term, are preferred to introduced species.

Until further research is conducted to determine if native or introduced species are preferable for reclamation of wildlife habitat, it is not possible to recommend selection of either group at the expense of the other. Moore et al. (1977; cited in Sims et al. 1984) suggest that plant species selection should focus on the successional status of the species rather than its genetic source. For the present time, species should be selected that are preferred by wildlife but that also can be grown with moderate to high success within the conditions of the reclamation site.

Wildlife habitat should not necessarily be equated with the production of forage (Scotter 1980). The question of 'the relative importance of forage-related compared with structure-related habitat features as predictors of habitat use' needs to be answered. Also '...research should be concerned not only with the quality and quantity of habitat but also with whether habitat can and will be used' (Scotter 1980:24).

6.3.2.3 Palatability. Forage palatability may be a valuable tool for managing artificially created wildlife habitat. Plants with low palatability could be seeded on areas sensitive to overuse (e.g., a high erosion hazard), or critical to other wildlife such as ground-nesting birds. Seasonal differences in palatability of plants raises the possibility of avoiding the problem of overuse of winter forage supplies early in the season. However, the effect of palatability on reclamation for wildlife are not well understood and further research is required.

Research on wildlife preferences for commercially available species is almost non-existent. Smith et al. (1979) found that captive elk fed dried grass forage appeared able to distinguish between closely related species. For example, intake rate was different for creeping red fescue, and chewings red fescue, bearded wheatgrass, and streambank wheatgrass and northern wheatgrass. Creeping red fescue and smooth bromegrass were preferred species at the mid-season phenological stage. Streambank wheatgrass, initially was shunned by the elk but later was consumed quite rapidly suggesting an acquired taste (USDA 1972).

Plant palatability in free-ranging situations is difficult to assess. Palatability rankings based on levels of utilization may reflect actual palatability as well as plant availability. In cases where palatable species are overgrazed or uncommon, less palatable and more commonly-occurring species may be utilized more than the palatable species. The nutritional value of these less palatable species may exceed the nutritional value of the palatable species under some range conditions (M. Ross, pers. comm.)

Observations of ungulate use of ground covers commonly seeded on reclamation sites in British Columbia and Alberta suggest that growing conditions and fertilization on reclaimed sites may alter the palatability of many plant species for wildlife. Elk will preferentially consume some species but will eat almost any of the species planted on a site (G. Harrison, pers. comm.; D. Lane, pers. comm.; D. Walker, pers. ob.). Bighorn sheep have also been observed not to be highly selective of ground cover species on reclaimed sites (G. Acott, pers. comm.).

6.3.2.4 Reclamation Potential. Selected species must, of course, be available as seed or for propagation and be viable under the reclamation conditions. The present studies by Pedocan (in prep.) and Dempster and Associates (in prep.) should provide valuable information on the reclamation potential of tree, shrub and ground covers and the growth potential of tree species on reclaimed soil, respectively. As a general guide, however, we have compiled a list of grass, legume, shrub and trees species which are suitable for wildlife habitat reclamation (Table 13). The list is not meant to be comprehensive as there already exist numerous reviews of potential species (e.g., Wallis and Wershler 1979; Watson et al. 1980; Ferguson 1983; McArthur 1983; Monsen 1983; Rumbaugh 1983; Norecol 1984).

6.3.3 Plant Community Reclamation

In section 5.0, we briefly described the major ecoregions of the mountain and foothills biomes, and the successional trends, wildlife communities and reclamation potential of these ecoregions. As a result of propagation problems and implementation costs (see above), we may not always be able to utilize all of the plant species that we require to meet the needs of the key wildlife species or to restore the various habitat strata for community development. Despite these difficulties in plant and seed supply, revegetation for wildlife habitat should still attempt to develop plant communities as opposed to monotypic or homogeneous block plantings, in order that successional processes are encouraged as much as possible.

In the following section, we briefly discuss the concept of plant community development in wildlife habitat reclamation and the distribution of plant communities in the reclamation site. Information on community location and structure was derived from McLeod River Coal Ltd. (1982), Hardy Associates (1982), Westar Mining (1983), WECO (1984) and Westmoreland (1984). Potential locations of plant communities in relation to specific physical features within 'typical' reclamation sites are illustrated in Figures 5 and 6. Specific revegetation techniques for wildlife habitat are considered in Section 6.3.4.

6.3.3.1 Grasslands. Reclaimed grassland communities might include an upland grass community, a lowland grass community and a riparian or sedge-dominated grassland.

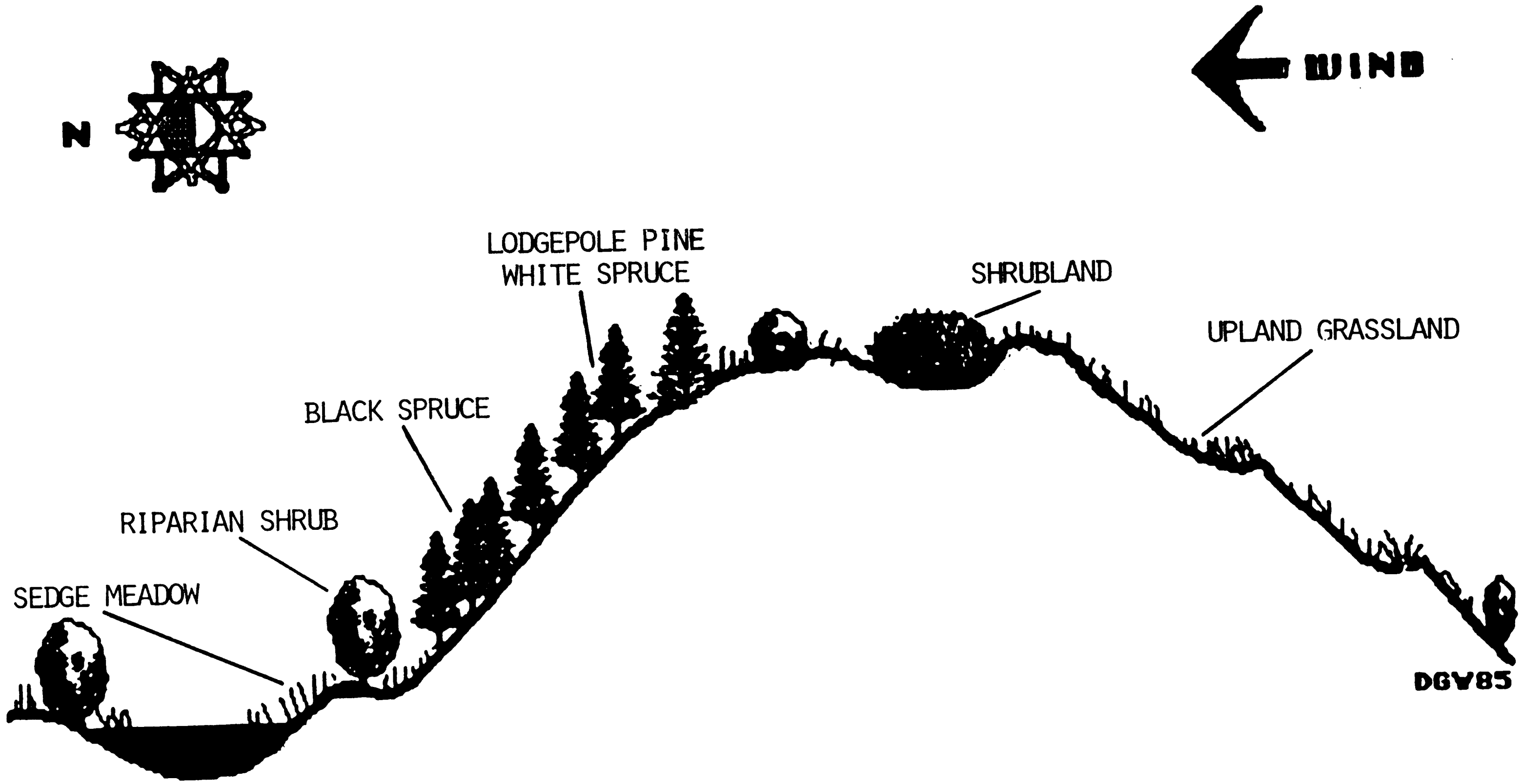

Figure 5. Potential locations for plant community establishment on an overburden storage area.

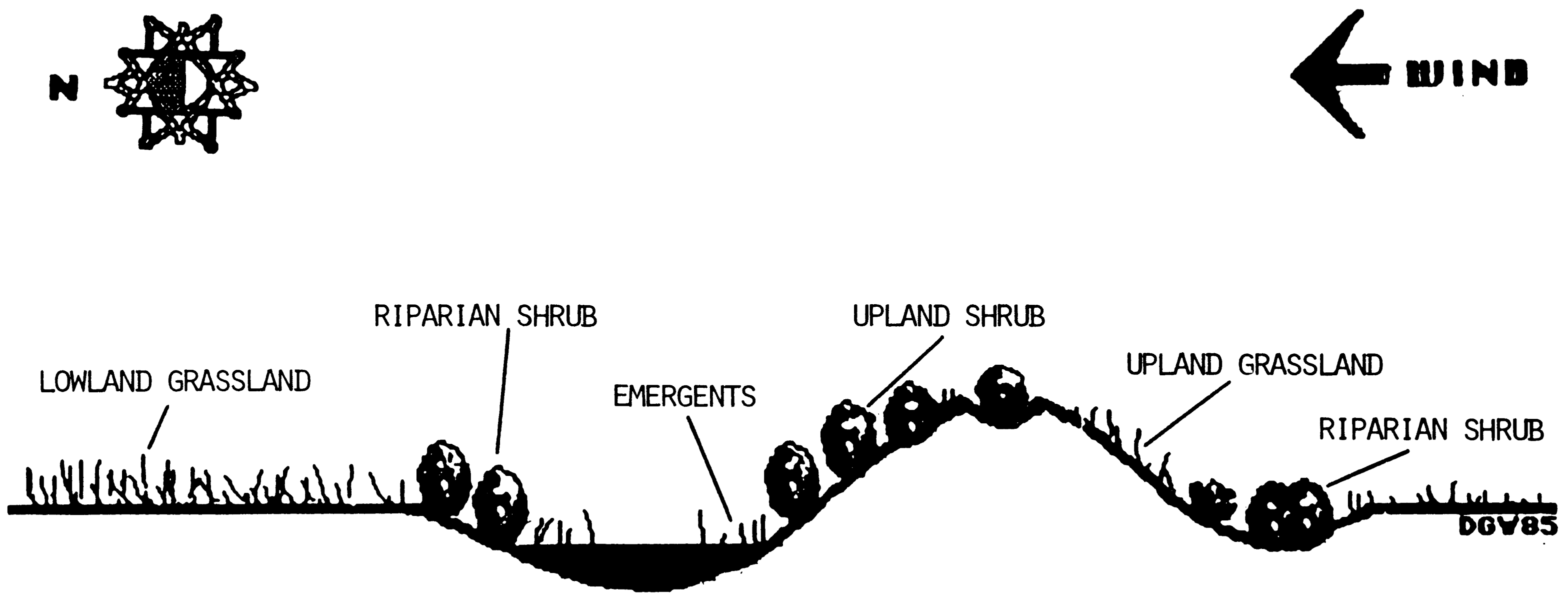

Figure 6. Potential locations for plant community establishment on flat terrain within a reclamation site.

Upland grass communities are best developed on xeric sites with a high degree of exposure to wind and sun. Planting mixes should include a mixture of predominantly warm season grasses (Westar Mining 1983). Upland grass communities would likely be an important component of elk and deer winter range as well as a year-round forage source for bighorn sheep and mountain goats.

Lowland grass communities can be established on mid-and lower slopes with eastern, southern or western exposures. Cool season grasses should preferably dominate the seed mix. Lowland grass communities would provide nesting cover for waterfowl and passerines, spring-fall foraging areas for ungulates, and habitat for some small mammals.

Riparian or sedge-dominated grasslands can be established on poorly drained areas at the base of slopes, in moist depressions or adjacent to reclaimed wetlands and watercourses. Sedges, graminoids and forbs adapted to hydric and mesic conditions should dominate the seed mix. Riparian grasslands would provide nesting cover for waterfowl and passerines and excellent cover and food for small mammals.

6.3.3.2 Emergent Aquatics. Emergent aquatic communities can be developed in association with permanent or semi-permanent wetlands or other waterbodies. Possible species include bulrushes, cattails, reed grasses, sedges, water lillies, and submergent vegetation such as duckweed and pondweed. Transfers of bottom ooze and rootstocks from adjacent natural wetlands can be employed to accelerate establishment of emergent vegetation (Crawford and Rossiter 1982). Emergent communities provide a food source for muskrat, beaver and some waterbirds, nesting sites and materials for waterfowl and some passerines and construction materials for muskrat.

6.3.3.3 Shrub Meadows. Shrub meadows can be established in association with lowland grass communities or riparian grassland communities. To maintain a relatively open community, mature shrubs should not occupy more than 25 percent of the area. Potential species include willows, alders and dwarf birches. Shrub meadows are best established in close association with waterbodies and wetlands in order to provide nesting cover for waterbirds and passerines. They can also be used as an ecotone between denser shrublands and grasslands.

6.3.3.4 Shrublands. Shrubland communities can include upland shrubland and riparian shrubland.

Riparian shrubland can be developed in a variety of mesic situations along waterbodies and watercourses, and in moist depressional sites and valley bottoms. Tall willows, dwarf birch and, possibly, alders should dominate the plantings. Balsam poplar could also be incorporated to eventually provide a tree stratum along watercourses. Riparian shrublands will provide cover and browse for most ungulates and white-tailed ptarmigan, a food source and construction materials for beaver, and nesting sites for passerines and some waterbirds.

Upland shrub communities can be established on east, south and west-facing slopes and in flat areas. Planting success will likely be highest if first plantings are concentrated in shallow depressions or draws. Potential species include willows, alder, red-osier dogwood, saskatoon and wood rose. At maturity, shrub densities should be in the range of 25 to 75 percent; higher densities may restrict browsing and wildlife movements. Upland shrub communities are important as a source of winter browse and cover for ungulates and snowshoe hares.

6.3.3.5 Deciduous Forest. Deciduous forest communities dominated by trembling aspen can be located in south to west facing areas with mesic to xeric moisture regimes. Mixed plantings of trembling aspen and several shrub species such as saskatoon, wood rose, red-osier dogwood, buffaloberry and bearberry would provide varied habitat strata and food sources for ungulates, small mammals and passerines. In xeric sites, ground juniper could also be planted as a ground cover.

6.3.3.6 Mixed-wood Forest. Mixed-wood forests are best suited for mid- to lower slope locations with east, west or south-facing aspects. Species mixes may include trees such as trembling aspen, lodgepole pine, Douglas fir, Englemann spruce and white spruce and shrub species such as red-osier dogwood, wood rose, saskatoon, high and low bush cranberry, alder and willow. This community can be established as an earlier successional stage for many of the coniferous-dominated communities (see below). At maturity, this community would provide a source of winter browse for ungulates and snowshoe hares, summer foods for small mammals and ungulates, and hiding cover and nesting sites for a number of passerine birds.

6.3.3.7 Coniferous Forest. Coniferous forest communities can be established in a variety of reclamation conditions. Alpine fir-white spruce forests can be established on north-facing slopes at mid to high elevations. Lodgepole pine-white spruce forests can provide good cover on flat or gently sloping north to northeasterly locations; alder is an important shrub component in this community. Lodgepole pine-black spruce communities are best located on mid to lower slope areas on northern and eastern aspects. Labrador tea, bog birch and bog cranberry should dominate the shrub stratum. Black spruce-tamarack forest communities can be planted in hydric to mesic sites on northern and eastern aspects or in flat areas. Dominant shrubs should include dwarf birches, willows and alder. During the first two decades after establishment, coniferous forests can provide some browse, hiding cover and reproductive cover for mammals and birds. At maturity, however, coniferous forests primarily provide thermal and hiding cover for wildlife plus food supplies for climax-adapted species such as red squirrels or caribou. Because coniferous forests provide only limited food supplies for most herbivores, coniferous units should be located in close proximity to more open communities such as shrublands, deciduous forest, shrub meadows and grasslands, which offer a greater abundance and diversity of plant foods.

6.3.4 Revegetation Configurations and Planting Patterns

Following selection of plant species appropriate for habitat reclamation and physical conditions in the area, consideration must be given to the placement and interspersion of communities on the site. Factors that should be considered include the size and spatial configurations of the units, and planting patterns within the units.

In the following discussion we have assumed that as a result of time and cost restrictions, the initial reclamation phase will concentrate on establishing shrub or tree habitat units interspersed with grasslands or shrub meadows. Additional units may then be established in the interstitial areas as time, funds and materials permit.

6.3.4.1 Habitat Unit Size. The determination of optimum size or maximum-minimum ranges for habitat units is a difficult and complex task. Useable habitat unit sizes vary among wildlife species as well as among the types of habitat being reclaimed (Thomas et al. 1979b). The surrounding habitat composition and topography in undisturbed sites also can affect the optimal size of reclaimed habitat units.

The most detailed information on habitat unit size for elk and deer was provided in an intensive wildlife-forestry study in the Blue Mountains of Oregon (Thomas et al. 1979a). Based on data for elk use of forest cover and openings (Reynolds 1962, 1966), Thomas et al. (1979b) suggested that the ideal cover: forage ratio for elk and deer was 40 percent cover to 60 percent forage. Thomas et al. (1979b) recommended that this ratio be used to guide forestry operations and reforestation plans such that 40 percent of the area was maintained or restored as forest cover and 60 percent as open grasslands or shrub meadows.

Based on Reynolds (1962, 1966) data, Thomas et al. (1976) also suggested that optimal hiding cover for elk is between 4 and 8 sight distances (e.g., 183 to 366 m) in width. Sight distance is defined as the width of a vegetation band capable of hiding 90 percent of an elk from a person. They also suggested that to maximize elk use, artificial openings should not have any point further than 183 m from cover, thus allowing for a maximum opening size of 366 m before additional cover units are required in an opening.

These distances have subsequently been used to determine the optimal size of undisturbed islands of habitat for elk (12 ha the approximate area of a circle with a radius of 183 m) (Thomas et al. 1979b) and the maximum distance between areas of woody and open cover (366 m) (e.g. Wallis and Wershler 1979; Westar Mining 1983). Restoration of cover: forage ratios for elk habitat also has been suggested as reclamation goals (Westar Mining 1983; Millson and Bondy 1984). Other work by Thomas et al. (1979b) suggests that thermal cover for elk on a summer or transitory range should consist of trees 12 m or higher, with an average canopy closure of 75 percent or more in habitat blocks of 12-24 ha.

Similar research on habitat requirements for wildlife in the mountain and foothills biomes of Alberta is virtually non-existent. Some studies have been undertaken by the Alberta Fish and Wildlife Division to determine optimal cover: forage ratios for selected wildlife species but results are not yet available (Millson and Bondy 1984). Based on the Blue Mountains study (Thomas et al. 1979a), it could be suggested that optimal unit size for elk habitat is 12 ha with forage and cover units spaced at distances no greater than 366 m from each other. Such extrapolation is not without problems, however, and care should be exercised in the application of this information to Alberta. Wildlife habitats, seasonal range use and hunting pressure in the Blue Mountains differ from those in Alberta and, consequently, the sight distances and cover: forage ratios also may differ. For example, seasonal and elevational range use by elk in the vicinity of the Fording Coal Mine near Elkford, B.C. is different from elk range use reported for the Blue Mountains and, as a result, critical spatial requirements may also differ (D. Lane, pers. comm.).

6.3.4.2 Spatial Configurations of Habitat Units.

6.3.4.2.1 Concept. Much of the revegetation efforts on coal mine areas inAlberta has concentrated on reseeding of agronomic and/or native ground cover mixes to provide erosion protection, assist in soil reconstruction and promote nutrient cycling. Large numbers of tree seedlings have also been or will be established at some sites (e.g., Luscar, Gregg River and Obed mines) to satisfy the Alberta Reforestation Guidelines. These plantings generally have involved only commercial timber species with an emphasis on use of lodgepole pine and white spruce.

Use of shrubs on reclamation areas is a relatively new practice. Intermixed plantings of trees and shrubs to promote plant community development have been employed on a minor scale at the Cardinal River (G. Acott, pers. comm.), Whitewood (Carbyn et al. 1984) and McIntyre (V. Belts, pers. comm.) mine sites. Community plantings also are planned at the Gregg River (M. Murphy, pers. comm.), Westar Mining (1983) and McLeod River Mines (McLeod River Coal 1982).

Clump or habitat unit plantings of woody vegetation can benefit wildlife in a number of ways. Once established, shrubs and tree cover can improve soil moisture by locally increasing snow accumulations, shading the soil and reducing wind evaporation

(Tessman 1982). If topsoil supplies are scarce, topsoil islands provide one method of creating microsites with acceptable soil depths and quality. These benefits may, in turn, promote the natural invasion of woody species into adjacent areas.

Woody habitat units provide structural and floristic diversity, particularly when established in grassland areas (Westar Mining 1983). Use of woody habitat units also increases the amount of edge and the availability of ecotone habitats to wildlife. Careful interspersion and shaping of woody habitat units can promote wildlife movements into and through the reclamation area by providing hiding cover and travel corridors.

6.3.4.2.2 Techniques. Implemented and proposed techniques to establish woody vegetation for wildlife include shrub clusters, topsoil islands, forest stringers, hedgerows and natural vegetation islands.

1. Shrub Clusters. Shrub clusters have been utilized or suggested in several wildlife habitat reclamation programs (Clausing 1981; Tessman 1982; WECO 1983; Westar Mining 1983) to improve soil moisture and to increase vegetation structure and diversity. Shrub clusters can provide nest sites for passerines as well as cover and browse for mammals and upland game birds.

   Shrub clusters can be encouraged by integrating shrub planting with the topography and soil moisture patterns. Most shrubs will grow well in lowlands, depressions, draws and on north-facing slopes. Tessman (1982) recommends that shrub clusters be planted exclusively with shrub stock and seed. Herbaceous and graminoid ground covers should be discouraged until the cluster is well-established in order to reduce competition for water and nutrients.

If dense ground cover already exists, the area should be scalped prior to planting of the shrubs or the vegetation removed with herbicides.

If shrub clusters are required on wind exposed slopes or ridgetops (e.g., as a component of ungulate winter range), it will probably be necessary to provide some physical protection for the shrub patch to reduce wind erosion and desiccation and to promote moisture accumulation (Tessman 1982; G. Acott, pers. comm.). Snow fencing has been used with limited success to protect island plantings at the Cardinal River Coal Mine (G. Acott, pers. comm.). Rock walls and soil berms may also be useful in protecting shrubs in exposed sites.

2. Topsoil Islands. Topsoil islands, by providing a relatively thick, high quality growth medium, can accelerate the establishment of a woody vegetation community. The concept has been employed on an experimental basis at the Cardinal River Coal site (G. Acott, pers. comm.) and was to be incorporated into the wildlife reclamation plan at the Gregg River mine (M. Murphy, pers. comm.). At the Cardinal River mine, the reclamation site was capped with regolith and seeded with a grass-legume seed mix. Islands of topsoil were created by applying a 35 to 40 cm layer of topsoil in discrete patches. A mixture of coniferous trees and deciduous shrubs were then planted on the islands. Success to date has been limited because of the highly exposed nature of the site and trampling by bighorn sheep. Research on the island concept is ongoing with emphasis on the use of native shrubs; 15 species which occur locally are being evaluated for use.

A preliminary study of the island concept (Wallis and Wershler 1979) suggested that tree islands be staggered along the perimeter and throughout the central portion of a mine site such that no island is more than 90 m from the undisturbed forest edge or an adjacent tree island (the 90 m distance is derived from line of site distances discussed by Thomas et al. [1976]) (Figure 7). The islands proposed for the Gregg River mine were to have been 3 ha in area with predominantly coniferous tree plantings (Hardy Associates 1982). Additional plantings of a mixed forest shrub community were to have been interspersed among the islands.

Westar Mining (1983) proposed a similar forest island concept, except that islands would be established on friable, uncompacted soil rather than topsoil deposits. Size, location and structure were to be determined on the basis of a number of site criteria and wildlife use. Tree and shrub species were recommended for four elevational stata and three slope positions within each stratum (Table 14).

3. Forest Stringers and Hedgerows. Forest stringers can be used to reduce wind exposure and soil moisture losses as well as to provide visual breaks and travel corridors for wildlife (Podoll 1979; Anderson and Markham 1981; Poston and Schmidt 1981; Westar Mining 1983; PFRA n.d.). Depending on the width of the stringers, some species such as upland birds also may utilize these areas for nesting sites and escape cover.

Forest stringers have been used in Montana (WECO 1983) and are presently being considered by several mines in

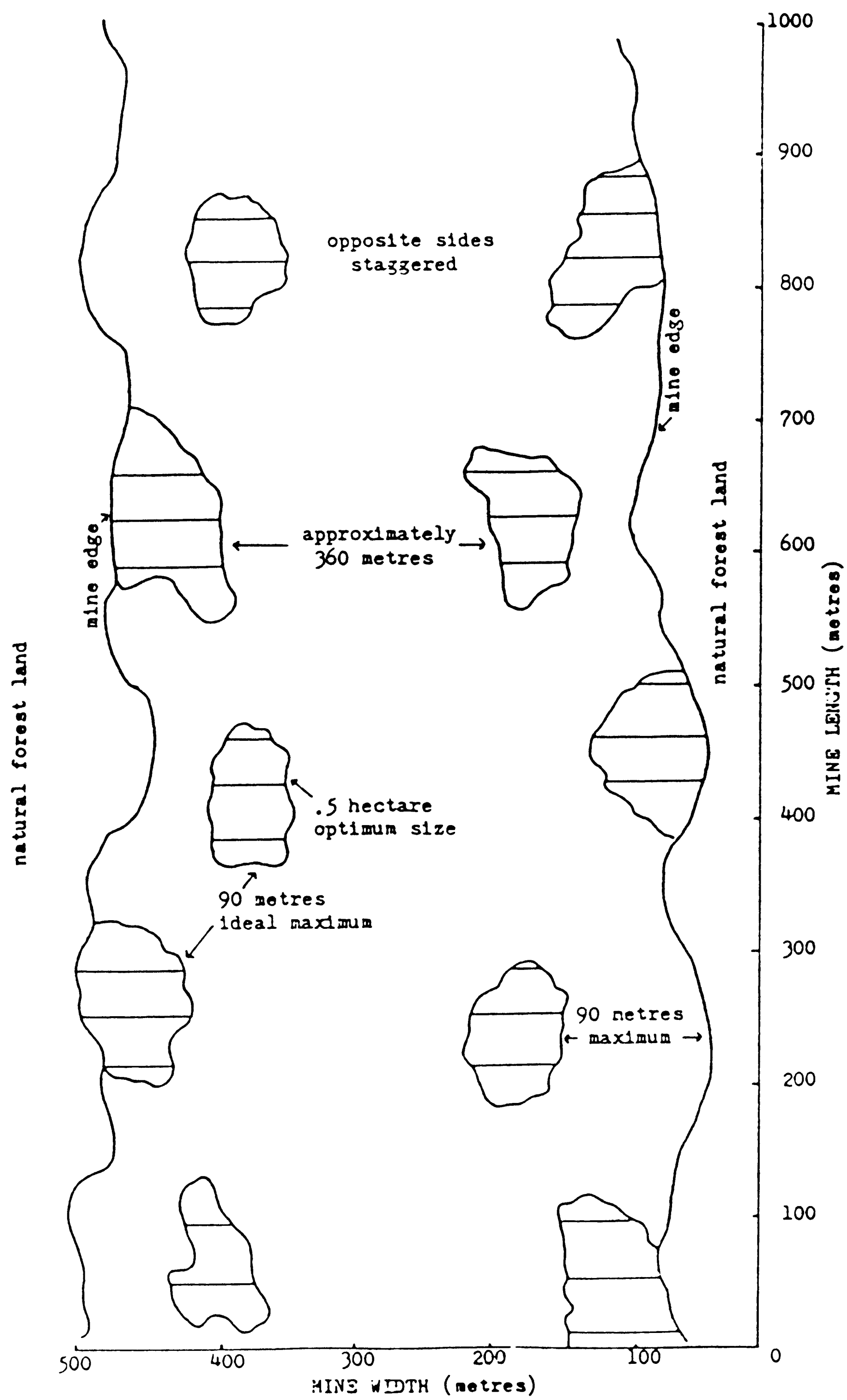

Figure 7. Woody vegetation islands proposed for the Cardinal River mine site. (Source: Wallis and Wershler 1979).

Table 14. Proposed species composition for tree islands at the Westar Mine (Shedding, mesic and receiving refer to the influence of the slope on the water regime. Source: Westar 1983).

High Elevation East and North Facing Slopes

Slope Position	Shedding	%	Mesic	%	Receiving	%
	Engelmann Spruce	60	Engelmann Spruce	60	Mountain Alder	50
	Whitebark Pine	40	Mountain Alder	30	Engelmann Spruce	40
			Whitebark Pine	10	Willow	10

Low Elevation East and North Facing Slopes

Slope Position	Shedding	%	Mesic	%	Receiving	%
	Engelmann Spruce	70	Engelmann Spruce	60	Engelmann Spruce	40
	Lodgepole Pine	30	Wavy-leaved Alder	20	Wavy-leaved Alder	30
	Cottonwood	10	Cottonwood	10	Willow	10
					Red Osier Dogwod	10
					Cottonwood	10

High Elevation West and South Facing Slopes

Slope Position	Shedding	%	Mesic	%	Receiving	%
	Saskatoon	45	Lodgepole Pine	35	Trembling Aspen	50
	Rose	45	Whitebark Pine	10	Engelmann Spruce	20
	Oregon Grape	10	Trembling Aspen	35	Willow	20
			Saskatoon	10	Saskatoon	10
			Rose	10		

Low Elevation West and South Facing Slopes

Slope Position	Shedding	%	Mesic	%	Receiving	%
	Saskatoon	40	Western Larch	10	Douglas Fir	20
	Rose	40	Douglas Fir	10	Western Larch	20
	Oregon Grape	20	Lodgepole Pine	20	Spruce	10
			Trembling Aspen	20	Cottonwood	20
			Douglas Maple)		Red Osier Dogwood	10
			Saskatoon)		Willow	10
			Rose)	40	Black Hawthorne	10
			Willow)			
			Cottonwood)			

Alberta and British Columbia (Wallis and Weshler 1979; Westar Mining 1983; G. Ascott, pers. comm.) to promote wildlife movements through and into sites. Wallis and Wershler (1979) suggested that stringers be established at intervals of approximately 1000 m and be continuous or with gaps no greater than 90 m. Forest stringers should conform to the natural topography of the site and compliment natural ungulate travel corridors such as valley bottoms, draws and ridgetops (Westar Mining 1983; PFRA n.d.; G. Ascott, pers. comm.). Anderson and Markham (1981) suggested use of hedgerows to promote wildlife movements to and from wetland areas and watercourses. Westar Mining (1983) may convert some of the abandoned haul roads on their site to wooded travel corridors for wildlife. Forest stringers also may be useful in providing protected corridors between bluffs or rock outcroppings (PFRA n.d.). Such corridors may be useful in encouraging movements of bighorn sheep and mountain goats between suitable forage areas. If prevailing winds are common from more than one direction, L-, U- or E- shaped designs can provide increased protection for wildlife (Proctor et al. 1983).

Wide multirow shelterbelts provide better wildlife habitat than narrow, single-row plantings (Podoll 1979; Poston and Schmidt 1981; Proctor et al. 1983). Protector et al. (1983) suggest a minimum of 10 to 15 rows for shelterbelts in areas subjected to blizzard conditions. Coniferous and deciduous trees should be planted in the central portion of the shelterbelt cross-section (Figure 8) with sequential rows of tall shrubs, low shrubs and tall ground covers (Poston and Schmidt 1981; PFRA n.d.). These mixed strata plantings offer better wind protection, promote snow

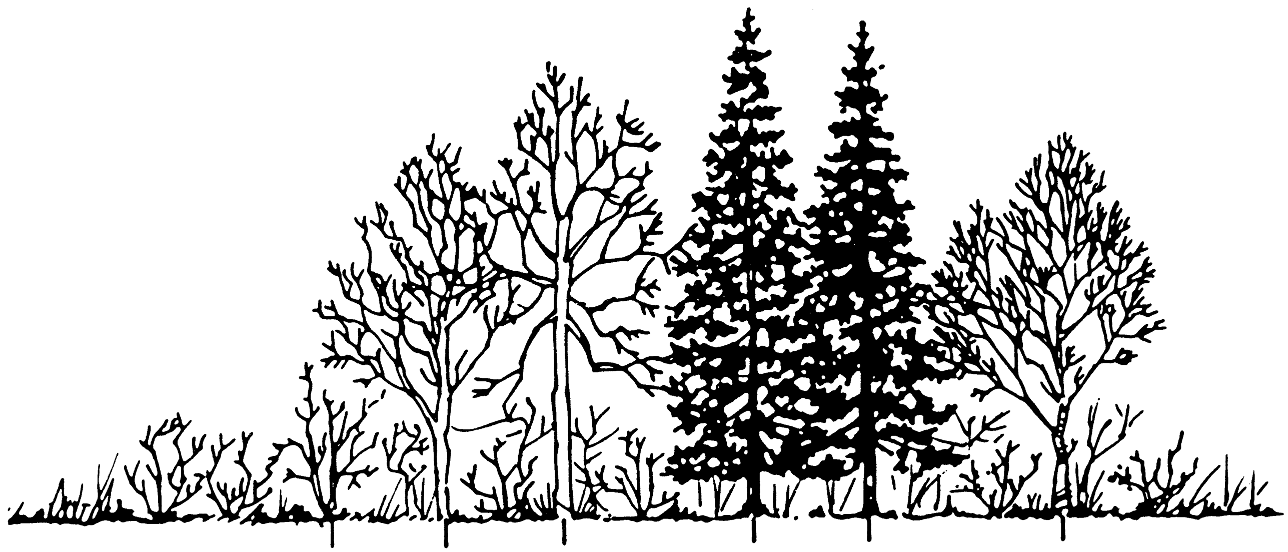

Figure 8. Schematic cross-section of a hedgerow or forest stringer. (Source: Polston and Scmidt 1981)

accumulation and provide increased structural and floristic diversity in a relatively narrow space. Undulating or irregularly-shaped hedgerows provide more habitat edge and ecotone habitat as well as a reduced line of sight distance and improved hiding cover for wildlife (PFRA n.d.).

4. Natural Vegetation Islands. Preservation of islands of natural wooded vegetation can provide immediate cover and forage for some species of wildlife while at the same time augmenting natural dispersal of native plant seed into reclaimed areas (Stanlake et al. 1978; Tessman 1982). Stanlake et al. (1978) evaluated ungulate use of three abandoned mine sites in British Columbia, and noted that intact vegetation islands were used intensively by ungulates for cover during use of or travel through the disturbed areas. Transplants of natural vegetation islands also have been recommended as a means of providing immediate cover for wildlife (Tessman 1982; Proctor et al. 1983). The location of intact natural islands should compliment the operational mine plan. Wide-scale clearing of the mine site should be avoided and as many vegetation islands as possible should be left within the mine development site.

6.3.5 Planting Configurations Within Habitat Units

Because of the small number of wildlife habitat reclamation programs that have been implemented in Alberta (or elsewhere), little information is available on optimal planting configurations for wildlife use.

6.3.5.1 Planting Structure. Schematic configurations for structuring habitat blocks, primarily windbreaks, have been propoed for some wildlife uses (Poston and Schmidt 1981; Proctor et al. 1983;

PFRA n.d.). A possible planting structure for forest stringers or hedgerows has already been discussed (Figure 8).

6.3.5.2 Plant Spacing. Literature is available on plant spacings for successful reforestation and revegetation (AFS 1979; Watson et al. 1980) but little information was found that addressed the optimal stocking rates for effective restoration of tree and shrub cover for wildlife use. The Alberta Forest Service Regeneration Guidelines (AFS 1979) recommend a minimum stocking rate of 1 seedling/8 m^2 or 1250 seedlings/ha. On the Gregg River Mine site, proposed stocking rates were 1100 trees/ha with spacings of 3 m x 3 m. This was estimated to provide a minimum of 800 trees/ha by the end of the first growing season. Shrubs were to be planted in clumps of 2 to 5 seedlings with a minimum 2 m spacing between clumps.

At the Westar Mine (Westar Mining 1983), stocking rates differ according to planned habitat type for a site. Shrubs are to be planted at 10 to 20 m spacings in grassland sites and at 3 to 5 m spacings in proposed winter range sites. In forest island plantings, stocking rates for all trees and shrubs combined will be 2000 stems/ha, with irregular spacing to promote a mosaic planting pattern and uneven edge.

For windbreaks, Proctor et al. (1983) suggested spacings of 1 to 1.2 m x 3.7 to 4.6 m for shrubs, 1.8 to 2.4 m x 3.7 to 6.1 m for tall bushy trees. Closer spacings were recommended for the windward edges of shelterbelts to provide increased wind protection and reduced snow drifting within the shelterbelt.

6.4 SPECIAL STRUCTURES

A variety of structures and techniques have been used to provide immediate improvements in structural and topographic diversity of wildlife habitat in disturbed areas. Some of the methods that may be of value in the mountain and foothills biomes include enhancement of highwalls, creation of rock talus, rock piles and brush piles, placement of logs, stumps, snags and artificial nesting structures.

6.4.1 Enhancement of Highwalls

6.4.1.1 Concept. During mining, many of the abrupt topographic features such as cliffs, gullies, badlands and rough breaks are altered. Because some of these features represent erosional formations, they are difficult to reconstruct. If the final cuts of a mine area are in erosionally stable material, the highwall could be enhanced for wildlife use (Tessman 1982; WECO 1982; Westar Mining 1983).

Cliff habitats provide shelter, escape corridors, visual barriers, nest and den sites, perch and roost sites, and loafing sites for a number of species (Maser et al. 1979a; Tessman 1982). If properly integrated with the surrounding landscape, revegetated and abutted with talus slope, reclaimed highwalls could also increase the aesthetic appeal of the site.

Highwalls have been maintained as part of the wildlife reclamation program at the Western Energy Mine in Montana (WECO 1982) and are to be incorporated into the reclamation plans at the Cardinal River (G. Acott, pers. comm.), Gregg River (M. Martin, pers. comm.), Crowsnest Resources (B. Densmore, pers. comm.) and the Westar Mining (1983) sites to provide escape terrain for bighorn sheep. Raptor nesting on the highwalls will be encouraged at all of these mines.

6.4.1.2 Technique. Highwall reclamation is most valuable in areas where natural bluff and cliff habitats are scarce. If intended as escape terrain for bighorn sheep or mountain goats, grassland areas should abut the formation on both the top and bottom of the highwall since close proximity of the highwall to dense forest cover provides predators with easy access to sheep and goats (W. Wishart, pers. comm.).

Highwalls with igneous or metamorphic substrates are preferable to sedimentary substrates because of the easily eroded nature of sedimentary rock (Maser et al. 1979a). Highwalls ideally should be located perpendicular to the slope contours and near the top of a divide rather than parallel to the contours or in a drainage bottom (Tessman 1982). Tessman (1982) provided a number of general suggestions for highwall development in Wyoming (Table 15). Maser et al. (1979a) indicate that increasing cliff height provides more suitable habitat for wildlife. With increasing height, upward-flowing warm air currents (thermals) are more predictable and suitable for raptors. Cliffs within 400 m of water are also more suitable for wildlife use (Maser et al. 1979a).

If the highwall is intended as escape terrain for bighorn sheep or mountain goats, surficial alterations of the highwall face may be necessary to provide adequate escape routes. At the Gregg River and Crowsnest Resources mines, all highwalls with slopes greater than 27° and 37°, respectively, are to be left as escape routes for wildlife (G. Acott, pers. comm.; B. Densmore, pers. comm.). Ledges or shallow caves in the cliff face can be created to provide raptor and corvid nest sites (Maser et al. 1979a; Tessman 1982; WECO 1982).

6.4.2 Talus

6.4.2.1 Concept. Talus is usually associated with cliff habitats and should be incorporated into most highwall enhancement projects. Talus provides reproductive and hibernation habitat for a number of species of small mammals and birds (Maser et al. 1979a). The pika is the only obligate talus species of wildlife in the mountain and foothills biomes but ground squirrels (golden-mantled, Columbian), hoary marmots, and Neotoma wood rats also frequently inhabit talus.

Table 15. Habitat considerations and specifications for highwall reclamation. (Source: Tessman 1982).

Consideration	Specifications
Length	The applicant must provide a biological justification for whatever length is selected. Smaller broken segments are preferred over one long continuous wall.
Height	The maximum height will be limited by safety and stability considerations. If possible, the height should be varied through the length of the highwall.
Configuration	The face should undulate in horizontal cross-section. In other words, the wall should project inward and outward, if possible, to provide visual barriers between raptor nest sites. The slope angles of the wall should also be varied as much as possible.
View	A broad unobstructed view from the face of the wall is preferred for raptors. Hence, the opposing slopes should be graded to the base as gradually as possible, rather than left steeply facing the wall.
Ledges	Recommended dimensions are 1/2 to 2 m in width, 2 to 10 m in length. The applicant should plan a variety of widths, lengths and heights for nesting, perching, roosting, and loafing sites of various avian species.
Holes	These should be blasted or drilled into the face of the wall. Recommended dimensions are 1/2 to 2 m in diameter and 1/2 to 2 m in depth. The applicant should plan a variety of sizes and heights from the base for use by raptors and small mammals.
Talus slopes	Talus slopes should consist of rock debris piled to varying heights along the base of the wall. Such debris may be deposited by blasting or they may be hauled in with equipment. Taluses should be broken rather than continuous. The function is primarily for small mammal den sites and to provide access partially up the wall.
Access corridors	These are means by which mammalian species may ascend the wall without going around the outer edges. They may be formed by blasting away sections of the wall face or by contouring overburden up to the top of the wall. One to three such sites would be sufficient along a 400 m highwall segment. Since these are part of the experimental practice, their slope may exceed the legal maximum, provided they are stable.
Vegetation	Whenever practical, species adapted to growth at the base or along the face of a natural rimrock should be planted. Woody species might include juniper (<u>Juniperus scopulorum</u>) and mountain mahogany (<u>Cercocarpus montanus</u>). Moist conditions will likely occur at the base providing suitable conditions for growth of various shrubs. Ledges may offer shrub sites as well. Vegetation planted along the top would help stabilize this erodible portion of the wall.
Impoundments	If an impoundment is included, the design must satisfy all requirements in the performance standards (Wyoming Department of Environmental Quality 1983). Impoundments cannot exceed 20 acre-feet (24,670 m^3) or involve a dam over 6.10 m in height. Phreatophytic vegetation should be planted along shorelines and the impoundment should abut talus slopes to prevent erosion and undercutting of the highwall.

Depth of talus and interstices among the rocks are important as they permit animals to move inside the talus to the right temperature and humidity regimes. Talus also provides access to highwall habitats (Tessman 1982).

6.4.2.2 Techniques. Talus composed of large metamorphic rocks is preferred to small rubble or sedimentary rocks, because the latter two types erode easily and do not provide stable living places for wildlife (Maser et al. 1979a). Talus of varying heights (and depths) provides a greater diversity of microsites (Tessman 1982). Larger talus areas also are preferable because they provide more habitat and are more stable than small talus areas (Maser et al. 1979a).

6.4.3 Rock Piles

6.4.3.1 Concept. Rock piles can be used to provide immediate cover for wildlife, particularly during the first several years after reclamation when vegetation cover is sparse. They can provide den sites, shelter and hibernacula for small mammals and raptor nest sites and perches (Maser et al. 1979b; Szafoni 1982; Tessman 1892; Proctor et al. 1983). They also provide immediate topographic diversity on a local scale and are particularly valuable to wildlife when constructed in association with waterbodies (Szafoni 1982). Westar Mining (1983) may use rock piles in their wildlife reclamation plan.

6.4.3.2 Technique. Rock pile height should be 1 to 4 m and occupy an area of less than 10 m^2 (Szafoni 1982; Tessman 1982; Proctor et al. 1983). Lengths can be variable and, in some cases, rock piles can be created to provide a windbreak for vegetation (e.g., shrub clumps) as well as wildlife habitat. Rock piles also can promote snow accumulation and increased soil moisture (Tessman 1982).

Rock piles are most useful to wildlife if the core of the pile is constructed of 1 to 3 large boulders 1 to 4 m in diameter surrounded by smaller rocks 1 m in diameter or less (Tessman 1982). They do not need to be neatly constructed as irregular edges and heights increase their attractiveness to wildlife. If rock piles are intended for use by raptors, they are best located near hilltops. In contrast, valley bottoms, draws and protected hillsides are optimum locations of rock piles for mammals (Tessman 1982; Proctor et al. 1983).

6.4.4 Brush Piles

6.4.4.1 Concept. Woody vegetation removed during the clearing of the mine site can be used to provide immediate cover for birds and mammals. Brush piles provide similar benefits as rock piles (Section 6.4.3) but are obviously not as permanent.

6.4.4.2 Technique. Brush piles can be constructed as mounds or hedgerows (Szafoni 1982; Proctor et al. 1983) and can be combined with rock piles to provide temporary cover (Proctor et al. 1983). To maximize wildlife use, brush piles should be constructed over a bowl-shaped depression or a log or rock base to provide clearance in the pile. Larger brush (up to 5 cm twig diameter and 1.2 m lengths) is the preferred construction material and should be anchored by pushing the branches into the soil or securing with wire or rocks (Tessman 1982; Proctor et al. 1983). Brush piles can be constructed to provide some protective cover along travel corridors, or near waterbodies for cover and nesting sites (Proctor et al. 1983).

6.4.5 Downfall, Stumps and Snags

6.4.5.1 Concept. Downfall, deadfall, stumps and snags are natural components of all forest ecosystems and provide important microsites for wildlife use. They are used as perching, nest and den sites (Maser et al. 1979b; Tessman 1982). Downfall, deadfall and stumps also encourage arthropod colonization with subsequent benefits in nutrient cycling and provision of a prey base for some birds and mammals. They are also important in mycorrhizal colonization (Maser et al. 1979b) and, by providing protection to newly-established seedlings, may improve seedling survival (Westar Mining 1983). The utilization and value of snags to wildlife has been reviewed by USDA (1983). The wildlife reclamation plan at the Westar mine may include deadfall placement. Snags have been used to attract wildlife at the Cardinal River (G. Accot, pers. comm.) and Westar mines (Westar Mining 1983).

6.4.5.2 Technique. Logs and stumps should be oriented parallel to the slope contours in order to serve as a sediment trap and accumulate moisture (Maser et al. 1979b). Large diameter logs are preferable to small diameter logs because the amount of cover for wildlife increases with log diameter. Because the value and uses of logs and stumps to wildlife are modified with decomposition (Maser et al. 1979b), logs of varying states of decay should be used.

Snags should be at least 20 to 30 cm DBH and 5 to 10 m in height (Thomas et al. 1979d; Tessman 1982; Westar Mining 1983). The base should be firmly anchored in rock or concrete. If use by raptors is intended, snags should be placed near hilltops on the lee side of the prevailing winds. Snags can also be placed near waterbodies and riparian zones. Although a mix of hard and soft snags (i.e., varying states of decay) is preferable, soft snags may collapse when moved; hard snags are more easily handled (Westar Mining 1983).

6.4.6 Artificial Nest Structures

6.4.6.1 Concept. Artificial nest structures can be constructed to replace nesting sites for cavity-nesting birds (e.g., owls, woodpeckers and some passerines), and platforms can be used during initial stages of reclamation as nesting sites normally provided by large mature trees (Szafoni 1982; Proctor et al. 1983). Nest boxes and platforms can also be used in wetland developments to provide nesting sites for cavity-nesting ducks (e.g., buffleheads), dabbling and diving ducks, and geese (Szafoni 1982; Proctor et al. 1983; Poston and Schmidt 1981). Western Energy Mines (Dahmer et al. 1982) and TransAlta Utilities (Scheideman and Stelfox 1981) have utilized nest boxes to attract raptors (e.g., American kestrel) and passerines, respectively, to their reclamation sites.

6.4.6.2 Techniques. Because different bird species require different types of nest boxes for successful nesting, boxes must be constructed with specific 'target' species in mind (Table 16) (Kalmbach et al. 1969, sited in Proctor et al. 1983). Proctor et al. (1983) review the use of boxes, platforms, baskets, cones and burrows for a number of bird species. Poston and Schmidt (1981) provide specifications for several nesting structures for waterbirds.

Table 16. Nest box dimensions and placement height (Source: Proctor et. al. 1983).

Species	Floor of Cavity cm	Depth of Cavity cm	Entrance above Floor cm	Diameter of Entrance cm	Height above Ground[1] m
Bluebird	13 x 13	20	15	4	1.5 to 3
Robin	15 x 20	20	(2)	(2)	1.8 to 4.5
Chickadee	10 x 10	20 to 25	15 to 20	3	1.8 to 4.5
Nuthatch	10 x 10	20 to 25	15 to 20	3	3.7 to 6
House wren	10 x 10	15 to 20	3 to 15	2.5-3	1.8 to 3
Swallows	15 x 15	15	3 to 13	4	2.4 to 4.5
Phoebe	15 x 15	15	(2)	(2)	2.4 to 3.7
Flycatchers	15 x 15	20 to 25	15 to 20	6.5	1.8 to 6
Flicker	18 x 18	41 to 46	36 to 41	6.5	1.8 to 6
Downy woodpecker	10 x 10	23 to 30	15 to 20	3	1.8 to 6
Hairy woodpecker	15 x 15	30 to 38	23 to 30	4	3.7 to 6
Screech owl	20 x 20	30 to 38	23 to 30	7.5	3 to 8
Saw-whet owl	15 x 15	25 to 30	20 to 25	6.5	3.7 to 6
Barn owl	25 x 46	38 to 46	10	15	3.7 to 5.5
Sparrow hawk	20 x 20	30 to 38	23 to 30	7.5	3 to 9

1 Data indicate that boxes at moderate heights, mostly within reach of a man on the ground, are readily accepted by many birds.

2 One or more sides open.

7.0 POTENTIAL WILDLIFE PROBLEMS IN RECLAMATION

7.1 ATTRACTION OF WILDLIFE TO RECLAMATION AREAS

Reclamation of wildlife habitat may generally be considered a problem of creating habitat that is attractive to wildlife. Once wildlife are present, however, they may hamper the reclamation effort through overuse of tree and shrub browse (e.g., deer and hare damage to seedlings), trampling of seedlings, and girdling of seedlings (e.g., small mammal damage). Below, we briefly describe the most common types of wildlife problems that have occurred at reclamation areas in Alberta and suggest potential control measures.

7.1.1. Browsing Damage to Trees and Shrubs

Ungulate damage to trees and shrubs has been reported by a number of mines in the Hinton-Edson region and in the southeast-coal block of British Columbia-Alberta. Several kinds of damage have been observed including overbrowsing, debarking and uprooting. Frequent browsing of established seedlings and clipping of newly-planted seedlings may result in decreased seedling vigor and mortality (Von Althen 1983). Clipping of conifer leaders by ungulates and snowshoe hares has been reported at the Coal Valley (C. Brinker, pers. comm.), Cardinal River Coal (G. Acott, pers. comm.), MacIntyre (V. Betts, pers. comm.) and Westar mines (T. Milligan, pers. comm.). At the Westar mine, overbrowsing of planted seedlings and adjacent natural shrubs by elk resulted in the mortality of some plants (Courtney 1977; T. Milligan, pers. comm.). Uprooting of newly-planted seedlings and bark stripping of trembling aspens was also reported (Courtney 1977; T. Milligan, pers. comm.; P. Ziemkiewicz, pers. comm.).

7.1.2 Trampling Damage to Trees and Shrubs

Trampling damage has only been reported on the Cardinal River mine site (G. Acott, pers. comm.). Bighorn sheep frequently bedded on the shrub and tree seedlings within the island plantings and contributed to the mortality of the seedlings through direct crushing and increased exposure to wind and snow abrasion (by removal of the protective snow cover). Bighorn sheep in Banff National Park also were observed to reduce the effectiveness of soil stabilizing mulches by trampling (Harrison 1984).

7.1.3 Girdling Damage by Small Mammals

Girdling damage by small mammals appears to be a common problem in reclamation sites where trees and shrubs have been planted in areas of established grass and legume cover (Green 1980). Girdling damage by microtine rodents and snowshoe hares can substantially reduce the success of reforestation programs by direct mortality of seedlings and young trees, weakening the seedling and increasing its susceptibility to insects and disease, and reduction of seedling growth (Jokela and Lorenz 1952; Cayford and Haig 1961; Buckner 1970; Radvanyi 1978; Von Althen 1983). Substantial amounts of girdling by small mammals (mostly microtine rodents) has been reported at the Judy Creek test site (Esso Resources 1984) and the Cardinal River (G. Acott, pers. comm.), Coal Valley (C. Brinker, pers. comm.) and Westar (T. Milligan, pers. comm.) mines. A review of small mammal (mice, squirrels and snowshoe hare) damage to trees and shrubs was compiled by Green (1979).

7.2 CONTROL OF WILDLIFE PROBLEMS

Several reviews have summarized methods of controlling wildlife damage in reclamation areas. The USDA (1979) assessed livestock and wildlife problems in reclamation areas as well as direct and indirect methods of controlling these problems. Green (1978) reviewed information on chemical, mechanical and environmental controls of small mammal damage to plants. Von Althen (1983) discussed a variety of mammal problems in reforestation areas in eastern Canada and recommended methods of control. A recent review by Sims et al. (1984) provides an overview of large and small mammal use of reclamation areas and methods of control.

7.2.1 Control of Large Mammal Problems

7.2.1.1 Indirect Control. Indirect control measures for large mammals such as elk, moose and deer can involve altering physical features of the site as well as increasing public access to the site to reduce its attractiveness to wildlife.

7.2.1.1.1 Plant Selection. Plant species that are not consumed by the problem species can be utilized on the reclamation site. This could involve the use of unpalatable species (see species accounts for habitat requirements; Appendices 4-13) or the use of physically inedible (e.g., thorny) species such as caragana. Observations of reduced browse damage on some tree species (e.g., spruce) when planted in mixed-planting (e.g., spruce with pine) (C. Brinker, pers. comm.) suggest that mixed plantings of preferred and unpreferred species may offer a solution to browse damage. However, no information is currently available on the optimal mixtures or dispersion of plants for control or the effectiveness of mixed plantings for control.

7.2.1.1.2 Hunting. Use of reclamation sites by problem animals may be controlled through use of controlled hunts (e.g., by government personnel) or recreational hunting. Public bow hunting of bighorn sheep on the Cardinal River mine site (G. Acott, pers. comm.) was initiated during fall 1984 to reduce bighorn sheep grazing on the reclamation site. Initial results indicated that the sheep responded quickly to the hunting pressure (i.e., moved off the mine site) but that they returned rapidly once hunting ceased. Public hunting of elk at the Westar site is proposed for the 1985 season (T. Milligan, pers. comm.). The effectiveness of public hunting programs in reducing wildlife use of reclaimed sites may be increased by use of scaring devices (e.g., propane canons) and intermittent reinforcement (e.g., selective killing of 1-2 animals).

7.2.1.1.3 Hay Mulches. Although hay mulches are not widely used on mine reclamation sites in the mountain and foothills biomes, hay and straw mulches may attract some ungulates such as elk and deer and, whenever possible, should not be used.

7.2.1.1.4 Attractants. Attractants have been suggested as a means of luring animals from the reclaimed sites. The effectiveness of attractants such as sweeteners, trace elements or salts sprayed on adjacent plant communities in reducing browse damage has not been widely tested (e.g., Dasmann et al. 1967).

7.2.1.1.5 Availability of Permanent Water. Permanent water may attract some mammals such as elk to an area or may encourage migratory species to remain in an area. As a result, waterbodies on a reclamation site should be located away from tree planting areas.

7.2.1.2 Direct Control. Direct methods of controlling large mammal damage to reclamation areas can involve treatments to the susceptible plants or modifications that directly influence the distribution of problem wildlife species.

7.2.1.2.1 Use of Protective Fencing. Reclaimed areas susceptible to overuse by wildlife can be enclosed with fencing. The most effective designs include 2.5 - 3.0 m high wire fencing or electric fencing (e.g., Kinsey 1976; Caslick 1980). Electric fencing may be of limited use in some areas since it becomes ineffective during deep snows (Kinsey 1976). Because of the high construction and maintenance costs of fences, fencing is only practical for protecting high concentration plantings of trees and shrubs (e.g., topsoil islands) as opposed to entire reclamation sites.

7.2.1.2.2 Protective Mesh or Tubing. Protection of seedlings or conifer leaders with plastic tubes or mesh (USFS 1971) is impractical for most large reclamation areas but may be useful in small scale plantings (e.g., shrub or tree clumps).

7.2.1.2.3 Repellents. Trees and shrubs may be protected by application of repellents. Two types of repellents -- odor repellents and taste repellents -- may be of some use (Von Althen 1983). Odor repellents include substances such as tankage (e.g., blood meal), moth balls and resin. Taste repellents are generally more effective than odor repellents (Von Althen 1983) and commonly contain either zinc dimethyldithiocarbamate cyclohexamine complexes (ZAC) or tetramethyl thiuran disulphide (TMTD). Repellents can be applied efficiently to large numbers of seedlings but must be reapplied 1-2 times annually. In areas where seedlings are fertilized or irrigated, the resulting lush growth may attract animals and be utilized despite the presence of the repellent.

7.2.2 Control of Small Mammal Problems

Methods of controlling small mammal damage to plants in reclamation areas were reviewed by Green (1978) and the reader is referred to this review for specific details. Three types of methods have been commonly utilized to control small mammal problems: chemical, mechanical or environmental controls. Chemical controls include repellents, chemosterilants, multiple dose rodenticides (e.g., anticoagulant-based poisons), and single-dose rodenticides (e.g., strychnine). Mechanical controls can involve physical barriers such as metal or plastic shields and fences, sonic repellents, and traps. Environmental controls encompass habitat manipulation, biological control, genetic manipulation and attractants (e.g., lure baits). Based on the advantages and disadvantages of each control method and the feasibility of the method for large scale control programs, Green (1978) concluded that control methods which directly reduce small mammal numbers are the least effective for controlling damage. Methods that directly remove animals such as chemosterilants, rodenticides, trapping and biological control, interfere with natural regulatory processes in the pest population and in some cases, may result in a compensatory increase in animal densities. Several of these controls also pose serious hazards to non-target species. In contrast, methods that focus on reduction of damage such as habitat manipulation, attractants, repellents and mechanical barriers, are effective and are preferred; natural regulatory processes are less likely to be disrupted and direct or secondary poisoning hazards are low or nonexistent.

Small mammal problems in reclamation areas are most effectively controlled through multi-treatment programs that involve habitat manipulation, attractant foods and, possibly, repellents. For example, by substantially decreasing the abundance of graminoids and legumes and the total density of the ground cover canopy, the suitability of the area for microtine rodents (the group of rodents suspected of causing most girdling damage) is greatly reduced. Consequently, fewer animals are present without disruption of natural regulatory processes, and girdling damage to trees and shrubs is reduced. Application of repellents on trees and shrubs and provision of alternative foods (e.g., lure baits) may help to further reduce amounts of damage (Green 1978).

7.3 HUMAN - WILDLIFE INTERACTIONS

As a safety precaution, hunting is prohibited within most mine sites during the pre-mining, operational and early abandonment phases of a mine. Assuming that portions of the mine site are useable by wildlife, the site offers a sanctuary from hunting for wildlife. Because mine sites may remain active for one to several decades, animals that utilize undisturbed and reclaimed lands may become accustomed to the lack of hunting and new cohorts may not be exposed to hunting. If areas are specifically reclaimed for wildlife, mine sites will be even more attractive to wildlife. Current land use legislation does not permit the restriction of public access to Crown land, hence the areas will be open to hunting on reversion to the Crown, unless special dispensation is granted by a government agency. A number of studies have shown that large mammals in previously unhunted areas are highly vulnerable to hunting and are easily overharvested once an area becomes accessible (e.g., Bergerud et al. 1968; McIlroy 1972; Lynch 1973; Leege 1976).

It is reasonable, therefore, to assume that wildlife in protected reclamation areas may also be more susceptible to hunting, once a reclamation area is abandoned and made accessible to the public. No documentation on this potential effect exists since none of the protected reclamation areas in this province have yet been abandoned.

The potential for overharvesting may be reduced by restriction of public access on abandonment or by conditioning the animals prior to abandonment. Once an area reverts to the Crown, public access could be gradually re-introduced to allow wildlife to adapt. Wildlife could also be conditioned prior to abandonment through use of an organized or controlled hunts. For example, Cardinal River Coal and Westar Mining have conducted or planned controlled public hunts of bighorn sheep and elk, respectively, on their properties, primarily to control overuse of the sites by wildlife (G. Accot, pers. comm.; T. Milligan, pers. comm.). Organized hunts by government or mine personnel could be implemented several years prior to full abandonment of a site to gradually re-introduce the wildlife to hunting pressure.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 INTEGRATION WITH FORESTRY LAND USES

From the perspective of the forest industry, forested areas in Alberta can generally be divided into two categories: forests that are suitable for commercial timber production and forests for non-commercial uses such as wildlife habitat, watershed protection and recreation (Millson and Bondy 1984). Although commercial timber production in an established forest is not exclusive of the latter three uses, reforestation guidelines for commercial timber are quite different from reforestation practices for wildlife habitat or recreation, and hence may alter the value of reforestation areas for these alternative uses.

The Alberta Forest Service considers land to be suitable for commercial timber production if the area is stocked with commercial tree species and is potentially capable of producing a minimum of 50 m3/ha gross timber volume at the end of a 120 year rotation period (Millson and Bondy 1984). Commercially-acceptable trees include spruce, pine, fir, larch, poplar (including aspen), and birch. Because these forest types also are of value for the maintenance of wildlife productivity and diversity, the potential exists for the integration of forestry and wildlife end uses on these lands.

The Alberta Forest Regeneration Survey Manual (AFS 1979), which provides restocking standards for timber management areas, has been used as a forestry reclamation standard for mine areas occurring on productive forest land. An area harvested primarily for the removal of coniferous timber is considered to be satisfactorily restocked when:

1. "80% or more of the sample plots are stocked with acceptable established coniferous seedlings, the

stocked plots being evenly distributed over the sample area" or,

2. "80% of the sample plots are stocked with acceptable established coniferous seedlings and an additional 20% of the sample plots are stocked with acceptable established deciduous seedlings and/or balsam fir and alpine fir, either individually or in the aggregate. The stocked plots must be evenly distributed over the sample area" (AFS 1979).

The area to be reforested (or reclaimed) "cannot contain any areas larger than 10 acres in extent which do not in themselves meet the required stocking standard". In addition, "identifiable areas larger than three acres which in themselves do not meet the required stocking standard must not in aggregate exceed 20 percent of the total area to be classified"(AFS 1979). Assuming that forestry is the primary land use objective, these guidelines provide opportunities for two major types of integration of wildlife end uses with forestry.

1. Assuming that an aggregate total of at least 80 percent of the reclamation site must be returned to commercial timber, the remaining area (up to 20 percent of the site) could potentially be reclaimed as habitat for wildlife; and

2. Interplanting of shrub and herb understories for wildlife with commercial timber overstory.

It is recognized that, in some areas of exceptional wildlife habitat (e.g., ungulate winter range), integration with forestry is not desireable.

8.1.1 Development of Small Habitat Blocks

Within a reforestation area, sites such as waterbodies, watercourses, seeps, cliffs and steep slopes are not considered to be productive forest land and can potentially be developed or enhanced for wildlife use. In addition, portions of the productive forest land could conceivably be modified for wildlife use, within the current constraints of the Forestry Restocking Guidelines, as long as individual areas do not exceed 4 ha (10 acres) in area and the aggregate total of these areas with sizes over 1.2 ha (3 acres) do not exceed 20 percent of the total reclaimed area. These latter areas for wildlife might include important habitat features such as riparian zones, south-facing slopes for winter range, or shrub clumps. Wildlife habitat reclamation in these areas can incorporate some or many of the techniques described in Section 6.0. However, the selection of the key species for reclamation in these sites should take into account and limit the potential of the selected guilds to interfere with or damage forest crops.

No examples of this method of integrating wildlife uses with commercial timber land use objectives are known for Alberta. Because these measures may be viewed as reducing forest productivity, the utilization of these methods may also be questioned by the forest industry. It is concievable, however, that growth and survival of commercial species could be enhanced by these measures, particularly if enhancement of small areas for wildlife were to reduce amounts of wildlife damage to the commercial species. For example, many deciduous shrubs are highly perferred as browse by ungulates in comparison to the commonly-planted commercial species of conifers (e.g., spruce, pine and fir). No quantitative data are known which show negative or positive effects of wildlife integration with commercial forestry and further research on this topic is recommended.

8.1.2 Interplanting

In natural successional areas, trees, shrubs and ground covers co-establish and develop as holistic forest communities. Current reforestation practices, however, strive to maximize wood production and generally discourage the development of shrub or herb/grass understories (D. Dempster, pers. comm.). Scarification, slash burning, and herbicide applications are utilized to promote tree growth, often at the expense of other components of the forest ecosystem (Alberta Fish and Wildlife Division 1978).

Although some areas are best suited for reclamation primarily to a forestry end use, interplanting of deciduous trees, shrubs and some ground covers with the commercial timber species could greatly improve the value of reforestation areas for wildlife. As discussed earlier, selection of the key wildlife species and, in turn, the selection of plant species for interplanting, should consider the implications for wildlife damage to commercial tree species. Potential for competition among the commercial tree species and the interplanted species also should be reviewed.

The seedling stocking rates for commercial tree species generally require a 2.5 - 3.0 m spacing between individual plants and are based on the need to control competition for water and nutrients among the seedlings. As a result, interplanting of non-commercial trees and shrubs must either displace commercial tree seedlings or potentially increase interspecific competition for nutrients and water. However, casual observations of reduced wildlife damage on some conifers when interplanted with other tree and shrub species, suggest that some benefits to growth and survival of commercial tree species may be realized as a result of interplanting (V. Betts, pers. comm.). Conclusive evidence is lacking, however, and further research is required (Sims et al. 1984). Should such benefits exist, there may be an advantage to reducing stocking rates of commercial seedlings to allow for interplanting of other trees and shrubs; the lower seedling density may be compensated by increased vigour and survival.

8.2 ASSESSMENT METHODOLOGIES

Wildlife habitat reclamation is a specialized form of habitat management and assessment of reclamation success must involve evaluations of habitat quality. Habitat quality has generally been assessed utilizing one of two possible approaches; population-based and habitat-based assessments. The utility of these approaches in evaluating reclamation success, particularly as they apply to the development of reclamation guidelines or standards, are reviewed briefly below.

For the purpose of this review, we have assumed that the objective for wildlife habitat reclamation is the restoration of an equal or greater amount of habitat than existed prior to disturbance. This may be achieved through enhancement of habitat quality and/or habitat quantity. However, the target wildlife species (or guilds) and/or the proposed habitat use need not necessarily be identical to those on the pre-mine site. For example, consider a proposed mine where elk are the most abundant large mammal and have been recognized by the Fish and Wildlife Division as an important wildlife management concern. If the mine is to remove primarily mature forest communities, and if elk winter range is suspected of limiting the elk population, a suitable objective for south-facing aspects within the reclamation site would be the creation of elk winter range.

Regardless of the selected land use for wildlife, it will be necessary to assess the pre-mining conditions in order to determine a range of values or a standard for reclamation. The pre-mine assessment can also provide information on animal abundance, existing vegetation communities and wildlife use of these habitats which, in turn, can provide information valuable to the development of the reclamation plan. Therefore, we have assumed that assessments of reclamation success will require assessments prior to mine development, as well as following establishment of the reclamation site.

8.2.1 Population Assessments

Population-based assessments provide indices of animal densities (or absolute numbers) and species diversity, which are generally assumed to be directly and positively related to habitat quality (Van Horne 1983). A broad range of techniques are available to provide estimates of population density or species diversity in mammal and bird populations; a review of these census methods is beyond the scope of this report, and will not be addressed here. Regardless of the census method, population-based assessments generally assume that areas with higher densities of animals or a higher species diversity are better quality habitats than areas with lower densities (Van Horne 1983).

Population-based assessments for reclamation success can be misleading because the assumed relationship between animal density and habitat quality is not always valid. Factors that may invalidate this assumption include census accuracy, seasonal variation, behavioural responses and extrinsic or off-site factors.

If population density is to be related to habitat quality, abundance estimates must be accurate and precise to ensure that a standard can be developed and that site densities can be compared to the standards. All sampling techniques designed to estimate animal abundance are subject to certain biases and inaccuracies, particularly if an animal is migratory, difficult to observe or has a clumped distribution (e.g., animals in herds or flocks). To improve the accuracy and reliability of these estimates, the sampling intensity must be increased both in terms of time and area. Such an increase in sampling intensity invariably is associated with prohibitively large increases in sampling cost.

Habitat-specific densities can also differ by season and among different wildlife groups. For example, winter habitat in Alberta is critical to the survival of many larger species of mammals, particularly ungulates, whereas spring breeding and nesting habitat are essential components of waterfowl habitat. As a result, population-based assessments would have to recognize these seasonal and interspecific differences in habitat use and provide adequate sampling to account for these differences.

Additional factors that can influence the validity of population-based assessments are behavioural responses or social interactions. In territorial species, dominant animals can prevent subordinate animals from utilizing an area or can suppress reproduction of subordinates in high quality habitat (e.g., bighorn sheep) (Van Horne 1983). In some cases, subordinate animals emigrate to habitat "sinks" and densities in these sinks may exceed densities in the higher quality habitat (Lidicker 1975). As a result, densities in lower quality habitat may be greater than in better quality habitat (Van Horne 1983).

External factors, unrelated to a site, can also influence animal densities. Predation or disease in undisturbed areas around a reclamation site may reduce animal numbers and restrict animal immigration to a site, irregardless of habitat quality on the site. For example, a recent lungworm epidemic in southwestern Alberta and southeastern British Columbia substantially reduced numbers of bighorn sheep in the region and sheep are now absent from some of the formerly occupied range (W. Wishart, pers. comm.). Absence of bighorn sheep in the vicinity of the Fording Coal mine has been attributed to this decline (D. Lane, pers. comm.). The absence or low numbers of animals on a site may also reflect a cyclic population change rather than poor quality habitat. Population cycles have been documented in some rodent and lagomorph species in Alberta (see review by Green 1979) and may occur over the longterm in some species of larger mammals and some species of birds.

Because density-based estimates of habitat quality are easily influenced by external factors unrelated to habitat quality, population-based assessments are poorly suited for evaluating reclamation success. In the event of low abundance, and, presumably, poor habitat quality, the factors associated with the poor ranking also are not readily apparent. Poor quality could be related to the absence or poor suitability of specific habitat features, the effects of external factors that influence population densities, or a combination of these two effects. Thus population-based assessments are not only poor indices of habitat quality but are also a poor investigative tool for improving habitat quality.

8.2.2 Habitat Assessment

Habitat-based evaluations of reclamation success are based on the assumption that particular, measurable habitat variables within the site largely determine the suitability of the area for a specific wildlife species or guild. The ability of an area to support wildlife is assessed by:

1. Determining the essential habitat requirements and preferences of the wildlife species of concern;
2. Measuring or subjectively evaluating the habitat conditions within a site; and
3. Comparing the existing (or potential) conditions within the site with those conditions considered optimal for the species or guild.

In general, accurate habitat data are less expensive to obtain than accurate population data, easily standardized among sites, not highly-time specific and not easily influenced by external factors. Deficiencies in habitat quality can also be readily identified by determining the habitat features with the lowest scores. The disadvantage of habitat-based approaches is that they rely on the correct identification and quantification of habitat characteristics that are essential to the use of a site by a species. Because an increasing number of methods are becoming available for assessing habitat quality and habitat models are available for a growing number of wildlife species in Alberta (e.g., IEC Beak 1984a; LGL Limited 1985), the latter disadvantage is not a major obstacle to the use of these methods. Since wildlife habitat reclamation requires the manipulation of specific habitat characteristics which can be measured by habitat-based assessments and because habitat-based methods are easily adapted to a wide range of conditions for a variety of species, we believe that habitat-based assessments are the only suitable methods for assessing reclamation success.

A variety of techniques have been developed for evaluating habitat characteristics on a site. All of these methods require measurment of certain habitat variables through field studies and/or remote sensing. Selection of methods to sample habitat or vegetation components is a complex subject, well beyond the scope of this review. Although an apparent large number of methods are available for assessing wildlife habitat, most systems can be grouped under one of two approaches: Habitat Evaluation Procedures (HEP) and Wildlife and Fish Habitat Relationships (WFHR) (Thomas 1982).

Habitat evaluation procedures involve the assessment of habitat suitability for individual species through use of numerical rating schemes in which key habitat factors are identified and rated, scores are weighted appropriately and a final value calculated. Examples of habitat evaluation procedures include Boyce (1977), Flood et al. (1977), Williams et al. (1978), Russell et al. (1980) and the United States Fish and Wildlife Service (USFW 1980). These systems have the advantages of being objective, repeatable within the same site, adaptable to a wide range of wildlife management concerns (e.g., emphasis on certain groups of wildlife or habitat strata), and through selection of guild representatives or key species can provide holistic evaluations of one or more habitat strata on a site. In addition, through the development of habitat suitability models that require measures of specific habitat components, standard methodologies can be established for field sampling. These standard measures can then be input into standard key species models to derive a measure of habitat value. In the case of one method, the Habitat Evaluation Procedures (USFW 1980), the suitability indices can be combined with measures of habitat area to obtain a dimensionless value that simulataneously summarizes habitat quantity and quality.

The WFHR approaches are based on a floristic and structual classification of habitats and categorization of all resident wildlife associated with the conditions in these habitats (e.g., Thomas 1976b; Patton 1978; Thomas 1979e). These methods generally involve an initial delineation of specific habitat types (e.g., coniferous forest, riparian shrub and meadow) within the study area. Each habitat is then described in terms of three general factors: the habitat association of all resident wildlife species for feeding, reproduction and resting (this is further subdivided into specific strata within the habitat), the value of special habitat elements such as snags, downfall and talus to wildlife, and the development of more complex habitat capability models for selected wildlife species (Thomas 1982). Although these methods initially focus on a description of the general requirements of all resident wildlife species within a habitat, these species are generally combined into groups or guilds with similar habitat responses. Indicator species can then be selected for these groups. Habitat values can be described in terms of species richness, provision of essential structual and floristic components, and/or provision of special features. However, specific valuation methodologies are not well defined and a number of different indices have been used to assess habitat value. One of the best know applications of this approach is the study of wildlife habitats in managed forests of the Blue Mountains of Oregon (Thomas 1979e). WFHR approaches provide information on wildlife diversity within habitats and, depending on the type of habitat capability models for the representative species of each habitat, are somewhat similar to the HEP type of evaluation methods. The major disadvantages of these methods are that they generally involve intensive field studies of both wildlife habitat and populations, methodologies for these evaluations are not well defined in relation to the HEP approaches, and indices of habitat value are not always compariable among areas. As discussed by Thomas (1982), however, the HEP and WFHR approaches are likely to eventually merge and, indeed, are compatable.

Of the available habitat evaluation techniques, we believe that the HEP type of assessments are preferable to the WFHR assessments for use in evaluation of reclamation success. The HEP methodologies are well defined (USFW 1980), habitat suitability models have been developed for some wildlife species in Alberta (IEC Beak 1984a-1984f; LGL Limited 1985) and other areas with similar habitats (e.g., USFW 1984a-1984d), the methods are adaptable to a wide range of habitat types and reclamation situations (because of the ability to combine measures of habitat quality and quantity into one summarizing variable) and the process has already been used to develop land management and reclamation plans in several areas in the United States.

Of the existing techniques, we believe that the Habitat Evaluation Procedures (HEP) program of the U.S. Fish and Wildlife Service (1980) is the most suitable approach for assessment of reclamation success. The HEP program was initially utilized in evaluating the effects of water resource developments on wildlife, but more recently has been used to develop enhancement plans for wildlife (e.g., Matulich et al. 1982). More recently, the HEP program has been employed successfully as a planning tool for surface mine reclamation activities in Texas (Rhodes et al. 1983). While the HEP program is discussed in detail elsewhere (U.S. Fish and Wildlife 1980), a brief overview is provided here.

The HEP approach quantifies habitat suitability as a dimensionless value which incorporates known relationships between specific habitat characteristics and indices of animal abundance or habitat use. A Habitat Suitability Index (HSI), which ranges between 0 and 1, provides a comparison of site conditions to optimal habitat conditions (0 represents no habitat and 1 represents optimal habitat). An overall habitat suitability index for the site can then be developed, based on an appropriate, arithmethic combinations of the individual SI values (calculated for each habitat characteristic) which reflects the relative importance of each characteristic. Because of the linearity of the species/habitat relationships developed in HEP, the magnitude of difference in HSI values generally reflects a similar magnitude of difference between habitat quality. For example, a site with an HSI value of 0.6 should potentially be twice as productive for a given wildlife species as a site with an HSI rating of 0.3.

A second important step in the HEP approach, particularly in its application to reclamation sites, is the determination of species- or guild-specific Habitat Units (HU's) for the site. Conversion of HSI values to HU's is achieved through multiplication of the HSI values by the area of available habitat (or the size of the reclamation area to be assessed) and serves two functions:

1. It permits the rapid calculation of a value that summarizes the total habitat availability on a site which, in turn, provides an easily comparable value between pre-mine and post-mine conditions (as discussed later in Section 8.3, we have assumed that habitat assessments will be conducted prior to mine development and following reclamation); and

2. It enables the habitat loss or gain and corresponding change in wildlife potential as a result of mine disturbance and reclamation to be determined.

If the reclaimed HU's are insufficient to replace the required number of pre-mine HU's, the HEP approach allows the habitat deficiencies to be easily identified through determination of the low scoring habitat features. Application of the HEP program to wildlife habitat reclamation in Alberta is further discussed in Section 8.3.

8.2.3 Timing of the Assessment

The period of time required between establishment of a wildlife habitat reclamation area and assessment should allow for sufficient development of the vegetation and stabilization of the terrain to ensure that habitat conditions are suitable for wildlife. Although direct assessments of existing habitat will guarantee that the site provides the necessary habitat conditions for a species or guild, the period of time required for a site to be restored to good or optimal conditions may be in the order of several to many decades depending on the mine location, climatic conditions, and the intended target species of wildlife. From an economic viewpoint, mine interests may regard this period of time as excessive for bond release.

Because different wildlife species (and guilds) respond differently to habitat characteristics, assessment time may differ depending on the target wildlife species. The location of a reclamation site (e.g., eco-region type, elevation, exposure to climatic extremes) may also influence the assessment time.

The optimization of the assessment time from both a biological and economic perspective requires a balance between minimizing the required time period, and ensuring that the habitat is established and will continue to develop normally. Because none of the existing wildlife reclamation areas in Alberta have been established for more than nine years (e.g., the wildlife reclamation area at the Whitewood Mine, established in 1976, was the first reclamation are to be developed specifically for wildlife), it is not feasible to utilize existing wildlife reclamation areas to determine an optimal assessment time.

Natural successional patterns and responses of wildlife to these temporal trends may provide some information applicable to reclamation assessments. Bunnell and Eastman (1976) assessed the relationships between successional trends after forest removal and availability of different types of wildlife food (e.g., annual/ perennial seeds, herbs, browse, conifer seed and arboreal lichens). Trends were based on an extensive review of the literature and represent an "average" successional example. Production of annual and short-lived perennial seeds was predicted to have the earliest peak (3 to 5 years after clearing), declining to low levels by 18 years after clearing. Herb production also increased rapidly within the first ten years and declined to low levels after 25 years; the rate of the decline was dependant, however, on competition from browse species. Amounts of energy in browse increased gradually, reaching a peak 18 to 22 years after clearing. Peak browse production, however, is highly variable among forest types, locations and reforestation practices (if tree seedlings have been planted). Production of conifer seed and arboreal lichens are dependent on the development of a more mature tree canopy and, consequently, peak production is not realized for a considerable period of time after clearing (e.g., 50 to 300 years). Use of early successional areas by browsing and grazing animals generally parallels these trends in food production (Alberta Fish and Wildlife 1978). In high snowfall areas, however, provision of cover and snow interception may influence or override the physical presence of the food resources.

Of the ten key species (and associated guild members) that were selected as representative of wildlife guilds in the mountain and foothills biomes, snowshoe hare, moose and elk are the species most strongly associated with early successional communities. All three groups utilize the herb and browse components of successional areas to varying extents in their diets. Based on the "idealized" relationships presented by Bunnell and Eastman (1976), it would appear that peak use of successional areas for food resources would occur 10 - 22 years after clearing. Assuming that vegetation development on reclamation areas will, at best, be equal or slower than on cleared (logged sites), at least the same period of time would be required to ensure that high quality successional habitats are available for wildlife on reclamationsites.

Our present knowledge of vegetation development on reclamation sites is inadequate to determine if assessment times of 10-22 years after reclamation would be appropriate to determine reclamation success for wildlife habitat. We require additional data on growth responses of trees and shrubs in reclamation areas, similar to those developed for the commercial tree species in the Commercial Forestry Study of the MFRRP program (D. Dempster, pers. comm.). Such relationships will not only allow us to determine the period of time required to establish stable, high quality wildlife habitat but it may also allow us to develop predictive relationships for tree and shrub growth. These predictive relationships may, in turn, allow us to conduct assessments at an earlier date with a high assurance that the reclamation objectives will be fulfilled.

8.3 CRITERIA FOR WILDLIFE HABITAT RECLAMATION STANDARDS

If wildlife habitat reclamation is to be recogonized as an alternative use for disturbed sites, it will be necessary to establish standards or guidelines for assessing reclamation efforts. In this portion of the report, we review existing reclamation legislation and discuss potential types of assessment criteria for wildlife habitat reclamation.

8.3.1 Reclamation Legislation

8.3.1.1 Alberta Reclamation Legislation. The Alberta Land Surface Conservation and Reclamation Act (LSCRA) addresses the conservation and reclamation of land disturbance. Several regulations associated with the LSCRA also affect reclamation programs:

1. Land Conservation Regulations (1974, amended 1976),
2. Regulated Coal Surface Operations Regulations (1974), and
3. Security Deposits Regulations (1974).

The Alberta Land Surface Conservation and Reclamation Act (LSCRA) is one of the few Acts in Canada that deals exclusively with the reclamation and conservation of land (Marshall 1983). The Land Conservation and Reclamation Division, Alberta Environment, is responsible for administering the act. The LSCRA provides an orderly six-stage process for review and approval of applications for reclamation orders and certificates of approval. These stages include submission of a development and reclamation plan, approval of the development and reclamation plan, posting of a reclamation bond, issuance of reclamation orders if reclamation work fails to obtain approval, issuance of surface control orders if an operator fails to comply with the reclamation orders, and issuance of a reclamation certificate if reclamation efforts meet the standards with subsequent return of the reclamation bond (Harrington 1979). Security deposits may involve a cash deposit of $5,000 - $25,000 depending on the size of mine or, at the discretion of the Minister of Environment, a security deposit based on a rate/tonne may be established (current levies range from $0.25 - 2.00/tonne) (Marshall 1983).

As a result of an industry-perceived need for greater flexibility in reclamation standards, the Guidelines for the Reclamation of Land in Alberta (ALCRC 1977) were issued in 1977 and are currently being amended. The guidelines provide direction and establish minimum requirements for drainage and erosion control, conservation of reclamation materials (e.g., topsoil), backfilling and recontouring, restructuring of the root zone, restoration of service and utilities and post-mining land management. The guidelines address revegetation of wildlife habitat as follows:

> "Where the prescribed post-disturbance land use is the establishment of permanent vegetation suitable for wildlife habitat, the operator is responsible for the establishment of various species and numbers of trees, grasses, forbs and shrubs of a density and composition which will provide food and cover for wildlife, consistent with the ecological zone of the region and satisfactory to the Approving Authority." (ALCRC 1977).

Wildlife habitat reclamation is also indirectly addressed in terms of drainage and erosion control, backfilling and recontouring (e.g., highwalls), and restructuring of the root zone.

Mining developments in the mountain and foothills biomes also are affected by the Coal Policy and the Policy for Resource Management of the Eastern Slopes (AENR 1977, draft revisions 1984). In the latter policy, eight land use areas were identified in the eastern slopes with different restrictions on mining and operating conditions.

8.3.1.2 Reclamation Legislation in Adjacent Provinces and States. In British Columbia, mine reclamation is governed by the Mining Regulation Act (Marshall 1983). The Mining Regulation Act provides very general guidelines for mine development and reclamation. More specific, yet flexible guidelines have been established for coal mines/exploration and minerals mines/exploration (B.C. Ministry Energy, Mines and Petroleum Resources 1982a, 1982b). Draft guidelines have been formulated but not implemented for reclamation of wildlife habitat (Foubister 1982).

Mine development and reclamation in Saskatchewan are within the authority of the Environment Act but as yet, no formal reclamation regulations have been approved (draft regulations were prepared in 1976 and have subsequently been used as guidelines in preparing reclamation guidelines) (Marshall 1983; S. McLeod, pers. comm.). Policy directives, environmental impact assessment procedures and permit/lease approval systems are usually employed to direct reclamation programs and enforce reclamation requirements. For example, specific reclamation guidelines have been developed for the Coronach and Estevan areas (Saskatchewan Environment 1983, 1984).

In Idaho, land reclamation is governed by the Idaho Surface Mining Act (Cushwa 1980; L.Jones, pers. comm.). The act requires the submission of a mine development and reclamation plan which is reviewed and approved by the State Board of Land Commissioners. If important fish and wildlife habitats are disturbed, the plan must meet the approval of the Department of Fish and Game. In terms of specific concerns for wildlife habitat reclamation, vegetation communities growing on the site prior to mining must be restored. Some requirements for recontouring of overburden and preparation of tailings ponds indirectly affect habitat reclamation.

Reclamation legislation in Montana includes some of the most rigorous and specific laws and guidelines in the United States or Canada. Mine reclamation is governed by the Montana Strip Mining and Reclamation Act (1973), the Montana New Hard Rock Law (1974), and the Strip Mine Coal Conservation Act (1973) (Cushwa 1980). The Montana reclamation laws require detailed pre-mine iventories of topographic features, vegetation and wildlife which are used as post-mine evaluation criteria. Reclamation of the site is required to return the topographic and vegetation diversity to pre-mining levels with subsequent restoration of wildlife habitat.

8.3.2 Recommended Criteria

During the interviews of government and industry specialists and review of literature for this study, a number of common concepts concerning desirable assessment criteria were discussed. Generally-accepted attributes for assessment criteria are:

1. A clear definition of the reclamation requirements. Reclamation criteria must clearly state the required reclamation objectives, the process for establishment of a standard, and the process for comparison of the site conditions with the standard. Clearly defined criteria allow the mining company to develop a comprehensive reclamation plan to achieve the required end goals and to identify and correct deficiencies prior to assessments;

2. The evaluation process should preferably be easily-understood and cost-effective. The techniques employed for evaluation should be accurate yet minimize the manpower and costs to complete the evaluation. An easily-understood method will also help ensure that the standards are fulfilled.

3. The criteria must be flexible to site variability. Although general province-wide standards may be developed, the criteria must allow for adaptation to the specific physical, climatic and biological conditions of the site;

4. The criteria must be adaptable to multiple land use objectives. Because wildlife end uses can and may often be integrated with other land uses (e.g., recreation, forestry, agriculture), the criteria must allow for adaptation to multiple land use;

5. The criteria must allow for input from management agencies. Wildlife habitat reclamation permits government management agencies to enhance regional

management plans. Irregardless of pre-mine land uses, the criteria should allow for modification of the final land use to compliment or directly influence regional management plans for one or more wildlife species;

6. The criteria must ensure that wildlife habitat has been successfully re-established. The criteria should provide accurate assessments of habitat quality and compare these to an accepted standard which is representative of high quality wildlife habitat within the region;

7. The criteria should try to minimize the time period prior to assessment. Because of the financial cost of posting a reclamation bond, industrial interests prefer criteria which minimize the assessment period. Because minimization of this period requires predictive assessment, the criteria must provide a high assurance of reclamation success; and

8. The criteria should specify procedures for remedial reclamation in the event of failure. In the event that reclamation on a site does not meet the accepted standard, procedures for identifying and correcting deficiencies should be discussed. Provisions for post-certification failures also should be described (e.g., designation of responsibility, actions).

8.3.3 Recommended Approach

As discussed earlier, we believe that a habitat-based assessment is the only suitable method of assessing reclamation success and that the HEP program (U.S. Fish and Wildlife 1980) is the most suitable habitat evaluation system for wildlife habitat reclamation. Utilization of the HEP program would involve three steps. In describing these steps, we have assumed that habitat models already exist for the key wildlife species in the mountain and foothills biomes.

8.3.3.1 Step One: Pre-mine Assessment. Prior to disturbance of the proposed mine site, baseline surveys would be conducted to determine the types of wildlife present, the use of habitats by wildlife and the distribution of vegetation communities and special features (e.g., cliffs, talus, wetlands, watercourses and licks). Key species for the reclamation plan would then be selected in cooperation with the Fish and Wildlife Division. If mutilple land uses are planned, reclamation guidelines must be established in cooperation with other government agencies. A baseline habitat assessment, utilizing the HEP process, would then be conducted to determine the distribution and number of baseline Habitat Units (HU's) for each of the selected key species. These values would then represent the standard for the reclamation assessment; HU values at the time of the reclamation assessment might be equal to or greater than the pre-mine HU's (or a proportion of these HU's if that is deemed appropriate by the regulatory agency).

8.3.3.2 Step Two: Development of the Reclamation Plan. Because the habitat evaluation models used in the HEP approach assess an area's ability to provide several essential habitat components (e.g., food, reproductive cover, thermal cover etc.) for each key species, these models will indicate specific habitat deficiencies and adequacies for any given area for a variety of reclamation plans. Consequently, they permit reclamation planners to focus on the most important habitat characteristics for a key species and incorporate these into the reclamation plan.

8.3.3.3 Step Three: Assessment. Once the reclamation area is ready for assessment (this could be determined by annual or bi-annual measurements of habitat characteristics and application of the HEP process), the HEP process would be used to determine the availability of HU's on the reclamation site. To be certified, a reclamation area would have to provide an equal or greater number of HU's than the accepted baseline standard of HU's. If an area did not provide sufficient HU's, the habitat characteristics that were deficient would be identified and corrective measures implemented.

8.4 RECOMMENDATIONS FOR FUTURE RESEARCH

Based on existing information and data deficiencies in reclamation technology, wildlife habitat relationships and assessment methodology, we require additional research concerning a number of topics.

8.4.1 Reclamation Technology

Aspects of wildlife habitat reclamation technology which require further study include:

1. Development of propagation techniques for a greater number of naturally-occurring species of shrubs and ground covers that are important dietary or structural components of wildlife habitat. The ability to propagate more of these species will provide a broader selection of species for use in wildlife habitat reclamation. Cultivars of trees, shrubs and ground covers that are adapted to and capable of reproducing in various elevational and site conditions also should be developed in order to promote the development of a self-sustaining vegetation community.

2. The feasibility and benefits of mixed-species plantings, particularly trees and shrubs. Benefits of utilizing native species and/or commercial species in these plantings should be examined. Effects of mixed planting on commercial timber production and in reducing wildlife damage to seedlings should be considered.

3. The benefits of variable planting schedules. Additional information is required on the effects of combined or separate plantings of ground covers, shrub covers, and/or tree covers and effects of separating these plantings through time. For example, is it benefical to plant shrubs and trees prior to ground cover establishment or to delay shrub and tree planting in combination with herbicide use, and

4. The effects of island plantings and topsoil islands on habitat establishment. Information is required on the optimal spacing of islands, their feasibility in promoting community establishment, the rate of plant invasion into inter-island areas, and use by wildlife. Some information regarding these topics will be provided through on-going studies at Westar Mining and Cardinal River Coal.

8.4.2 Wildlife Habitat Relationships

Although a considerable amount of research has focused on wildlife-habitat relationships, few of these studies have attempted to determine the critical habitat requirements of a species and fewer still have attempted to define critical limits or ranges for these requirements. A cooperative study of wildlife habitat requirements by the Alberta Fish and Wildlife Division, Alberta Forestry and St. Regis (Millson and Bondy 1984) may provide some of this information. Considering that more specific information is required on the functional responses of wildlife species to habitat characteristics and on critical habitat requirements, other research requirements include:

1. Range size requirements for wildlife. Data are needed on the size of areas that wildlife require to meet various habitat requirements for food, cover and water. For example, what is the minimum size of shrub

clusters that are useful to moose or the minimum size of pond required by beaver? Critical limits and ranges are more important than average values.

2. The relative importance of vegetation characteristics versus physical characteristics. Information for each key species on the importance of physical habitat features such as slope, aspect, topography, and special features in relation to vegetation characteristics is required.

3. Forage preferences and palatability. Additional information should be obtained on the preferences and palatability of forb, gramineous, and shrub species. Effects of mixed plantings of preferred and unpreferred species on forage or browse utilization should be examined. Other aspects for consideration include optimal planting ratios of preferred: unpreferred species and the distribution of preferred: unpreferred species within a site; and

4. Acceptable levels of forage and browse use. In order to avoid overuse of forage or browse resources on a site, we require information on the effects of browse and forage use, particularly repeated use, on plant productivity and survival. Ongoing studies at Cardinal River Coal and Westar Mining may provide some of this information.

8.4.3 Assessment Methodology

Very little information is presently available on the response of wildlife to reclamation areas, particularly sites that have been reclaimed specifically for a single species or species group of wildlife. As a result, knowledge applicable to developing reclamation criteria or standards for wildlife reclamation is extremely limited. Important research considerations for assessment methodology include:

1. Growth responses of trees and shrubs. Because little is presently known about the growth and survival responses of tree and, particularly, shrubs on reclamation sites, it is not possible to use predictive relationships in assessments of wildlife habitat reclamation;

2. Responses of wildlife to reclamation. Since few longterm wildlife habitat reclamation projects have been initiated in the province or adjacent areas and almost no systematic monitoring of wildlife use has been conducted, very little information is available on wildlife responses to different reclamation methods. As a result, we cannot readily identify preferred methodologies or relate wildlife response to plant growth responses (see Point 1). Consequently, we presently are unable to incorporate predictive capabilities in assessment processes;

3. Ecosystem responses. Development of models to simulate community succession on reclamation sites would allow information on growth responses of trees, shrubs and ground cover to be integrated. Additional information on animal responses, effects of island planting, and multiple end uses could be incorporated to provide a predictive tool to examine the effects of various mine practices and reclamation methods on community development; and

4. Multiple end use strategies. We need to further examine the feasibility, benefits and costs of multiple land uses on a reclamation site. For

example, what are the effects of rotational cattle grazing on areas reclaimed as wildlife habitat, or the effects on commercial timber production if wildlife end uses are incorporated as a secondary reclamation objective? Predictive models, as described in Point 3, may also be useful for examining the effects of multiple land uses on reclamation planning and implementation.

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A.F.W.D. 1978. Environmental effects of forestry operations in Alberta: Fish and Wildlife Division concerns and recommendations. Fish and Wildlife Division, Alberta Recreation, Parks and Wildlife, Edmonton. 106 pp.

key words: wildlife, forestry, disturbance.

Effects of forestry practices on fish and wildlife in Alberta are reviewed. Recommendations for mitigation are proposed.

A.F.W.D. 1984. Status of the fish and wildlife resources in Alberta. Fish and Wildlife Division, Alberta Energy and Natural Resources, Edmonton. ENR Rep. No. 1-87. 123 pp.

key words: birds, mammals, status and distribution.

Summarizes the current status of wildlife populations in the province.

A.F.S. 1979. Alberta forest regeneration survey manual. Alberta Forest Service, Edmonton. 43 pp.

Key words: forest regeneration, assessment, standards.

Standards and methodology for assessing reforestation in Alberta are presented.

Agriculture Canada. 1977. Altai wild ryegrass. Information Division. Canada Department of Agriculture. Publication 1602.

key words: altai wild ryegrass, range improvement, grasses.

An information bulletin on altai wild ryegrass comparing it to other range grasses.

Agriculture Canada. 1980. New northern wheatgrass licensed. Agriculture Canada Information Bulletin 1869:11-12.

key words: northern wheatgrass, pasture, grasses, Elbee.

A new variety of wheatgrass (Elbee) was licensed in Canada after being developed at Lethbridge, Alberta. The variety is important as fall and winter pasture.

A.L.C.R.C. 1977. Guidelines for the reclamation of land in Alberta. Alberta Environment and Alberta Energy and Natural Resources. Edmonton, Alberta. n.p.

key words: reclamation, coal, guidelines.

Provides recommendations for reclamation of land disturbed by coal mining. Provisions for reclamation for forestry, agriculture and wildlife are discussed.

Allen, A.W. 1983. Habitat suitability index models: beaver. USDI Fish and Wildlife Service, Washington D.C. 20 pp.

key words: beaver, _Castor_ _canadensis_, habitat use, habitat assessment.

Provides a review of information on habitat use by beavers, and presents a quantitative model for assessing habitat suitability.

Allen, A.W. and R.D. Hoffman. 1984. Habitat suitability index models: muskrat. USDI Fish and Wildlife Service, Washington D.C. 28 pp.

key words: muskrat, Ondatra zibethicus, habitat use, habitat assessment.

Reviews habitat information considered pertinent to impact assessment and habitat management studies, and provides a quantitative habitat model.

Anderson, W.J. and B.J. Markham. 1981. Integrated reclamation for wildlife and agriculture: a literature review. RRTAC Report 80-14. Alberta Land Conservation and Reclamation Council, Edmonton. 53 pp.

key words: wildlife, agriculture; disturbance.

The potential for mitigation of wildlife habitat enhancement and creation with agriculture in Alberta is reviewed.

Anonymous. 1972. A statement of concern by the Northern Wild Sheep Council on the effects of coal mining on wild sheep populations in western Canada and northwestern United States. Pages 116-117, in: Transactions of the 1972 Northern Wild Sheep Council, Hinton, Alberta.

key words: bighorn sheep, Ovis canadensis, status and habitat distribution, habitat use.

Discusses habitat requirements of bighorn sheep in relation to possible impacts of coal mining on sheep habitat.

Ashley, G.H.W. 1954. The distribution and status of the beaver of the lower Bow River valley, Banff National Park, 1954. Canadian Wildlife Service, Edmonton. 10 pp.

key words: beaver, Castor canadensis, food habits, habitat use.

Outlines the status of all beaver colonies known to occur in the area.

Banfield, A.W.F. 1947. The mammals of Waterton Lakes National Park. Canadian Wildlife Service, Wildlife Management Bulletin, Series 1, No. 1.

key words: mammals, status and distribution, habitat use.

Summarizes the status of mammals in Waterton Lakes National Park.

Banfield, A.W.F. 1958. The mammals of Banff National Park, Alberta. National Museum of Canada, Bulletin No. 159, Biological Series No. 57. 53 pp.

key words: mammals, status and distribution, habitat use.

Summarizes the available information on mammals known to occur in Banff National Park.

Banfield, A.W.F. 1977. The mammals of Canada. University of Toronto Press. 438 pp.

key words: mammals, status and distribution.

Outlines the range and general ecology of all mammals known to occur in Canada.

Barr Engineering Co. and J.P. Borovsky. 1980. Enhancement of fish and wildlife resources in the reclamation of hard rock mined lands in the upper midwest. USDI Fish and Wildlife Service, Washington D.C. FWS/OBS - 80/64. 123 pp.

key words: fish, wildlife, reclamation, hard rock mines.

This manual describes methods of enhancing or reclaiming wildlife and fisheries habitat in the upper midwestern United States. Reclamation activities are described for wildlife habitat as well as for forestry and agricultural end uses with allowances for wildlife.

Bartos, D.L. 1978. Modeling plant succession in aspen ecosystems. Pages 208-211, in Proceedings of the First International Rangeland Congress. Denver, Colorado. Society of Range Management.

key words: succession, aspen, western U.S., regeneration model.

A model simulating the natural successional changes from as aspen site to conifers.

B.C. Ministry of Energy, Mines and Petroleum Resources. 1982a. Guidelines for coal exploration. Minerals Resources Division, Victoria. 79 pp.

key words: coal, exploration, guidelines.

The manual presents guidelines to minimize the environmental effects of coal exploration in British Columbia.

B.C. Ministry of Energy, Mines and Petroleum Resources. 1982b. Guidelines for minerals exploration. Minerals Resources Division, Victoria. 45 pp.

key words: minerals, exploration, guidelines.

The manual present guidelines to minimize the environmental effects of mineral exploration in British Columbia.

Bentz, J.A. 1981. Effects of fire on the subalpine range of Rocky Mountain bighorn sheep in Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 192 pp.

key words: bighorn sheep, Ovis canadensis, habitat use.

Presents results of studies on floristic composition and use of fire-disturbed sites by bighorn sheep in Alberta.

Berdusco, R.J. and A.W. Milligan. 1977. Surface reclamation situations and practices on coal exploration and surface mine sites at Sparwood, B.C. Paper No. 6, in: Proceedings of the Canadian Land Reclamation Association, Edmonton.

key words: coal, reclamation, exploration, mining.

Describes the ongoing reclamation program at Kaiser Resources Ltd.

Berg, B.P. 1983. Wild and domestic ungulate interactions in the Bob Creek area, southwestern Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 153 pp.

key words: elk, Cervus elaphus, food habits, habitat use.

Presents results of studies on food habits and habitat use of elk (and other ungulates) on a major winter range in southwestern Alberta.

Berg, B.P. and R.J. Hudson. 1981. Elk, mule deer, and cattle: functional interactions on foothills range in southwestern Alberta. Pages 509-519, in: Proceedings of the Wildlife Livestock Relationships Symposium, Coeur d'Alene, Idaho.

key words: food habits, habitat use, elk, mule deer, cattle.

Documents the amount of resource overlap of elk, mule deer and cattle in the foothills of southwestern Alberta.

Bergerud, A.T., H.E. Butler and D.R. Miller. 1984. Antipredator tactics of calving caribou: dispersion in mountains. Can. J. Zoology 62:1566-1575.

key words: caribou, Rangifer tarandus, habitat use, food habits, nutrition.

Provides results of a study on caribou in Spatsizi Provincial Park, interior British Columbia.

Bergerud, A.T., F. Manuel, and H. Whalen. 1968. Harvest reduction of a moose population in Newfoundland. J. Wildl. Manage. 32:722-728.

key words: moose, hunting, harassment.

Numeric responses of moose populations in previously inaccessible areas of Newfoundland to hunting were assessed.

Best, D.A., G.M. Lynch and O.J. Rongstad. 1977. Annual spring movements of moose to mineral licks in Swan Hills, Alberta. North American Moose Conference and Workshop 13: 215-228.

key words: moose, Alces alces, habitat use.

Reports results of a radiotelemetry study of moose movements in the Swan Hills, as these relate to travel to natural mineral licks.

Bezeau, L.M., L.E. Lutwick, A.D. Smith and A. Johnston. 1967. Effect of fertilization on chemical composition, nutritive value, and silica content of rough fescue, Festuca scabrella. Can. J. Plant Sci. 47: 269-272.

key words: rough fescue, chemical composition, fertilization.

Describes response of rough fescue to fertilization.

Black, H., R.J. Scherzinger and J.W. Thomas. 1975. Relationships of Rocky Mountain elk and Rocky Mountain mule deer habitat to timber management in the Blue Mountains of Oregon and Washington. Pages 11-31, in: J. Peek (ed.). Transactions of the Elk-Logging-Roads Symposium, University of Idaho, Moscow.

key words: elk, Cervus elaphus, habitat use.

Discusses elk habitat requirements in the Pacific Northwest.

Bloomfield, M.I. 1979a. The ecology and status of mountain caribou and caribou range in central British Columbia. M.Sc. Thesis, University of Alberta, Edmonton. 318 pp.

key words: caribou, Rangifer tarandus, habitat use, food habits.

Reports results of studies on caribou populations and habitat in east-central British Columbia, including a discussion of impacts of development and human settlement.

Bloomfield, M. 1979b. The impact of development, settlement and associated activities on mountain caribou in central British Columbia, Canada. Proc. 2nd International Reindeer and Caribou Symposium, Roros, Norway.

key words: caribou, Rangifer tarandus, habitat use.

Summarizes effects of human activities on caribou in east-central British Columbia.

Bloomfield, M. 1980. Closure of the caribou hunting season in Alberta - management of a threatened species. Alberta Fish and Wildlife Division, Edson.

key words: caribou, Rangifer tarandus, status and distribution, habitat use.

Discusses threats to caribou in Alberta and the need to close hunting of this species until data on habitat requirements and population dynamics can be developed.

Bloomfield, M., J. Edmonds and J. Steele. 1981. First annual report of the Berland - A La Peche caribou study. Alberta Fish and Wildlife Division, Edson. 54 pp.

key words: caribou, Rangifer tarandus, habitat use, spatial behaviour, food habits.

Discusses preliminary results of a study of caribou habitat utilization, food habits, behaviour and disturbance responses in west-central Alberta.

Bloomfield, M. and M. Sword. 1981. Proposal to designate Alberta's caribou as a threatened species. Alberta Fish and Wildlife Division, Edson. 22 pp.

key words: caribou, Rangifer tarandus, status and distribution.

Discusses the current status of this species in Alberta.

Boag, D.A. and J.W. Kuceniuk. 1968. Protein and caloric content of lodgepole pine needles. Forestry Chron. 44:28-31.

key words: spruce grouse, Canachites canadensis, nutrition.

Provides data on protein and energy content of pine needles obtained from spruce grouse habitat in southwestern Alberta.

Boag, D.A., K.H. McCourt, P.W. Herzog and J.H. Alway. 1979. Population regulation in spruce grouse: a working hypothesis. Can. J. Zool. 57:2275-2284.

key words: spruce grouse, Canachites canadensis, population dynamics.

Summarizes results of 10 years of studies in southwestern Alberta and evaluates the evidence for population regulation.

Boag, D.A., S.G. Reebs and M.A. Schroeder. 1984. Egg loss among spruce grouse inhabiting lodgepole pine forests. Can. J. Zool. 62:1034-1037.

key words: spruce grouse, Canachites canadensis, habitat use.

Reports results of studies on factors influencing loss of eggs from clutches deposited in simulated and natural nests of spruce grouse in southwestern Alberta.

Boyce, S.G. 1977. Management of eastern hardwood forests for multiple benefits (DYNASTMB). USDA For. Serv. Res. Pap. SE-168. Asheville, N.C. 116 pp.

key words: habitat assessment, wildlife key species.

Describes a method of evaluating wildlife habitat through use of key or indicator wildlife species.

Brink, V., A. Lackhurst and D. Morrison. 1972. Productivity estimates from alpine tundra in British Columbia. Can. J. Plant Sci. 52:321-323.

key words: alpine, productivity, carrying capacity, ungulates.

Provides estimates of productivity of alpine tundra and carrying capacity of alpine ranges for domestic and native ungulates.

Brown, R.W. and R.S. Johnston. 1979. Revegetation of disturbed alpine rangelands. Pages 79-94, in: D.A. Johnson (ed.). Special Management Needs of Alpine Ecosystems. Society for Range Management, Denver, Colorado.

key words: revegetation, alpine, disturbance.

Discusses problems associated with species selection and methods of alpine revegetation.

Brown, R.W., R.S. Johnston and D.A. Johnson. 1978. Rehabilitation of alpine tundra disturbances. J. Soil and Water Cons. 33:154-160.

key words: alpine tundra, disturbance, revegetation, habitat enhancement.

Describes characteristics of alpine tundra disturbances and methods of rehabilitation.

Browning, E.R. (ed.). 1982. Wildlife user guide for mining and reclamation. USDA Forest Service Gen. Tech. Rep. INT-126. Intermountain Forest Range Expt. Stn., Ogden, Utah. 77 pp.

key words: wildlife, impact assessment, reclamation, mitigation.

This guide describes in general terms the management and reclamation of wildlife habitat in relation to ongoing or planned minerals mining. Topics discussed are the legal framework, land management planning, impact assessment, mitigation and opportunities for wildlife management.

Buckner, C.H. 1970. The strategy for controlling rodent damage to pines in the Canadian mid-west. Proc. Vert. Pest. Conf. 4:43-48.

key words: rodents, damage, reforestation.

Methods of controlling small rodent damage to pine plantations in Manitoba are discussed. Methods considered include rodenticicles, repellents, mechanical shields and habitat manipulation.

Bunnell, F.L. and D.S. Eastman. 1976. Effects of forest management practices on wildlife in the forests of British Columbia. Pages 631-689 in: Proc. Div. I, I.U.F.R.O. XVL World Congress, Oslo.

key words: wildlife, habitat, succession, forestry.

Responses of wildlife to clearing of forest cover by logging operations and subsequent successional growth are examined.

Burgess, S.A. 1980. Effects of stream habitat improvements on invertebrates, trout populations and mink activity. J. Wildl. Manage. 44:871-880.

key words: stream enhancement.

Stream habitat for fish was improved by pool development and changes in channel morphology. Habitat improvement resulted in increased numbers and biomass of trout and crayfish. Mink activity increased in the vicinity of the habitat improvement area, and was associated with the increase in crayfish availability.

Carbyn, L.N. 1975. Factors influencing activity patterns of ungulates at mineral licks. Can. J. Zool. 53:378-384.

key words: elk, Cervus elaphus, habitat use.

Presents results of a study on effects of weather and predation pressure on use of mineral licks by elk and mule deer in Jasper National Park.

Carbyn, L.N., J. Stelfox and H. Scheidemann. 1984. Wabamun habitat improvement program. Prepared for Transalta Utilities by Stony Plain Fish and Game Association. 11 pp.

key words: wildlife enhancement, revegetation, wildlife monitoring.

Results of the 1984 wildlife enhancement work and the wildlife monitoring studies at the Whitewood Mine site are discussed.

Caslick, J.W. 1980. Deer proof fences for orchards: a new look at economic feasibility. Proc. Vertebrate Pest Conf. 9:161-162.

key words: deer, damage, control, fencing.

The use and economic feasibility of wire mesh fences to protect orchard trees from deer damage is considered.

Cayford, J.H. and R.A. Haig. 1961. Mouse damage to forest plantations in southeastern Manitoba. J. Forest. 59:124-125.

key words: rodents, damage, reforestation.

Types and amounts of rodent damage to forest (tree) plantations in Manitoba are discussed.

Clarke, C.H.D. 1942. Wildlife investigations in Banff and Jasper National Parks in 1941. National Parks Bureau, Ottawa.

key words: mammals, status and distribution, habitat use.

Includes data on habitat utilization and status of snowshoe hare, moose, caribou and other species.

Clausing, T.A. 1981. Skookumchuk wildlife enhancement project. Washington Dept. Game. 38 pp.

key words: wildlife enhancement, integrated land use, wetlands, revegetation, special structures.

A wildlife habitat enhancement area was devleoped as part of the Centralia Steam Electric Generating Project.

Conroy, M.J., L.W. Gysel and G.R. Dudderar. 1979. Habitat components of clear-cut areas for snowshoe hares in Michigan. J. Wildl. Manage. 43:680-690.

key words: snowshoe hare, *Lepus americanus*, habitat use.

Discusses winter use by hares of clear-cuts in Michigan, and provides recommendations for management of hare habitat.

Courtney, J. 1977. Elk and mule deer use of partially disturbed range during a mild east Kootenay winter. Kaiser Resources Ltd., Sparwood, B.C. 117 pp + appendices.

key words: elk, mule deer, coal mine, reclamation.

Use of a traditional winter range and coal mine reclamation sites by elk and mule deer was monitored. Both species adapted well to human presence. Reclaimed areas appeared to provide additional winter range.

Cowan, I. McT. 1947. Range competition between mule deer, bighorn sheep and elk in Jasper Park, Alberta. N. Am. Wildl. Conf. 12:223-227.

key words: bighorn sheep, *Ovis canadensis*, elk, *Cervus elaphus*, food habits.

Details winter food habits of bighorn sheep and elk in the Athabasca Valley, Jasper National Park.

Cowan, I. McT. and V.C. Brink. 1949. Natural game licks in the Rocky Mountain National Parks of Canada. J. Mammal. 30:379-387.

key words: mammals, habitat use.

Discusses lick use by bighorn sheep, mountain goats, moose, elk, caribou and deer in the mountain national parks, and presents chemical analyses of lick material.

Crawford, R.D. and J.A. Rossiter. 1982. General design considerations in creating artificial wetlands for wildlife. Pages 44-47, in: W.D. Svedarsky and R.D. Crawford (eds.). Wildlife Values of Gravel Pits. Univ. Minn. Agric. Exp. Station, Misc. Publ. 17-1982.

key words: wetlands, creation, enhancement.

Methods of enhancing existing wetlands or creating new wetlands for wildlife are discussed. Techniques discussed include shoreline complexity, bottom contouring, soil ammendements and islands.

Cushwa, C.T. 1980. A summary of fish and wildlife information needs to surface mine coal in the United States. Part 2. The status of state mining regulations as of January 1980 and the fish and wildlife information needs. Prepared for Office of Surface Mining, Reclamation and Enforcement and Fish and Wildlife Service by Science Applications Inc. FWS 14-16-0009-79-092. 61 pp.

key words: coal mining, regulations.

Part 2 of a three part series to assist government and industry in determining fish and wildlife needs for new coal mining operations. This report documents the status of individual state surface mining regulations.

Dahmer, T.D., N.C. Forrester, J.M. Lockhardt and T.P. McEneaney. 1982. Nest box use by American kestrels on and around western surface-mined lands. Pages 210-212, in: Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecol. Inst. Tech. Publ. 14.

key words: raptors, American kestrel, habitat enhancement, surface mines.

Nest boxes for American kestrels were installed on and around revegetated surface-mined lands in Montana and Wyoming. There were no detectable differences in breeding success or production among the natural and revegetated habitats.

Dasmann, R.F., A.L. Hubbard, W.M. Longhurst, G.T. Ramstead, J.H. Harn and E. Culvert. 1967. Deer attractants, an approach to the deer damage problem. J. Forest. 65:564-566.

key words: deer, damage, control.

The use of various attractants such as sprays of sweeteners or trace metals, supplemental food and felling of trees to control deer damage is discussed.

Dickson, K.L. and D. Vance. 1981. Revegetating surface mined lands for wildlife in Texas and Oklahoma. USDI Fish and Wildlife Service, Washington D.C. FWS/OBS-81/25. 121 pp.

key words: wildlife, mammals, birds, reclamation, habitat enhancement, habitat creation, coal mines.

This guide discusses techniques for the reclamation of disturbed areas as wildlife habitat. Basic requirements of wildlife are discussed as well as development of management goals and a revegetation plan. Specific recommendations are provided on species selection for shrubs and ground cover, and costs.

Dodds, D.G. 1960. Food competition and range relationships of moose and snowshoe hare in Newfoundland. J. Wildl. Manage. 24:52-60.

key words: snowshoe hare, Lepus americanus, moose, Alces alces, food habits, habitat use.

Reports the favored browse plants of snowshoe hares and moose in Newfoundland, and assesses the degree of competition between the two species.

Dolbeer, R.A. and W.R. Clark. 1975. Population ecology of snowshoe hares in the central Rocky Mountains. J. Wildl. Manage. 39:535-549.

key words: snowshoe hare, Lepus americanus, habitat use, spatial behaviour, population dynamics.

Provides results of a study on population dynamics of snowshoe hares in Colorado and Utah.

Erickson, J. 1981. Memorandum dated 24 November. Dep. Env. Quality, Lander, Wyoming, Cited in Tessman 1982. (not seen)

Errington, P.L. 1961. Muskrats and marsh management. Stackpole Co., Harrisburg, PA. 183 pp.

key words: muskrat, Ondatra zibethicus, food habits.

Provides a general discussion of muskrat ecology and management in North America.

Esso Resources Limited. 1984. Judy Creek test mine reclamation studies. Part B. Wildlife Studies. Esso Resources Canada Limited, Oil Sands, Coal and Minerals Division, Calgary, Alberta. 70 pp. + appendices.

key words: small mammals, ungulates, wildlife, reclamation, recolonization, browsing, damage.

Wildlife studies at the Judy Creek test mine included small mammal populations studies and effects on reforestation, ungulate habitat use and general wildlife recolonization. Results of a monitoring from 1979 to 1983 are reported.

Etter, H.M. 1971. Preliminary report of water quality measurements and revegetation trials on mined lands at Luscar, Alberta. Internal Rep. NOR-3. Northern Forest Research Centre, Edmonton. 19 pp.

key words: coal mines, revegetation, hydroseeding.

Research included measurement of drainage systems and revegetation trials on overburden dumps.

Etter, H.M. 1972. Protection and reclamation of bighorn sheep range in the foothills of Alberta. Pages 95-97, in: Transactions of the 1972 Northern Wild Sheep Council, Hinton, Alberta.

key words: bighorn sheep, Ovis canadensis, habitat use, habitat assessment.

Discusses importance of bighorn sheep winter range and outlines approaches to habitat reclamation post-disturbance.

Etter, H.M. 1973. Mined-land reclamation studies on bighorn sheep range in Alberta, Canada. Biological Conservation 5:191-195.

key words: bighorn sheep, Ovis canadensis, habitat use, habitat assessment.

Discusses importance of bighorn sheep winter range and outlines approaches to habitat reclamation post-disturbance.

Ferguson, R.B. 1983. Use of rosaceous shrubs for wildland plantings in the intermountain west. Pages 136-149, in: Managing Intermountain Rangelands - Improvement of Range and Wildlife Habitats. USDA Forest Service Gen. Tech. Rep. INT-157. Intermountain Forest Range Exp. Stn., Ogden, Utah.

key words: revegetation, shrubs, wildlife.

Information on rosaceous shrubs is presented for use in range improvement projects. Form and rate of growth, reproduction, longevity, geographical distribution, forage values, response to fire and herbicides and the effects of insects and disease are discussed.

Fitzmartyn, G.A. and G.L. Holroyd. 1978. Winter mammal use in the Lake Louise Planning Unit 1974 to 1977. Natural History Research Division, Parks Canada Western Region, Calgary. 75 pp.

key words: mammals, habitat use.

Presents data on winter habitat use by snowshoe hare, elk, moose and other species in the Lake Louise area.

Flood, B.S., M.E. Sangster, R.D. Sparrowe, and T.S. Baskett. 1977. A handbook for habitat evaluation procedures. Resour. Publ. 132. U.S. Dep. Inter., Fish and Wildl. Serv., Washington, D.C. 77 pp.

key words: habitat assessment, wildlife, key species.

Describes a method of evaluating wildlife habitat through use of key or indicator wildlife species.

Flook, D.R. 1959. Moose using water as refuge from flies. J. Mammal. 40:455.

key words: moose, *Alces alces*, habitat use.

Details observations of moose in the Trout River, N.W.T.

Flook, D.R. 1964. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Pages 119-128, in: D.J. Crisp (ed.). Grazing in Terrestrial and Marine Environments. Blackwell Sci. Publ., Oxford.

key words: mammals, food habits, habitat use.

Discusses diets, habitat selection and interspecific relationships of mountain goats, bighorn sheep, moose, elk and mule deer in Banff and Jasper National Parks.

Flook, D.R. 1970. Causes and implications of an observed differential in the survival of wapiti. Canadian Wildlife Service Report Series Number 11.

key words: elk, Cervus elaphus, nutrition, habitat use, population dynamics.

Provides an analysis of elk population dynamics, based partly on data from Jasper and Banff National Parks.

Foubister, L.J. 1982. Reclamation for wildlife habitat. Draft Unpubl. MS. British Columbia Ministry of the Environment, Victoria. 4 pp.

key words: wildlife, reclamation, mitigation, guidelines.

Recommendations are provided for reducing the effects of mining on wildlife. Methods of improving reclamation for wildlife are briefly discussed.

Fritz, R.S. 1979. Consequences of insular population structure: distribution and extinction of spruce grouse populations. Oecologia 42:57-66.

key words: spruce grouse, Canachites canadensis, habitat use.

Reports on regional distribution and abundance of spruce grouse in relation to patchy habitat in the Adirondack Mountains, New York.

Fuller, T.K. and L.B. Keith. 1981. Woodland caribou population dynamics in northeastern Alberta. J. Wildl. Manage. 45:197-213.

key words: caribou, Rangifer tarandus, habitat use, spatial behaviour.

Presents results of studies on movements and habitat use of radio-collared caribou in the Birch Mountains, northeastern Alberta.

Fuller, W.A. 1951. Natural history and economic importance of the muskrat in the Athabasca-Peace Delta, Wood Buffalo Park. Canadian Wildlife Service, Wildlife Management Bulletin, Series 1, No. 2.

key words: muskrat, Ondatra zibethicus, food habits.

Provides results of ecological and management studies of the muskrat in northeastern Alberta.

Gates, C.C. 1975. Aspects of the environment - lungworm (Nematoda: Metastrongyloidea) - bighorn sheep (Ovis c. canadensis) system. M.Sc. Thesis, University of Alberta, Edmonton. 55 pp.

key words: bighorn sheep, Ovis canadensis, nutrition, habitat use, disease.

Presents results of a study to investigate the role of nutrition and other environmental factors in lungworm infections of sheep in the upper Red Deer River area.

Gates, C.C., and R.J. Hudson. 1983. Foraging behaviour of wapiti in a boreal forest enclosure. Naturaliste can. 110:197-206.

key words: elk, feeding behaviour, forage.

Presents data on feeding habits of elk in the Ministik area east of Edmonton.

Geist, V. 1971. Mountain sheep. A study in behaviour and evolution. Wildlife Behaviour and Ecology Series, University of Chicago Press, Chicago and London. 383 pp.

key words: bighorn sheep, Ovis canadensis, habitat use, spatial behaviour.

Presents data on habitat use, home ranges, movements and behaviour of bighorn sheep in Banff National Park and elsewhere.

Geist, V. 1972. On the significance of thermoclines to the biology of wintering mountain sheep. Pages 75-77, in: Transactions of the 1972 Northern Wild Sheep Council, Hinton, Alberta.

key words: bighorn sheep, Ovis canadensis, nutrition, habitat use.

Discusses energetic consequences of thermoclines and theoretical relationships with quality of forage intake by bighorn sheep.

Geist, V. 1975. Harassment of large mammals and birds. Report to the Berger Commission, September 1975. 62 pp. + Appendices.

key words: wildlife, disturbance, harassment, responses.

Potential effects of harassment and disturbance on wildlife are discussed. Behavioural and physiological responses of wildlife to harassment are reviewed and mitigation measures are reviewed.

Geist, V. and R.G. Petocz. 1977. Bighorn sheep in winter: do rams maximize reproductive fitness by spatial and habitat segregation from ewes? Can. J. Zool. 55:1802-1810.

key words: bighorn sheep, Ovis canadensis, habitat use, spatial behaviour.

Discusses winter distribution and habitat use by bighorn sheep in Banff National Park.

Giron, B.A. 1981. Wildlife use of man-made wetlands in the prairie pothole region: a selected annotated bibliography. South Dakota Coop. Wildl. Res. Unit. Tech. Bull. No. 2. 23 pp.

key words: wetlands, habitat enhancement, habitat manipulation, waterfowl, wildlife.

Reviews studies concerned with the use of man-made wetlands in the northern glaciated prairie and parkland regions of North America. Most of the studies presented focus on the use of man-made wetlands by waterfowl.

Giroux, J.F. 1981. Use of artificial islands by nesting waterfowl in southeastern Alberta. J Wildl. Manage. 45:669-679.

key words: waterfowl, nesting, islands.

Use of artificial islands by nesting waterfowl during three consecutive years was investigated. Information is provided on nesting densities nad nesting success. Means of improving construction, position and vegetation on islands are suggested.

Godfrey, W.E. 1966. The birds of Canada. National Museums of Canada Bull. No. 203, Biol. Series No. 73. Ottawa. 428 pp.

key words: birds, status and distribution.

Outlines the range and general ecology of all bird species known to occur in Canada.

Green, J.E. 1978. Techniques for control of small mammal damage to plants: a review. LGL Limited Report for Alberta Oil Sands Environmental Research Program. AOSERP Report 38. 111 p.

key words: small mammals, damage, control.

The effectiveness of chemical, physical and environmental methods of controlling small mammal damage to plants is reviewed.

Green, J.E. 1979. The ecology of five major species of small mammals in the AOSERP study are: a review. LGL Limited Report for Alberta Oil Sands Environmennal Research Program. AOSERP Report 72. 104 pp.

key words: snowshoe hare, Lepus americanus, food habits, habitat use, spatial behaviour, population dynamics.

Reviews the literature on habitat utilization by snowshoe hares, and on potential damage caused by this species.

Green, J.E. 1980. Small mammal populations of northeastern Alberta. II. Populations in reclamation areas. LGL Limited Report for the Alberta Oil Sands Environmental Research Program. AOSERP Report 108. 136 pp.

key words: rodents, damage, reclamation, control.

The results of a 18 month monitoring study of small mammal populations on a mine reclamation area are presented. Several methods of controlling reodent damage to tree also were discussed.

Green, J.E., W.R. Koski, M.S.W. Bradstreet, T.R. Eccles and J.A. Taylor. 1984. Wetland habitat classification and evaluation: criteria for assessment of fish and wildlife habitat in Alberta. LGL Limited Report for Alberta Agriculture Wetland Drainage Inventory, Planning Division, Alberta Environment, Edmonton, 163 pp.

key words: mammals, habitat assessment.

Provides reviews of key wetland-related wildlife species habitat requirements, including snowshoe hare, beaver, muskrat and moose.

Green, J.E. and K.S. Yonge. 1984. Wildlife end uses in reclamation: concepts and opportunities. Unpubl. MS. Presented at the RRTAC Workshop, Edmonton, 1 May 1984. 26 pp.

key word: wildlife, reclamation, integration, planning.

Discusses conceptual approaches to wildlife reclamation and briefly reviews some of the major types of techniques. Reasons for the restricted use of wildlife reclamation in past projects are discussed.

Hall, W.K. 1977. Status and management of the Rocky Mountain goat, Oreamnos americanus, in the province of Alberta. Pages 8-14, in: W. Samuel and W.G. MacGregor (eds.). Proceedings of the First International Mountain Goat Symposium, Kalispell, Montana.

key words: mountain goat, Oreamnos americanus, status and distribution.

Reviews distribution and management of mountain goats in Alberta.

Hammond, M.C. and G.E. Mann. 1956. Waterfowl nesting islands. J. Wildl. Manage. 20:345-352.

key words: waterfowl, nesting, islands, enhancement.

Information is presented on the use of artificial nesting islands by waterfowl. Waterfowl use is compared to the size, shape and structure of islands.

Hardy Associates. 1982. Development and reclamation plan. Gregg River Resources Limited. Five year mine plan. Prepared for Gregg River Resources by Hardy Associates Limited. 97 pp.

key words: reclamation, wildlife habitat, mitigation.

A reclamation plan for the Gregg River Mine is presented. Wildlife habitat considerations include community placement and plant species selection.

Harrington, D.G. 1979. Implementation of reclamation legislation in Alberta. Pages 257-269 in: Proc. Fourth Annual Meeting Can. Land Reclam. Ass., Regina, Sask.

key words: reclamation, legislation, precedures.

Discusses the legal process for applications and operation of a mine development plan.

Harrison, G. 1981. Rehabilitation plan: Whistlers Mountain, Jasper National Park. Natural History Research Division, Western Region, Parks Canada. 68 pp.

key words: alpine, revegetation, shrubs, seeding.

Discusses rehabilitation at Whistlers Mountain and problems caused by trampling by tourists.

Harrison, G. 1984. The establishment and maintenance of herbaceous cover on disturbance sites in the National Parks. Presented at the RRTAC Workshop, Edmonton. 1 May 1984. 10 pp.

key words: revegetation, herbs, grasses, mountain, alpine.

Discusses a number of past and ongoing reclamation and revegetation programs in Banff and Jasper National Parks.

Haynes, R.J. 1978. The surface mining control and reclamation act of 1977 and potential impacts on fish and wildlife. Proc. Ann. Conf. S.E. Assoc. Fish and Wildlife Agencies 32:790-796.

key words: reclamation, legislation.

The land surface reclamation act of 1977 is discussed and its implications to fish and wildlife resources are examined.

Haywood, J.L. and D.M. Shackleton. n.d. Moose habitat use and food habits in northwestern North America: an annotated bibliography. Prepared for Foothills Pipe Lines (Yukon) Ltd. 18 pp. (Section A), 187 pp. (Section B).

key words: moose, Alces alces, habitat use, food habits, spatial behaviour.

Synthesizes information from studies in northwestern North America on moose habitat utilization, food habits, movements and use of mineral licks (Section A), and provides annotations for 125 references (Section B).

Hebert, D. and I. McT. Cowan. 1971. Natural salt licks as a part of the ecology of the mountain goat. Can. J. Zool. 49:605-610.

key words: mountain goat, Oreamnos americanus, habitat use.

Discusses lick use by mountain goats in southeastern British Columbia.

Herricks, E.E. 1982. Development of aquatic habitat potential of gravel pits. Pages 196-207, in: W.D. Svedarsky and R.D. Crawford (eds.). Wildlife Values of Gravel Pits. Univ. Minn. Agric. Exp. Station, Misc. Publ. 17-1982.

key words: wildlife, fish, enhancement.

Methods of enhancing gravel pits for fish and wildlife habitat are reviewed. Several examples are presented.

Herzog, P.W. 1977a. Dispersion and mobility in a local population of spruce grouse (*Canachites canadensis franklinii*). M.Sc. Thesis, University of Alberta, Edmonton. 98 pp.

key words: spruce grouse, *Canachites canadensis*, spatial behaviour.

Provides results of radiotelemetry studies of movements and spacing of spruce grouse in southwestern Alberta.

Herzog, P.W. 1977b. Summer habitat use by white-tailed ptarmigan in southwestern Alberta. Can. Field-Nat. 91:367-371.

key words: white-tailed ptarmigan, *Lagopus leucurus*, habitat use.

Documents occurrence of white-tailed ptarmigan in relation to physical and floristic features of summer habitat, southwestern Alberta.

Herzog, P.W. 1978. Food selection by female spruce grouse during incubation. J. Wildl. Manage. 42:632-636.

key words: spruce grouse, *Canachites canadensis*, food habits.

Reports observations on food selection by incubating spruce grouse in southwestern Alberta, and on the relationship between food resources, location of feeding sites and territorial behaviour.

Herzog, P.W. 1980. Winter habitat use by white-tailed ptarmigan in southwestern Alberta. Can. Field-Nat. 94:159-162.

key words: white-tailed ptarmigan, *Lagopus leucurus*, habitat use, food habits, spatial behaviour.

Documents winter habitat use and movements of white-tailed ptarmigan in southwestern Alberta.

Herzog, P.W. and D.A. Boag. 1978. Dispersion and mobility in a local population of spruce grouse. J. Wildl. Manage. 42:853-865.

key words: spruce grouse, *Canachites canadensis*, spatial behaviour.

Provides results of radiotelemetry studies of movements and spacing of spruce grouse in southwestern Alberta.

Herzog, P.W. and D.M. Keppie. 1980. Migration in a local population of spruce grouse. Condor 82:366-372.

key words: spruce grouse, Canachites canadensis, spatial behaviour.

Reports data on migration of spruce grouse in southwestern Alberta and discusses factors influencing migratory vs. resident tendencies of individuals within the population.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press. Seattle and London. 730 pp.

key words: vascular plants, identification.

A key to the flora of the Pacific Northwest.

Holroyd, G.L. and K.J. VanTighem. 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume III: the wildlife inventory. Canadian Wildlife Service, Edmonton.

key words: mammals, birds, status and distribution, habitat use.

Discusses wildlife habitat use, status and management in relation to a broad land classification system, incorporating historic data and field survey data collected during 1974-81.

Hosie, R.C. 1979. Native Trees of Canada. Fitzhenry & Whiteside Ltd. Don Mills. 380 pp.

key words: trees, identification.

A key to the trees of Canada.

Hook, D.L. 1973. Production and habitat use by Canada geese at Freezeout Lake, Montana. M.S. Thesis, Montana State University. 53 pp.

key words: waterfowl, Canada geese, enhancement, habitat use.

Presents the results of a study of Canada goose productivity and habitat use. Information on spacing of nesting pairs is presented.

Hubbard, W.A. 1969. The grasses of British Columbia. B.C. Prov. Museum, Dept. Recreation and Conservation. Handbook No. 9. Victoria, B.C. 205 pp.

key words: grasses, identification.

A key to the grasses of British Columbia.

Hubbard, W.F. and M.A.M. Bell. 1977. Reclamation of lands disturbed by mining in mountainous and northern areas: A selected bibliography and review relevant to British Columbia and adjacent areas. Prepared for Ministry of Mines and Petroleum Resources, Victoria, B.C. 255 pp.

key words: reclamation, bibliography, mining, mountains, B.C.

A selection of abstracts from papers related to the problem of reclamation in the alpine and arctic regions.

Hudson, R.J. 1981. Agricultural potential of wapiti. Alberta Wildlife Production Research Committee Bulletin 3(4).

key words: elk, game ranching, agricultural potential.

Summarizes state of knowledge of elk biology and the agricultural potential of this species.

Hudson, R.J. and M.T. Nietfeld. 1985. Effect of forage depletion on the feeding rate of wapiti. J. Range Manage. 38:80-82.

key words: elk, forage, feeding rate, behaviour.

Evaluates forage intake and consumption rates of elk and average daily forage removal due to grazing and trampling.

Hudson, R.J., E.S. Telfer and R. Christian. 1981. Productivity of wild ruminants. Alberta Wildlife Production Research Committee Bulletin (June Wildlife Management Seminar).

key words: population dynamics, forage utilization, carrying capacity, game ranching.

Discusses potential of wild ruminants for game ranching.

IEC Beak Consultants Ltd. 1984a. Species/habitat relationship model for beaver. Draft Report for Alberta Fish and Wildlife Division, Edmonton.

key words: beaver, Castor canadensis, habitat assessment.

Provides a quantitative model for assessing suitability of land units as beaver habitat in Alberta.

IEC Beak Consultants Ltd. 1984b. Species/habitat relationship model for elk. Draft Report for Alberta Fish and Wildlife Division, Edmonton.

key words: elk, Cervus elaphus, habitat assessment.

Provides a quantitative model for assessing suitability of land units as elk habitat in Alberta.

IEC Beak Consultants Ltd. 1984c. Species/habitat relationship model for moose. Draft Report for Alberta Fish and Wildlife Division, Edmonton.

key words: moose, Alces alces, habitat assessment.

Provides a quantitative model for assessing suitability of land units as moose habitat in Alberta.

IEC Beak Consultants Ltd. 1984d. Species/habitat relationship model for woodland/mountain caribou. Draft Report for Alberta Fish and Wildlife Division, Edmonton.

key words: caribou, Rangifer tarandus, habitat assessment.

Provides a quantitative model for assessing suitability of land units as caribou habitat in Alberta.

IEC Beak Consultants Ltd. 1984e. Species/habitat relationship model for mountain goat. Draft Report for Alberta Fish and Wildlife Division, Edmonton.

key words: mountain goat, Oreamnos americanus, habitat assessment.

Provides a quantitative model for assessing suitability of land units as mountain goat habitat in Alberta.

IEC Beak Consultants Ltd. 1984f. Species/habitat relationship model for bighorn sheep. Draft Report for Alberta Fish and Wildlife Division, Edmonton.

key words: bighorn sheep, Ovis canadensis, habitat assessment.

Provides a quantitative model for assessing suitability of land units as bighorn sheep habitat in Alberta.

Institute for Land Rehabilitation. 1978. Rehabilitation of western wildlife habitat: a review. Prepared for Western Energy and Land Use Team, USDI, by Inst. of Land Rehabilitation. FWS/OBS 78/86. 237 pp.

key words: wildlife habitat, reclamation, enhancement, legislation.

A comprehensive review of techniques for enhancing or reclaiming wildlife habitat is provided for the Western United States. Wildlife habitat requirements, revegetation techniques, contouring and legislation are examined.

Islam, M.R. and S.K. Takyi. 1984. Cadomin reclamation project: 3, 4 and 5 year results. ENR Tech. Report No. T/56. Alberta Forest Service, Edmonton. 50 pp.

key words: fertilization, plant cover, reclamation, coal mine.

Summarizes results of reclamation experiments on an abandoned subalpine mine spoil.

Johnson, J.D. 1975. An evaluation of the summer range of bighorn sheep (*Ovis canadensis canadensis*) on Ram Mountain, Alberta. M.Sc. Thesis, University of Calgary. 135 pp.

key words: bighorn sheep, *Ovis canadensis*, habitat use.

Discusses results of studies on summer range of bighorn sheep in west-central Alberta.

Johnson, R.L. 1977. Distribution, abundance and management status of mountain goats in North America. Pages 1-7, *in*: W. Samuel and W.G. MacGregor (eds.). Proceedings of the First International Mountain Goat Symposium, Kalispell, Montana.

key words: mountain goat, *Oreamnos americanus*, status and distribution.

Reviews current status of the mountain goat throughout North America, based on questionnaires sent to management agencies.

Johnson, T.K. 1982. Impact of surface coal mining on elk calving: a progress report. Pages 133-137, *in*: Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecol. Inst. Tech. Publ. 14.

key words: elk, calving, coal mines, disturbance.

Elk calving behaviour was monitored in connection with habitat disturbance associated with a surface land mine on a traditional calving area. Preliminary results suggest a high degree of fidelity to the calving areas and continued use despite disturbance.

Johnston, A., L.M. Bezeau and S. Smoliak. 1968. Chemical composition and in vitro digestibility of alpine tundra plants. J. Wildl. Manage. 32:773-777.

key words: alpine tundra, digestibility, chemical composition, bighorn sheep, forbs, shrubs.

Forage species were analyzed for crude protein, calcium, phosphorus, ash, silica and cellulose, and in vitro digestibility studies were conducted.

Jokela, J.J. and R.W. Lorenz. 1959. Mouse injury to forest planting in the prairie region of Illinois. J. Forest. 57:21-25.

key words: rodents, damage, reforestation.

The amounts of damage to a tree plantation in Illinois and factors contributing to this damage are discussed.

Kadlec, R.H. 1981. How natural wetlands treat wastewater. Pages 241-254 in: B. Richardson (ed.). Wetland values and management. Minnesota Water Planning Board, St. Paul.

key words: wetlands, water treatment.

Examines the ability of wetlands to treat wastewater and sewage effluent. Mechanisms involved in water treatment and methods to improve these mechanisms are discussed.

Kalmbach, E.R., W.L. McAtee, F.R. Courtsal, and R.E. Ivers. 1969. Homes for birds. U.S. Fish and Wildlife Service. Conserv. Bull. 14. n.p. Cited in Proctor et al. 1983.

Kaye, R.G. and J.M. Roulet. n.d. The distribution and status of caribou. A background paper for the four mountain parks planning program. Parks Canada, Calgary. 18 pp.

key words: caribou, Rangifer tarandus, status and distribution, habitat use.

Summarizes past and present distribution and status of caribou in Jasper and Banff National Parks, and discusses factors affecting the current size, distribution and habitat use of caribou populations in the Jasper area and contiguous provincial lands.

Keith, L.B. 1963. Wildlife's ten year cycle. University of Wisconsin Press, Madison. 201 pp.

key words: snowshoe hare, Lepus americanus, population dynamics.

Analyses the available data on population cycles in snowshoe hares.

Keith, L.B. 1966. Habitat vacancy during a snowshoe hare decline. J. Wildl. Manage. 30:828-832.

key words: snowshoe hare, Lepus americanus, habitat use spatial behaviour.

Discusses changes in numbers and distribution of snowshoe hares near Rochester, Alberta, during a cyclic decline.

Keith, L.B., J.R. Cary, O.J. Rongstad and M.C. Brittingham. 1984. Demography and ecology of a declining snowshoe hare population. Wildlife Monographs, No. 90. 43 pp.

key words: snowshoe hare, Lepus americanus, food habits, population dynamics.

Presents results of studies near Rochester, Alberta, on effects of malnutrition, predation and low temperatures on overwinter survival of snowshoe hares.

Keith, L.B. and L.A. Windberg. 1978. A demographic analysis of the snowshoe hare cycle. Wildlife Monographs, No. 58. 70 pp.

key words: snowshoe hare, Lepus americanus, habitat use, population dynamics.

Outlines demographic changes in snowshoe hare populations during 15 years of study near Rochester, Alberta.

Kelsall, J.P. and E.S. Telfer. 1974. Biogeography of moose with particular reference to western North America. Naturaliste can. 101:117-130.

key words: moose, Alces alces, status and distribution, food habits, habitat use.

Discusses distribution of moose in relation to browse availability, climate, habitat alteration and other factors.

Keown, M.P., N.R. Oswalt, E.B. Perry and E.A. Dardeau Jr. n.d. "Literature Survey and Preliminary Evaluation of Streambank Protection Methods", U.S. Army Engineer

Waterways Experiment Station, Hydraulics Laboratory, Mobility and Environmental Systems Laboratory, Soils and Pavements Laboratory, Technical Report H-77-9, May 1977. Cited in Nelson et al. 1978.

Keppie, D.M. 1975. Dispersal, overwinter mortality, and population size of spruce grouse (Canachites canadensis franklinii). Ph.D. Thesis, University of Alberta, Edmonton. 113 pp.

key words: spruce grouse, Canachites canadensis, population dynamics.

Provides results of studies on population regulation of spruce grouse in southwestern Alberta.

Keppie, D.M. 1977. Snow cover and the use of trees by spruce grouse in autumn. Condor 79:382-384.

key words: spruce grouse, Canachites canadensis, habitat use.

Presents data from southwestern Alberta on frequency of sighting spruce grouse in trees vs. on the ground during fall, and analyses these data in relation to snowfall and extent of snow cover.

Keppie, D.M. 1979. Dispersal, overwinter mortality and recruitment of spruce grouse. J. Wildl. Manage. 43:717-727.

key words: spruce grouse, Canachites canadensis, population dynamics.

Provides results of studies on population regulation of spruce grouse in southwestern Alberta.

Keppie, D.M. and P.W. Herzog. 1978. Nest site characteristics and nest success of spruce grouse. J. Wildl. Manage. 42:628-632.

key words: spruce grouse, Canachites canadensis, habitat use.

Provides data on characteristics of nesting sites used in southwestern Alberta, and discusses factors influencing nest success.

Kerr, G.R. 1965. The ecology of mountain goats in west central Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 96 pp.

key words: mountain goat, Oreamnos americanus, food habits, habitat use.

Reports on studies of food habits and habitat use by mountain goats in the Grande Cache area.

Kilcher, M.R. and J. Looman. 1983. Comparative performance of some native and introduced grasses in southern Saskatchewan, Canada. J. Range Manage. 36:654-657.

key words: grasses, establishment, nutrition, forage.

Compares native and introduced grass species with respect to nutrient content and forage yield.

Kinsey, C. 1976. Tests of two electric deer barrier fences. Minn. Wildl. Res. Quart. 36:122-138.

key words: deer, damage control, fencing.

Use of single conductor and wire/flag conductor fences to restrict deer movements were assessed.

Klein, D.R. and R.G. White. 1978. Grazing ecology of caribou and reindeer in tundra systems. Pages 469-472, in: Proceedings of the First International Rangeland Congress. Denver, Colorado. Society of Range Management.

key words: caribou, reindeer, tundra, grazing, forage selection, Alaska.

Includes a summary of research accomplishments by Alaska Cooperative Wildlife Research Unit and the Institute of Arctic Biology on caribou and reindeer with respect to range ecology productivity and socio-economic parameters.

Kuhn, J.A. and B. Martens. 1980. Coal mine development and elk biology: environmental impact assessment in Alberta and British Columbia. Pages 273-282, in: M.S. Boyce and L.D. Hayden-Wing (eds.). North American Elk: Ecology, Behavior and Management. The University of Wyoming (revised edition). 294 pp.

key words: elk, Cervus elaphus, habitat assessment.

Discusses factors involved in determining impact of coal mine development on elk populations in the Rockies.

Lance, W.R. 1980. The implications of contagious ecthyma in bighorn sheep. Pages 262-268, in: Proc. Biennial Symposium Northern Wild Sheep and Goat Council, Salmon, Idaho.

key words: bighorn sheep, Ovis canadensis, disease.

Reviews occurrence of contagious ecthyma in North America and discusses consequences for individual animals and herd mortality patterns.

Lawrence, T. 1977. Altai wild ryegrass. Canada Department of Agriculture Publ. 1602. 17 pp.

key words: wild ryegrass, pasture, grasses.

Properties of Altai wild ryegrass are compared with Russian wild ryegrass, crested wheatgrass and intermediate wheatgrass, and performance of cattle fed Altai wild ryegrass is evaluated.

Leege, T.A. 1976. Relationship of logging to the decline of the Pete King elk herd. Pages 6-10 in: Proc. Elk-Logging Roads Symposium, Univ. of Idaho, Moscow.

key words: elk, logging, hunting, access.

Moose numbers in areas made accessible by logging roads declined as a result of overharvesting and avoidance of the area by remaining animals.

Leege, T.A. 1984. Guidelines for evaluating and managing summer elk habitat in northern Idaho. Wildlife Bulletin No. 11, Idaho Dept. of Fish and Game. 38 pp.

key words: elk, Cervus elaphus, habitat assessment.

Outlines a tabular method of evaluating elk habitat quality in northern Idaho.

Leeson, B.F. 1984. Mitigating major projects in National Parks. Pages 137-140 in: P. Thompson, D. Thompson and S. Stephansson (eds.). Symposium on Environmental Mitigation: Solutions to Problems. The Alberta Society of Professional Biologists, Edmonton.

key words: wildlife, fisheries, mitigation, highways, human disturbances.

Discusses a number of problems relating to highway construction and tourist use in Banff National Park. Reclamation of sheep wintering range, stream re-creation and slope stabilization are discussed.

Lesko, G.L., H.M. Etter and T.M. Dillon. 1975. Species selection, seedling establishment and early growth on coal mine spoils at Luscar, Alberta. Information Rep. NOR-X-117. Northern Forest Research Centre, Edmonton. 37 pp.

key words: coal mine spoil, revegetation, hydroseeding, establishment.

Thirty species, including grasses, forbs, shrubs and trees, were hydroseeded on two coal mine spoil areas and germination and establishment were studied.

LGL Limited. 1985. Slave River Hydro Mammal Studies. Interim Report II. Prep. for Alberta Power Ltd., TransAlta Utilities Corporation and Alberta Utilities and Telecommunications. 15 pp + appendices.

key words: mammals, habitat, population, assessment.

Habitat models for 13 species of mammals are presented. Critical habitat features, specific to the boreal forest biome, are considered for each species.

Lidicker, W.Z. Jr. 1985. The role of dispersal in the demography of small mammals. Pages 103-128 in F.B. Golley, K. Petrusewicz and L. Ryszkowski (eds.). Small mammlas: their productivity and population dynamics. Cambridge Univ. Press, New York.

key words: small mammals, dispersal, population regulation.

The effects of dispersal on small rodent demography are examined. The influence of age and sex of animals on dispersal also are discussed.

Lynch, G.M. 1973. Influence of hunting on an Alberta moose herd. N. Amer. Moose Conf. and Workshop. 9:123-135.

key words: moose, hunting, access.

Increased access to remote areas was considered to be a major cause of increased moose harvests and eventual overharvesting.

Lynch, G.M. 1976. Some long range movements of radio tagged moose in Alberta. North American Moose Conference and Workshop 12:220-235.

key words: moose, Alces alces, spatial behaviour.

Reports studies of radio-collared moose in the Swan Hills.

Lyon, J.L. 1980. Management implications of elk and deer use of clear-cuts in Montana. J. Wildl. Manage. 44:352-362.

key words: elk, white-tailed deer, mule deer, clear cuts, roadways, vegetation cover.

Elk and deer pellet groups were counted in and adjacent to clear-cuts of various sizes and ages in Montana. Pellet distributions suggested that animals enter clear-cuts in search of better forage but that use was influenced by a need for security (e.g., cover, ease of movements).

MacArthur, R.A., V. Geist and R.H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. J. Wildl. Manage. 46:351-358.

key words: bighorn sheep, Ovis canadensis, habitat use.

Presents data on telemetered heart rates and behavioural responses of bighorn sheep reacting to human disturbance in the Sheep River area, southwestern Alberta.

MacArthur, R.A., R.H. Johnston and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. Can. J. Zool. 57:2010-2021.

key words: bighorn sheep, Ovis canadensis, habitat use.

Presents results of studies on telemetered heart rates and behaviour of bighorn sheep in relation to habitat use and disturbance factors in the Sheep River area, southwestern Alberta.

MacDonald, S.D. 1968. The courtship and territorial behaviour of Franklin's race of the spruce grouse. Living Bird 7:4-25.

key words: spruce grouse, Canachites canadensis, spatial behaviour.

Reports results of a study of courtship displays of male and female grouse in southwestern Alberta.

Marshall, I.B. 1983. Mining, land use, and the environment. II. A review of mine reclamation activities in Canada. Lands Directorate, Environment Canada, Ottawa. 288 pp.

key words: reclamation, legislation.

This is a comprehensive preview of mining in Canada with specific reference to areas of land disturbance and the existing regulatory controls for reclamation in Canada.

Maser, C., J.E. Rodiek and J.W. Thomas. 1979a. Cliff, talus and caves. Pages 96-103, in: J.W. Thomas (ed.). Wildlife Habitat in Managed Forests. The Blue Mountains of Washington and Oregon. USDA Forest Service Agric. Handbook No. 553.

key words: cliffs, talus, wildlife.

The value of cliffs, talus and caves to wildlife is reviewed. Information is presented on the general ecology of wildlife that utilize these natural features.

Maser, C., R.G. Anderson, K. Cormack, J.T. Williams and R.E. Martin. 1979b. Dead and down woody material. Pages 78-95, in: J.W. Thomas (ed.). Wildlife Habitat in Managed Forests. The Blue Mountains of Washington and Oregon. USDA Forest Service Agric. Handbook No. 553.

key words: snags, wildlife, enhancement.

The value of snags, deadfall and downfall to wildlife is examined. Information is presented in the general ecology of wildlife that utilize this material.

Maser, C., J.W. Thomas, I.D. Luman and R. Anderson. 1979. Wildlife habitats in managed rangelands - the Great Basin of southeastern Oregon. Man-made habitats. USDA Forest Service Gen. Tech. Rep. PNW-86. Pac. N.W. Forest Range Exp. Station. 40 pp.

key words: wildlife habitat, habitat construction, habitat enhancement.

This report describes the use of man-made structures by wildlife. Most of the methods described involve modification or maintenance of old abandoned structures such as homesteads, rock piles, fences, and bridges. Some of the methods involve construction of new habitat.

Matulich, S.C., J.E. Hanson, I. Lines and A. Farmer. 1982. HEP as a planning tool: an application to waterfowl enhancement. N. Amer. Wildl. Nat. Res. Conf. 47:111-127.

key words: habitat evaluation, HEP, reclamation.

An example of how the HEP program can be utilized to assess impacts to wildlife and to plan wildlife enhancement programs is presented.

McCourt, K.H. 1969. Dispersion and dispersal of female and juvenile Franklin's grouse in southwestern Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 137 pp.

key words: spruce grouse, _Canachites canadensis_, spatial behaviour, habitat use.

Presents data on dispersion, dispersal and habitat use of spruce grouse in southwestern Alberta.

McCourt, K.H., D.A. Boag and D.M. Keppie. 1973. Female spruce grouse activities during laying and incubation. Auk 90:619-623.

key words: spruce grouse, _Canachites canadensis_, habitat use, food habits.

Reports on activity patterns of nesting female spruce grouse in southwestern Alberta, including observations on feeding behaviour.

McCrory, W.P. 1969. Final report on study of natural licks used by mountain goats and bighorn sheep in Jasper National Park. Canadian Wildlife Service, Edmonton, 93 pp.

key words: mountain goat, _Oreamnos americanus_, bighorn sheep, _Ovis canadensis_, habitat use.

Discusses seasonal use and sex and age composition of goats and sheep using natural mineral licks in Jasper National Park.

McCrory, W.P., D.A. Blood, D. Portman and D. Harwood. 1977. Mountain goat surveys in Yoho National Park, British Columbia. Pages 69-73, _in_: W. Samuel and W.G. MacGregor (eds.). Proceedings of the First International Mountain Goat Symposium, Kalispell, Montana.

key words: mountain goat, _Oreamnos americanus_, habitat use.

Discusses habitat use by mountain goats in eastern British Columbia.

McFetridge, R.J. 1977a. Strategy of resource use by mountain goats in Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 148 pp.

key words: mountain goat, _Oreamnos americanus_, food habits, nutrition, habitat use, population dynamics.

Presents results of studies on habitat use, food habits and population structure of mountain goats in the Grande Cache area, and discusses possible influences of resource development on goat populations and habitat.

McFetridge, R.J. 1977b. Strategy of resource use by mountain goat nursery groups. Pages 169-173, in: W. Samuel and W.G. MacGregor (eds.). Proceedings of the First International Mountain Goat Symposium, Kalispell, Montana.

key words: mountain goat, Oreamnos americanus, habitat use.

Discusses habitat selection by female and immature mountain goats in the Grande Cache area.

McIlroy, C.W. 1972. Effects of hunting on black bears in Prince William Sound. J. Wildl. Manage. 36:828-837.

key words: black bears, hunting, population repsonses.

Following the opening of a previously inaccessible area of Alaska for hunting, the black bear population was sharply reduced.

McLachlin, R.A. 1970. The spring and summer dispersion of male Franklin's grouse in lodgepole pine forest in southwestern Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 153 pp.

key words: spruce grouse, Canachites canadensis, spatial behaviour, habitat use.

Presents data on dispersion and habitat use of spruce grouse in southwestern Alberta.

McLaughlin, R.T. 1979. Chapter 8. Mammals. Prep. by Beak Consultants for Environmental Protection Service. Pages 104-138 in: Summary of impacts of linear facilities on northern ecosystems. A Literature Review.

key words: mammals, disturbances, piplines, roads.

The potential responses of linear facilities such as roadways, railways, transmission lines and railroads and the potential effects on mammal populations are discussed.

McLean, A. and J.H.G. Smith. 1973. Effects of climate on forage yields and tree ring widths in British Columbia. J. Range Management. 26(6):516-519.

key words: trees, forest, rangelands, tree rings, climate, B.C.

A comparison of forest rangeland production as related to climate and tree growth.

McLeod River Coal Limited. 1982. McLeod River project. Volume II. Environmental impact assessment. ManAlta Coal Limited, Calgary. 336 pp.

key words: reclamation, wildlife, revegetation.

The report is the environmental impact assessment and preliminary reclamation plan for the McLeod River Coal Mine. Baseline conditions, potential impacts and proposed revegetation plans are presented.

Medin, D.E. and R.B. Ferguson. 1971. Shrub establishment on game ranges in the northwestern United States. Pages 359-368, in: Wildland Shrubs - Their Biology and Utilization. An International Symposium. Utah State University, Logan, Utah.

key words: shrubs, game ranching, habitat enhancement, ungulates.

Outlines principles and procedures for improving big game ranges by seeding and planting shrubs.

Mill, T.A. and P. Anderson. 1980. Inventory of non-game mammals in Kananaskis Country. Kananaskis Country Planning Document #3. Alberta Fish and Wildlife Division, Edmonton. 71 pp.

key words: mammals, status and distribution.

Reviews the current status of small mammals and furbearers known to occur in the Kananaskis area.

Millar, J.B. 1953. An ecological study of the moose in the Rock Lake area of Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 123 pp.

key words: moose, Alces alces, food habits, habitat use, spatial behaviour.

Reports studies on the ecology of moose east of Jasper National Park.

Millson, R. and J. Bondy. 1984. Revegetation planning to meet forestry and wildlife reclamation. Unpubl. MS. Presented at the RRTAC Workshop, Edmonton, 1 May 1984. 14 pp.

key words: wildlife, reclamation.

The needs and potential approaches to wildlife habitat reclamation and forestry are discussed. Potential for integration of these uses are examined.

Mitchell, W.W. 1970. Revegetation problems and progress. Agroborealis 2: 18-19,22. Cited in Sims et al. 1984.

Mitchell, W.W. 1973. Adaptation of species and varieties of grasses for potential use in Alaska. Pages 2-6, in: Proceedings of the Symposium on the Impact of Oil Resource Development on Northern Plant Communities. Fairbanks, Alaska. University of Alaska, Institute of Arctic Biology, Fairbanks, Alaska. Cited in Sims et al. 1984.

key words: grasses, reclamation, Alaska.

Adaptation of species for use in Alaska reclamation.

Monenco Consultants Limited. 1983. Soil reconstruction design for the reclamation of oilsands tailings. RRTAC Rep. 83-1. 196 pp.

key words: soil, oil sands, reclamation, forest ecosystems, tailings.

A study of the oilsands in northeastern Alberta and the strategies for soil reconstruction and revegetation.

Monsen, S.B. 1983. Plants for revegetation of riparian sites within the intermountain range. Pages 83-94, in: Managing Intermountain Rangelands - Improvement of Range and Wildlife Habitats. USDA Forest Service Gen. Tech. Rep. INT-57. Intermountain Forest Range Exp. Station, Ogden, Utah.

key words: revegetation, riparian.

Revegetation of riparian zones is frequently difficult because many sites have been seriously altered, and reconstruction of the entire plant community may be required. Techniques and species are recommended to minimize streambank erosion.

Moore, R.T., S.L. Ellis and D.R. Duba. 1977. Advantages of natural successional processes on western reclaimed lands. Pages 274-282, in: Proceeding of Fifth Symposium on Surface Mining and Reclamation. Louisville, Kentucky. National Coal Assoc. Washington, D.C. Cited in Sims et al. 1984.

key words: reclamation, mining, natural succession.

Natural succession and how it benefits reclamation.

Morgantini, L.E. 1979. Habitat selection and resource division among bighorn sheep, elk and mule deer in western

Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 187 pp.

key words: bighorn sheep, Ovis canadensis, elk, Cervus elaphus, habitat use.

Discusses habitat selection by bighorn sheep and elk in the upper Red Deer River area.

Morgantini, L.E. 1984. Elk in the Canadian Rocky Mountains. The Panther-Red Deer-Clearwater region in Banff National Park. Report for Banff National Park Warden Service. 64 pp.

key words: elk, Cervus elaphus, status and distribution, habitat use, spatial behaviour.

Documents distribution, movements and habitat use by elk in the eastern boundary area of Banff National Park.

Morgantini, L.E. and R.J. Hudson. 1980. Human disturbance and habitat selection in elk. Pages 132-139, in: M.S. Boyce and L.D. Hayden-Wing (eds.). North American Elk: Ecology, Behavior and Management. The University of Wyoming (revised edition). 294 pp.

key words: elk, Cervus elaphus, habitat use, spatial behaviour.

Discusses effects of vehicular activity and hunting on habitat selection by elk on the Ya Ha Tinda Ranch, upper Red Deer River.

Morgantini, L.E. and R.J. Hudson. 1981. Sex differential in the use of the physical environment by bighorn sheep (Ovis canadensis). Can. Field-Nat. 95:69-74.

key words: bighorn sheep, Ovis canadensis, habitat use, spatial behaviour.

Discusses habitat selection by bighorn sheep in the upper Red Deer River area.

Morgantini, L.E. and R.J. Hudson. 1983. Nutritional significance of altitudinal migrations for wapiti. Pages 109-112, in: 62nd Annual Feeder's Day Report. Agriculture and Forestry Bulletin (Special Issue). University of Alberta, Edmonton.

key words: elk, Cervus elaphus, food habits, nutrition, habitat use, spatial behaviour.

Discusses movements and related food habits of elk wintering in the foothills and summering in Banff National Park.

Morgantini, L.E. and R.J. Hudson. 1985. Changes in diets of wapiti during a hunting season. J. Range Manage. (in press).

key words: elk, *Cervus elaphus*, food habits, nutrition.

Documents changes in species composition and nutrient content of diets of elk displaced by hunting along the upper Red Deer River.

Morgantini, L.E. and C.D. Olsen. 1983. Pipeline construction and wild ungulates. Results of a two year monitoring program along the Edson Mainline Loop. Wildland Resources Consultants Limited Report for NOVA, An Alberta Corporation.

key words: elk, *Cervus elaphus*, food habits, habitat use, spatial behaviour.

Presents results of studies on elk food habits, habitat use, distribution and movements along a pipeline corridor in the Brazeau River area.

Morgantini, L.E. and W.B. Russell. 1983. An assessment of three selected elk winter ranges in the Rocky Mountains region. Wildland Resources Consultants Limited Report for Alberta Fish and Wildlife Division. 265 pp.

key words: elk, *Cervus elaphus*, food habits, habitat use, habitat assessment.

Reports detailed studies of floristic composition, productivity, condition and use by elk of winter ranges along the upper Red Deer, Clearwater and Blackstone Rivers.

Moss, E.H. 1983. Flora of Alberta. Second Edition University of Toronto Press, Toronto. 687 pp.

key words: vascular plants, identification.

A identification manual for the vascular flora of Alberta.

Mussell, D.J. 1982. Utilization of the Kootenay Plains of western Alberta by ungulates. Report for Alberta Public Lands Division, Edmonton. 44 pp.

key words: mammals, habitat use.

Describes use of the Kootenay Plains by elk, moose and bighorn sheep, based on pellet group counts.

Nelson, R.W., G.C. Horak and J.E. Olson. 1978. Western reservoir and stream habitat improvements handbook. USDI Western Energy and Land Use Team. FWS/OBS-78/56.

key words: fish, wildlife, reservoirs, enhancement, reclamation.

This is a comprehensive review of methods to enhance and create fisheries and wildlife habitat in conjunction with hydro electric projects. Techniques are presented for use in watercourses and waterbodies.

Nielsen, P.L. 1973. The mammals of Waterton Lakes National Park, Alberta. Canadian Wildlife Service, Edmonton. 176 pp.

key words: mammals, status and distribution, habitat use.

Summarizes available information on the status, habitat use and general ecology of all mammals known to occur in Waterton Lakes National Park.

Nietfeld, M., J. Wilk, K. Woolnough and B. Hoskin. 1984. Wildlife habitat requirement summaries for selected wildlife species in Alberta. Alberta Fish and Wildlife Division, Edmonton.

key words: mammals, habitat use, spatial behaviour.

Summarizes key habitat requirements of beaver, elk, moose, caribou, mountain goat and bighorn sheep (and other selected mammals and birds) based on a review of selected literature.

Norecol. 1984. Use of native plant species in reclamation of wildlife habitat at the Fording River operations. Phase I: Review of food habits. Prepared for Cominco Limited by Norecol Environmental Consultants Limited.

key words: wildlife, food habitats, reclamation.

A review of the known important plant foods for moose, bighorn sheep, mountain goat, woodland caribou and deer is presented. Recommendations concerning revegetation for wildlife also are made.

Odum, E. 1971. Fundamentals of ecology. Third Edition. W.B. Saunders Co., Philladelphia, PA. 574 pp.

key words: ecology.

A text presenting the fundamental principles of ecology.

Olson, R.A. 1981. Wetland vegetation, environmental factors, and their interaction in strip mine ponds, stock dams and natural wetlands. USDA Forest Service Gen. Tech. Rep. RM-85. Rocky Mountain Forest Range Exp. Stn., Fort Collins, Colorado. 19 pp.

key words: wetlands, wetland wildlife, wetland vegetation, strip mine ponds.

Chemical and physical characteristics of strip mine ponds and stock dams were assessed in the western Great Plains area. Effects of these factors on wetland vegetation and wildlife are discussed.

Patton, D.R. 1978. RUN WILD: a storage and retrieval system for wildlife habitat in USDA For. Serv. Gen. Tech. Rep. RM-51. Rocky Mt. For. and Range Exp. Collins, Colo. 8 pp.

key words: habitat assessment, habitat descriptions, wildlife communities.

Pease, J.L., R.H. Vowles and L.B. Keith. 1979. Interaction of snowshoe hares and woody vegetation. J. Wildl. Manage. 43:43-60.

key words: snowshoe hare, Lepus americanus, food habits, nutrition.

Reports results of field observations and feeding trials on browse utilization by snowshoe hares in the Rochester area, Alberta.

Peek, J.M. 1974. A review of moose food habits studies in North America. Naturaliste can. 101:195-215.

key words: moose, Alces alces, food habits.

Reviews and discusses available data on moose food habits.

Pendergast, B. and J. Bindernagel. 1977. The impact of exploration for coal on mountain goats in northeastern British Columbia. Pages 64-68, in: W. Samuel and W.G. MacGregor (eds.). Proceedings of the First International Mountain Goat Symposium, Kalispell, Montana.

key words: mountain goat, Oreamnos americanus, status and distribution.

Discusses factors relating to declines in mountain goat populations following coal mining and related activities in eastern British Columbia.

Pendergast, B.A. and D.A. Boag. 1970. Seasonal changes in diet of spruce grouse in central Alberta. J. Wildl. Manage. 34:605-611.

key words: spruce grouse, Canachites canadensis, food habits.

Provides details of seasonal diets of adult and juvenile spruce grouse from the Swan Hills, based on analysis of crop contents.

Pendergast, B.A. and D.A. Boag. 1971. Nutritional aspects of the diet of spruce grouse in central Alberta. Condor 73:437-443.

key words: spruce grouse, Canachites canadensis, nutrition.

Provides data on digestibility and gross energy, lignin, crude fibre, protein and mineral contents of major foods of spruce grouse in the Swan Hills.

Peterson, E.B. and H.M. Etter. 1970. A background for disturbed land reclamation and research in the Rocky Mountain region of Alberta. Information Rep. A-X-34. Northern Forest Research Centre, Edmonton. 45 pp.

key words: reclamation, coal mines, mountains.

Reviews information and research on reclamation of surface coal mines in the Rocky Mountains.

Peterson, E.B. and N.M. Peterson. 1977. Environmental studies no. 3: revegetation information applicable to mining sites in northern Canada. Supply and Services Canada Cat. No. R71-19/13-1977. 405 pp

key words: bibliography, revegetation, mine sites.

Annotated bibliography providing information on revegetation of mine sites in northern Canada.

PFRA. n.d. Planting trees for wildlife habitat. Prairie Farm Rehabilitation Administration, Indian Head, Saskatchewan. 12 pp.

key words: wildlife, trees, shrubs, hedgerows.

Methods of improving agricultural shrublands and hedgerows for wildlife are discussed. Suitable tree and shrub species that are available for use are recommended.

Podoll, E.B. 1979. Utilization of windbreaks by wildlife. Pages 121-127 in: Windbreak management. Great Plains Agricultural Council Publication No. 92. 132 pp.

key words: wildlife, hedgerows, revegetation.

Wildlife use of windbreaks is reviewed. Methods of improving windbreaks for wildlife by species selection and planting patterns are discussed.

Porsild, A.E. 1974. Rocky Mountain wild flowers. National Museum of Natural Sciences and Parks Canada. 454 pp.

key words: wild flowers, species list.

Describes wild flowers found in the Rocky Mountains, including grasses, sedges, forbs and shrubs.

Poston, H.J. and R.K. Schmidt. 1981. Wildlife habitat. A handbook for Canada's prairies and parklands. Canadian Wildlife Service, Edmonton. 51 pp.

key words: wildlife, enhancement, revegetation, wetlands.

This manual provides a number of guidelines and recommendations for private landowners to enhance their land for wildlife. Topics considered include shoreline stabilization, hedgerows, shrubland, wetlands and special structures.

Preble, E.A. 1908. A biological investigation of the Athabasca-Mackenzie region. U.S. Biological Survey, North American Fauna No. 27. 574 pp.

key words: mammals, birds, status and distribution.

Provides a detailed annotated list of birds and mammals observed along the Athabasca River.

Proctor, B.R., R.W. Thompson, J.E. Bunin, K.W. Fucik, G.R. Tamm and E.G. Wolf. 1983. Practices for protecting and enhancing fish and wildlife on coal surface-mined land in the Powder River-Fort Union Region. Prepared for USDI Fish and Wildlife Service by Science Applications Inc. FWS/OBS-83/10. 246 pp.

key words: small mammals, ungulates, raptors, waterfowl, habitat reclamation, habitat enhancement.

This handbook contains information on the best current practices to protect and enhance wildlife resources on surface-mined land in the northern Great Plains of the

United States. Current legislation applicable to this geographic area is described. Information presented includes details on implementation, maintenance and management for a variety of techniques as well as risks and limitations, approximate costs and manpower requirements.

Quarin, D. 1982. Reclamation practices at Coleman Collieries Ltd. Proceedings Alberta Reclamation Conference, Edmonton. CLRA/AC 82-1. 75 pp.

key words: reclamation, coal mine, hydroseeding, hand-seeding.

Describes reclamation techniques used at the Coleman Collieries mine site.

Radvanyi, A. 1978. The return of the rodents--year three in the assessment of harmful small mammals in the Alberta oil sands reclamation and afforestation program. Final Report. Fisheries and Environment Canada, Can. Wildl. Serv. 82 pp.

key words: rodents, damage, control, reforestation.

Results of a three year monitoring study of small rodents populations in a mine reclamation area are presented. Use of poison bait feeders in controlling damage to trees also is reviewed.

Redmond, G.W., D.M. Keppie and P.W. Herzog. 1982. Vegetative structure, concealment, and success at nests of two races of spruce grouse. Can. J. Zool. 60:670-675.

key words: spruce grouse, Canachites canadensis, habitat use.

Compares features of nesting locations and nest success in southwestern Alberta and New Brunswick.

Reynolds, H.G. 1962. Use of natural openings in a pondersosa pine forest of Arizona by deer, elk and cattle. USDA Forest Service, Rocky Mountain For. and Range Exp. Station. Res. Note 78. 4 pp.

key words: elk, deer, cattle, habitat use.

A study of the response of elk, deer and cattle to natural openings in forest communities. Information on the relationship between clearing size and amount of use in provided.

Reynolds, H.G. 1966. Use of openings in a spruce-fir forest of Arizona by elk, deer and cattle. USDA Forest Service, Rocky Mountain For. and Range Exp. Station. Res. Note RM-66. 4 pp.

key words: elk, deer, cattle, habitat use.

A study of the responses and habitat use of deer, elk and cattle in spruce-fir forests of Arizona. Data is provided on the relationships between the opening sizes and amounts of use.

Rhodes, M.J., T.J. Cloud and D. Haag. 1983. Habitat evaluation procedures for planning surface mine reclamation in Texas. Wildl. Soc. Bull. 11:222-232.

key words: habitat evaluation, reclamation.

Habitat evaluation procedures (HEP) of the U.S. Fish and Wildlife Service were used to evaluate the relative impact and wildlife habitat development potential of several reclamation alternatives for large surface mine projects.

Rideout, C.B. 1974. A radio telemetry study of the ecology and behavior of the Rocky Mountain goat in western Montana. Ph.D. Thesis, University of Kansas, Lawrence. 145 pp.

key words: mountain goat, _Oreamnos americanus_, habitat use.

Presents data on habitat use and use of space by mountain goats in Montana.

Rolley, R. and L. Keith. 1979. A review of moose habitat requirements. Alberta Recreation, Parks and Wildlife Report for the Alberta Oil Sands Environmental Research Program. AOSERP Project TF1.1. 25 pp.

key words: moose, _Alces alces_, habitat use.

Reviews existing information on factors influencing habitat selection by moose.

Rumbaugh, M.D. 1983. Legumes - their use in wild land plantings. in: S.B. Monsen and N. Shaw (eds.). Managing Intermountain Rangelands - Improvement of Range and Wildlife Habitats. USDA Forest Serv. Gen. Tech. Rep. INT-57. Intermountain Forest Range Expt. Station, Ogden Utah.

key words: wildlife, revegetation, legumes.

The use of legumes in enhancing wildlife habitat is examined and species most suitable for enhancement are recommended.

Russell, K.R., G.L. Williams, B.A. Hughes and D.S. Walsworth. 1980. Wildlife mitigation and management planning system - demonstrated on oil development. Colo. Coop. Unit, Colo. State Univ., Fort Collins, Colo.

key words: habitat assessment, wildlife, key species.

Describes a system for evaluating wildlife habitat through use of a key or indicator species.

Russell, W., R. Annas and L. Knapik. 1984. Potential natural vegetation data base for Alberta habitat subregions. Prepared for Alberta Energy and Natural Resources, Fish and Wildlife Division. Pedocan Land Evaluation Ltd. 197 pp.

key words: revegetation, habitat inventory, wildlife.

An inventory of Alberta including current vegetative cover, land surface disturbance, landforms, aquatic forms, soils, and ecological moisture regime.

Russell, W.B. and S.K. Takyi. 1979. The Cadomin reclamation research project: first year results (1978). Alberta Forest Service, Edmonton. ENR Report No. 121. 47 pp.

key words: coal mine, reclamation, native grass, nurse crops, topsoiling, fertilizer.

Evaluates the use of native and agronomic species, fertilizer, nurse crops and the addition of topsoil in reclamation.

Salt, J.R. 1984. Some notes on white-tailed ptarmigan in the Alberta Rockies. Alberta Naturalist 14:121-125.

key words: white-tailed ptarmigan, breeding, habitat use, productivity, predation.

Describes habitat and feeding and breeding patterns of white-tailed ptarmigan.

Salt, J.R. and R. Clarke. 1979. Mammalian fauna of the Kananaskis Lakes,upper Kananaskis River and Highwood Pass region, Alberta. Alberta Naturalist 9:22-45.

key words: mammals, status and distribution, habitat use.

Provides an annotated checklist of mammals in the Kananaskis area, based primarily on work undertaken during 1976-77.

Salt, W.R. and J.R. Salt. 1976. The birds of Alberta. Hurtig Publishers, Edmonton. 498 pp.

key words: birds, status and distribution.

Compiles information on distribution and general ecology of all bird species known to occur in Alberta.

Salter, R.E. and R.J. Hudson. 1980. Range relationships of feral horses with wild ungulates and cattle in western Alberta. J. Range Manage. 33:266-271.

key words: elk, Cervus elaphus, moose, Alces alces, food habits, habitat use.

Presents results of studies on habitat utilization by elk and moose in the foothills along the Red Deer River.

Samuel, W.M., G.A. Chalmers, J.G. Stelfox, A. Loewen and J.J. Thomson. 1975. Contagious ecthyma in bighorn sheep and mountain goat in western Canada. J. Wildl. Dis. 11:26-31.

key words: mountain goat, Oreamnos americanus, bighorn sheep, Ovis canadensis, disease.

Reviews history and pathology of contagious ecthyma in wild goat and sheep populations in western Canada.

Saskatchewan Environment. 1983. Reclamation guidelines, SPC Coronach Mine. Saskatchewan Environment, Regina. 7 pp.

key words: guidelines, reclamation.

Reclamation guidelines are presented for the SPC Coronach mine in Saskatchewan. Most guidelines refer to eventual agricultural use.

Saskatchewan Environment. 1984. Reclamation guidelines for the Estevan Mining Area. Saskatchewan Environment, Regina. 7 pp

key words: guidelines, reclamation.

Reclamation guidelines are presented for the Estevan mining area in Saskatchewan. Most of the guidelines refer to eventual agricultural use.

Scheidemann, H. and J.G. Stelfox. 1981. Wabamun habitat improvement program, 1976-81. Prepared for Transalta Utilities by Stony Plain Fish and Game Association. 31 pp.

key words: habitat enhancement, revegetation, special structures.

The progress of the habitat enhancement program at the Whitewood Mine is reviewed from its inception in 1976 up to 1981.

Scott, D. and W.D. Billings. 1964. Effects of environmental factors on standing crop and productivity of an alpine tundra. Ecol. Monogr. 34:243-270.

key words: alpine, vegetation, root:shoot ratio.

Relates root:shoot ratios of alpine plants to moisture levels of different sites.

Scotter, G.W. 1980. Management of wild ungulate habitat in the western United States and Canada: a review. J. Range Manage. 33:16-27.

key words: ungulates, habitat management, habitat enhancement.

The importance of habitat conservation, habitat use and development to management of wild ungulates is discussed. This review considers a number of methods to intensify management of ungulate habitat including rehabilitation, modification of range and forest practices, better use of existing habitat, and manipulation of wild ungulate numbers and distributions.

Searing, G.F. 1979. Distribution, abundance and habitat associations of beavers, muskrats, mink and river otters in the AOSERP study area, northeastern Alberta. LGL Limited Report for the Alberta Oil Sands Environmental Research Program. AOSERP Report 73. 119 pp.

key words: muskrat, Ondatra zibethicus, beaver, Castor canadensis, food habits, habitat use, spatial behaviour.

Provides a detailed review of the literature on habitat utilization by muskrat and beaver.

Searing, G.F. 1981. Effects of elevated linear developments on wildlife: a review and annotated bibliography. Prep. for Foothills Pipelines Ltd. by LGL Limited. 87 pp.

key words: mammals, disturbance, pipelines.

Effects of elevated linear developments such as gas or oil pipelines on wildlife and responses to man-made crossing facilities are reviewed. An annotated bibliography of relevant literature is provided.

Selner, J., P. King and D. Hildebrandt. 1977. Progress report for Tent Mountain coal-mined land: reclamation trials (1975-76). Alberta Forest Service, Edmonton. ENR Report No. 32. 57 pp.

key words: coal mine, reclamation, subalpine, alpine.

Reports on studies of native vs. agronomic species, amendments to the growth medium and vegetation establishment.

Shank, C.C. 1979. Human-related disturbance to northern large mammals. A bibliography and review. Prep. for Foothills Pipe Lines Ltd., Calgary. 254 pp.

key words: mammals, disturbance, behaviour, physiology, population.

The potential effects of human-related disturbances on mammal physiology, population changes and behaviour are discussed. An annotated bibliography of pertinent literature is also provided.

Shank, C.C. 1982. Age-sex differences in the diets of wintering Rocky Mountain bighorn sheep. Ecology 63:627-633.

key words: bighorn sheep, Ovis canadensis, food habits, spatial behaviour.

Presents results of studies on winter diets of bighorn sheep in Banff National Park.

Sharp, P.L. 1973. The birds of Waterton Lakes National Park. Canadian Wildlife Service, Edmonton. 347 pp.

key words: birds, habitat use.

Synthesizes known information on breeding status, seasonal occurrence, and habitat use of all bird species occurring in Waterton Lakes National Park.

Sims, H.P. and C.B. Powter. 1982. Land surface reclamation: an international bibliography. Alberta Land Conserv. Reclam. Council Report RRTAC 82-1. 2 Vols. 292 pp.

key words: reclamation, methodology.

This report is an extensive bibliography of the international reclamation literature. Many of the references concern technical aspects of reclamation methodology. Species selection, community development wildlife problems and legislation also are considered.

Sims, H.P., C.B. Powter and J.A. Campbell. 1984. Land surface reclamation: a review of the international literature. Alberta LandConserv. Reclam. Council Report RRTAC 84-1. 2 Vols. 1549 pp.

key words: reclamation, methods, legislation.

This publication is an extremely comprehensive literature review on land surface reclamation. Although it is intended for use in Alberta, a wide range of international literature is examined. Most portions of this report address technical aspects of reclamation. Discussions of species selection, community development and wildlife problems are directly applicable to wildlife reclamation.

Sindelar, B.W., R.L. Hodder and M.E. Majerus. 1973. Surface mined land reclamation research in Montana. Progress Report 1972-1973. Montana State University, Agricultural Research Station, Bozeman, Montana. Research Report 40. 122 pp.

key words: reclamation, surface mines, soil stabilization, methodology.

Experimental approaches to soil stabilization and revegetation for reclamation of surface-mined land are discussed. Most techniques focus on the preparation of the land surface and soil for revegetation.

Skovlin, J.M. 1982. Habitat requirements and evaluations. Pages 369-413, in: J.W. Thomas and D.E. Toweill (eds.). Elk of North America: Ecology and Management. Stackpole Books. 698 pp.

key words: elk, Cervus elaphus, habitat use, habitat assessment.

Provides a detailed, comprehensive review of elk habitat utilization.

Slough, B.G. and R.M.F.S. Sadleir. 1977. A land capability classification system for beaver (Castor canadensis Kuhl). Can. J. Zool. 55:1324-1335.

key words: beaver, Castor canadensis, food habits, habitat use, habitat assessment.

Presents a land capability classification system for beaver based on work in northern interior British Columbia.

Smith, D.A., R.J. Hudson and D.W. Walker. 1979. Native grass food selection by elk (prelminary results). David Walker & Associates Limited, Edmonton. 25 pp.

key words: elk, grasses, food selection.

Reports a cafeteria style feeding trial using native and agronomic grass species fed to two tame elk.

Smoliak, S. and L.M. Bezeau. 1966. Chemical composition and _in vitro_ digestibility of range forage plants of the _Stipa-Bouteloua_ prairie. Can. J. Plant Sci. 47:161-167.

key words: forage, grasses, chemical composition, digestibility, Stipa-Bouteloua prairie.

A group of native and introduced grasses, one sedge and four shrubs were analyzed for phosphorus, digestible energy, and crude protein and cellulose content.

Smoliak, S., R.A. Wroe, S.G. Klumph, B.G. Schuler and A. Johnston. 1979. Forage production on selected native prairie sites in southern Alberta. Agr. Can. Res. Stn., Lethbridge. 36 pp.

key words: forage, grasses, forbs, shrubs, rangeland, stocking rates.

Discusses six types of southern Alberta rangeland in relation to productivity and stocking rates.

Soper, J.D. 1947. Observations on mammals and birds in the Rocky Mountains of Alberta. Can. Field-Nat. 61:143-173.

key words: mammals, birds, status and distribution, habitat use.

Provides an annotated list detailing the author's observations of mammals and birds in the Rockies.

Soper, J.D. 1964. The mammals of Alberta. The Queen's Printer, Edmonton. 402 pp.

key words: mammals, status and distribution.

Compiles information on distribution and general ecology of all mammal species known to occur in Alberta.

Soper, J.D. 1970. The mammals of Jasper National Park, Alberta. Canadian Wildlife Service Report Series Number 10.

key words: mammals, status and distribution, habitat use.

Summarizes available information on the status, habitat use and general ecology of all mammal species known to occur in Jasper National Park.

Soper, J.D. 1973. The mammals of Waterton Lakes National Park, Alberta. Canadian Wildlife Service Report Series. Number 23.

key words: mammals, status and distribution, habitat use.

Summarizes available information on the status, habitat use and general ecology of all mammal species known to occur in Waterton Lakes National Park.

Sopuck, L.G., C.E. Tull, J.E. Green and R.E. Salter. 1979. Impacts of development on wildlife: a review from the perspective of the Cold Lake Project. LGL Limited Report for Esso Resources Canada Limited, Calgary. 400 pp.

key words: mammals, birds, disturbance effects.

Summarizes the literature on effects on wildlife of water level alterations, vegetation clearing, physical barriers and human disturbance associated with development activities.

Spilsbury, R.H. and E.W. Tisdale. 1944. Soil-plant relationships and vertical zonation in the southern interior of British Columbia. Sci. Agr. 24(9):395-436.

key words: soil, plants, temperature, precipitation, B.C., P/E ratio.

Relationship between plant growth and P/E ratio at different elevations.

Stanlake, E.A., D.S. Eastman and M.G. Stanlake. 1978. Ungulate use of some recently reclaimed strip mines in southeastern British Columbia. Fish and Wildlife Report R-1, B.C. Ministry of Recreation and Conservation, Victoria. 82 pp.

key words: ungulates, mines, reclamation.

This report summarizes the findings of a 3-year study of ungulate use of reclaimed areas in southern British Columbia. Information on responses to the vegetation, landform and age of area is presented.

Stelfox, J.G. 1971. Bighorn sheep in the Canadian Rockies: a history 1800-1970. Can. Field-Nat. 85:101-122.

key words: bighorn sheep, _Ovis canadensis_, status and distribution, habitat use.

Reviews historic distribution and abundance of bighorn sheep in Alberta.

Stelfox, J.G. 1976a. Range ecology of Rocky Mountain bighorn sheep. Canadian Wildlife Service Report Series. Number 39.

key words: bighorn sheep, _Ovis canadensis_, food habits, habitat use, population dynamics, disease.

Presents results of studies on six winter ranges (two each in Jasper, Banff and Waterton Lakes National Park) to evaluate factors contributing to population fluctuations and die-offs of bighorn sheep.

Stelfox, J.G. 1976b. Diseases and parasites of bighorn sheep in Canadian National Parks, 1966 to 1972. Canadian Wildlife Service, Edmonton. 132 pp.

key words: bighorn sheep, _Ovis canadensis_, disease.

Collates results of disease-parasite studies on bighorn sheep and correlates these with range condition, ungulate densities and condition, and weather.

Stelfox, J.G. 1978. Seasonal distributions of Rocky Mountain bighorn sheep in Canadian National Parks, 1966-1972. Canadian Wildlife Service, Edmonton. 149 pp.

key words: bighorn sheep, _Ovis canadensis_, status and distribution.

Outlines seasonal and year-long distributions of bighorn sheep inthe mountain national parks, and discusses distribution in relation to range requirements, weather and human activities.

Stelfox, J.G. 1981. Effects on ungulates of clear-cutting in western Alberta: the first 25 years. Canadian Wildlife Service, Edmonton. 46 pp.

key words: mammals, habitat use.

Updates results of ongoing studies on the effects of logging on wildlife in the Hinton area.

Stelfox, J.G. and J.A. Bindernagel. 1978. Caribou behaviour in relation to human-elk-wolf influences, Jasper National Park, 1971-1974. Canadian Wildlife Service, Edmonton. 59 pp.

key words: caribou, Rangifer tarandus, habitat use.

Examines the problem of encroachment of elk and hikers ontocaribou ranges in Jasper National Park, and summarizes data on seasonal habitat use.

Stelfox, J.G. and Jasper National Park Warden Service. 1974. The abundance and distribution of caribou and elk in Jasper National Park, 1971 to 1973. Canadian Wildlife Service, Edmonton. 84 pp.

key words: caribou, Rangifer tarandus, elk, Cervus elaphus, status and distribution, habitat use.

Details the past and current status of caribou and elk in Jasper National Park, and correlates seasonal distributions with main features of habitat.

Stelfox, J.G., P. Kuchar and J.A. Bindernagel. 1978. Range ecology of mountain caribou (Rangifer tarandus caribou) in Jasper National Park, 1971-1974. Canadian Wildlife Service, Edmonton. 121 pp.

key words: caribou, Rangifer tarandus, food habits, habitat use, spatial behaviour.

Reports results of detailed studies of food habits and habitat use of caribou in Jasper National Park.

Stelfox, J.G. and R.D. Taber. 1969. Big game in the northern Rocky Mountain coniferous forest. Pages 197-222, in: R.D. Taber (ed.). Coniferous Forests of the Northern Rocky Mountains: Proceedings of the 1968 Symposium. Center for Natural Resources, Missoula, Montana.

key words: mammals, habitat use, spatial behaviour.

Discusses altitudinal distribution patterns of elk, moose, caribou, mountain goats and bighorn sheep in the Rockies, and seasonal movements.

Stelfox, J.G., E.S. Telfer and G.M. Lynch. 1973. Effects of logging on wildlife. Fish and Game Sportsman Magazine, Fall 1973.

key words: mammals, birds, habitat use.

Discusses effects of logging on wildlife in the Alberta foothills, with particular reference to ongoing studies in the Hinton area.

Stevens, W.E. 1955. Adjustments of the northwestern muskrat (*Ondatra zibethicus spatulatus*) to a northern environment. Ph.D. Thesis, University of British Columbia, Vancouver. 196 pp.

key words: muskrat, *Ondatra zibethicus*, food habits.

Presents results of studies on muskrat ecology in the Mackenzie Delta.

Stoecker, R.E. 1982. Creating small islands for wildlife and visual enhancement. Pages 48-51, *in*: W.D. Svedarsky and R.D. Crawford (eds.). Wildlife Values of Gravel Pits. Univ. Minn. Agric. Exp. Stn., Misc. Publ. 17-1982.

key words: wildlife, waterfowl, islands, wetlands.

Methods of improving the aesthetic quality and value of wetlands to wildlife are reviewed. Particular emphasis is given to the creation of artificial islands and bottom diversity.

Strong, W.L. and K.R. Leggat. 1981. Ecoregions of Alberta. Resource Evaluation and Planning Division, Alberta Energy and Natural Resources, Edmonton. ENR Technical Report No. T/4. 64 pp.

key words: ecoregions, vegetation, climate, soils.

Classifies Alberta into a number of ecoregions based on climate and vegetation, and provides a detailed description of each.

Strong, W.L. and H.G. Vriend. 1980. Ecological land classification hierarchies and elk distributions in southwestern Alberta. Pages 99-106, *in*: D.G. Taylor (ed.). Land/wildlife Integration. Proceedings of a Technical Workshop to Discuss the Incorporation of Wildlife Informationinto Ecological Land Surveys, Saskatoon, Saskatchewan.

key words: elk, *Cervus elaphus*, habitat use, habitat assessment.

Integrates elk distribution data with a land classification system to determine major features of elk habitat.

Sullivan, J.P. and J.G. Stelfox. 1974. Wildlife food habits and seasonal ranges in Jasper townsite area, summer 1974. Canadian Wildlife Service, Edmonton. 75 pp.

key words: elk, Cervus elaphus, bighorn sheep, Ovis canadensis, food habits, habitat use.

Presents results of studies on summer food habits of elk and of habitat use by elk and bighorn sheep in Jasper National Park.

Sverre, S.F.S. 1972. Some ecological effects of beaver upon the watersheds in the Porcupine Hills, Alberta. M.Sc. Thesis, Brock University, St. Catharines, Ontario. 144 pp.

key words: beaver, Castor canadensis, food habits, habitat use, spatial behaviour.

Presents results of studies on beaver habitat use and distribution in the Porcupine Hills, southwestern Alberta.

Szafoni, R.E. 1982. Wildlife considerations in the development of riparian communities. Pages 59-66, in: W.D. Svedarsky and R.D. Crawford (eds.). Wildlife Values of Gravel Pits. Univ. Minn. Agric. Exp. Stn., Misc. Publ. 17-1982.

key words: wildlife, watercourse, riparian, reclamation.

Methods of restoring riparian communities or enhancing existing riparian communities are discussed. Other methods of enhancing waterbodies for wildlife also are considered.

Takyi, S.K. 1981. Methods of establishing native grasses on coal overburden: first year report (1980). Alberta Forest Service, Edmonton. 22 pp.

key words: overburden, seeding methods, mulches, native grass, mine spoil, reclamation.

Assesses seeding methods and grass mixes on coarse and pervious material.

Takyi, S.K. and R.H. Leitch. 1981. Influence of roll-out mats and ridging on the establishment of plant cover on an unamended coal spoil: a progress report for 1980. Alberta Forest Service, Edmonton. ENR Report No. T/20-80. 25 pp.

key words: coal mine, reclamation, mine spoil, erosion control, mulches.

Compares three erosion control materials (hold/gro, excelsior blanket and jute net and ridging) and provides measurements of dry matter production and percent cover.

Takyi, S.K. and W.B. Russell. 1980. The Cadomin reclamation research project: second year results (1979). Alberta Forest Service, Edmonton. ENR Report No. 155. 54 pp.

key words: reclamation, coal spoil, coal mine, overburden, companion crops, native grass.

Summarizes results of the second growing season for reclamation experiments (native and agronomic species with and without fertilizer) in the Rocky Mountain foothills.

Techman Engineers Limited. 1983. Woody plant establishment and management for oil sand mine reclamation. Report #OSESG-RRTAC 83-5. 130 pp.

key words: shrubs, establishment, management, reclamation, oil sands.

Reviews the existing information on establishment and management of woody plants.

Telfer, E.S. 1978a. Ungulate use in the Marmot Creek experimental watershed. Canadian Wildlife Service, Edmonton. 50 pp.

key words: elk, Cervus elaphus, moose, Alces alces, habitat use.

Discusses habitat selection by elk and moose in the Kananaskis area, based on pellet group counts.

Telfer, E.S. 1978b. Cervid distribution, browse and snow cover in Alberta. J. Wildl. Manage. 42:352-361.

key words: elk, Cervus elaphus, moose, Alces alces, habitat use.

Correlates winter distribution of elk, moose and mule deer with browse availability and other habitat features in the Porcupine Hills and in the Hinton area.

Telfer, E.S. and J.P. Kelsall. 1971. Morphological parameters for mammal locomotion in snow. Unpubl. MS. Presented at 51st Annual Meeting American Society of Mammologists, University of British Columbia, Vancouver. 10 pp.

key words: caribou, Rangifer tarandus, habitat use.

Discusses adaptions of caribou to snow cover.

Telfer, E.S. and J.P. Kelsall. 1979. Studies of morphological parameters affecting ungulate locomotion in snow. Can. J. Zool. 57:2153-2159.

key words: elk, _Cervus elaphus_, moose, _Alces alces_, habitat use.

Presents data on morphological adaptations of elk and moose to snow conditions.

Tessman, S.A. 1982. Habitat reclamation procedures for surface mines in Wyoming. Pages 185-194, _in_: Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecol. Inst. Tech. Publ. 14.

key words: habitat, reclamation, coal mining.

Provides a summary of habitat reclamation practices currently recommended by the Wyoming Game and Fish Department. Methods are emphasized that provide maximum habitat diversity and that are self-renewing or permanent habitat structures. Means of using on-site materials also are described.

Thilenius, J.F. 1975. Alpine range management in the western United States - principles, practices, and problems. The status of our knowledge. USDA Forest Service Res. Paper RM-157. Rocky Mountain Forest and Range Exp. Stn., Fort Collins, Colorado. 32 pp.

key words: alpine, range management.

Describes the alpine zone and management of the forage resource.

Thirgood, J.V. and P.F. Ziemkiewicz. 1978. Reclamation of coal surface-mined land in western Canada. Pages 537-552, in: F.W. Schaller and P. Sutton (eds.). Reclamation of Drastically Disturbed Lands.

key words: reclamation, legislation, mines.

This publication is an overview of land surface mining activities in western Canada. Information is provided on types and extend of mining.

Thomas, J.W., R.J. Miller, H. Black, J.E. Rodick and C. Maser. 1976. Guidelines for maintaining and enhancing wildlife habitat in forest management in the Blue Mountains of Oregon and Washington. N. Amer. Wildl. Nat. Res. Conf. 41:452-476.

key words: habitat enhancement, mammals, birds.

Describes methods for assessing wildlife/timber relationships that can be related to timber management activities. Information is provided on maintenance and enhancement of habitat for elk, cavity nesters, and wildlife dependent on talus habitats.

Thomas, J.W., C. Maser and J.E. Rodick. 1979a. Edges. Pages 48-59, in: J.W. Thomas (ed.). Wildlife Habitats in Managed Forests. The Blue Mountains of Washington and Oregon. USDA Forest Service, Agric. Handbook No. 553.

key words: wildlife, habitat, edge, management.

This publication provides an extensive and detailed overview of habitat edge to wildlife. Widllife use of various vegetation communities is discussed.

Thomas, J.W., C. Maser and J.E. Rodick. 1979b. Riparian zones. Pages 40-47, in: J.W. Thomas (ed.). Wildlife Habitats in Managed Forests. The Blue Mountains of Washington and Oregon. USDA Forest Service, Agric. Handbook No. 553.

key words: wildlife, habitat, management.

The use and value of riparian zones by wildlife are discussed. The general ecology of species that most commonly utilize those areas is reviewed.

Thomas, J.W., H. Black, R.J. Scherzinger and R.J. Pedersen. 1979c. Deer and elk. Pages 104-127, in: J.W. Thomas (ed.). Wildlife Habitats in Managed Forests. The Blue Mountains of Washington and Oregon. USDA Forest Service, Agric. Handbook No. 553.

key words: deer, elk, habitat disturbance.

Use of habitat by deer and elk are reviewed with particular reference to the need for visual and thermal cover.

Thomas, J.W., R.G. Anderson, C. Maser and E.L. Bull. 1979d. Snags. Pages 60-77, in: Wildlife Habitats in Managed Forests. The Blue Mountains of Washington and Oregon. USDA Forest Service, Agric. Handbook No. 553.

key words: wildlife, snags, habitat.

The importance of hard and soft snags to wildlife and the types of habitats provide by snags are reviewed.

Thomas, J.W. 1979e. Wildlife habitats in managed forests - The Blue Mountains of Oregon and Washington. U.S. Agric. Handb. No. 553, U.S. Gov. Print. Offi., Washington, D.C. 512 pp.

key words: habitat assessment, habitat descriptions, wildlife communities.

This publication describes an intensive long-term study of wildlife habitat structure, wildlife use and wildlife communities in the Blue Mountains of Oregon. Values of different habitat types and strata and special habitat features to wildlife are discussed.

Thomas, J.W. 1982. Needs for and approaches to wildlife habitat assessment. N. Amer. Wildl. Nat. Res. Conf. 47:35-46.

key words: habitat assessment, methodoglogy.

Discusses the major types of habitat assessment techniques and some of the major advantages and disadvantages and suitable application of each assessment approach.

Thompson, D.C., D.M. Ealey and K.H. McCourt. 1980. A review and assessment of the baseline data relevant to the impacts of oil sands developments on large mammals in the AOSERP study area. McCourt Management Limited Report for the Alberta Oil Sands Environmental Research Program. AOSERP Report 64. 155 pp.

key words: moose, Alces alces, caribou, Rangifer tarandus, habitat use, food habits, spatial behaviour, population dynamics.

Reviews available ecological data on moose and woodland caribou, and identifies data gaps relevant to the assessment of impacts of oil sands development.

Todd, A.W. 1978. Methodology used for Alberta Land Inventory of furbearers. Alberta Fish and Wildlife Division, Edmonton. 68 pp.

key words: muskrat, Ondatra zibethicus, beaver, Castor canadensis, habitat use, food habits, habitat assessment.

Reviews habitat requirements of muskrat and beaver, and outlines a classification system for assessing the capability of land units for beaver or muskrat production in Alberta.

Tomm, H. 1981. Reclamation survey of the Panther River coal exploration disturbances. Reforestation and Reclamation Branch, Alberta Forest Service, Edmonton. 45 pp.

key words: reclamation, coal mine, disturbance, reforestation, establishment.

Assesses reclamation at the Panther River coal area with respect to elevation, aspect, species establishment and erosion control.

Tomm, H.O., J.A. Beck and R.J. Hudson. 1981. Response of wild ungulates to logging practices in Alberta. Can. J. For. Res. 11:606-614.

key words: moose, *Alces alces*, habitat use.

Reports results of studies on responses of moose (and deer) to logging practices in the Whitecourt, Grande Prairie and Rocky-Clearwater Forests, based on pellet group counts and assessment of browse use.

Tomm, H.O. and W.B. Russell. 1981. Native grass and cultivated grass-legume seed mixture trials on subalpine coal-mined disturbances in Alberta: a progress report for 1980. Alberta Forest Service, Edmonton. ENR Report No. T/21-80. 41 pp.

key words: reclamation, coal mine, native grass, legumes, companion crops.

Reports research to evaluate and compare different seed mixes for alpine and subalpine revegetation.

Troelsen, J.E. and J.B. Campbell. 1959. Nutritional quality of forage crops adapted to southwestern Saskatchewan as determined by their digestibility and dry matter intake when fed to sheep. Can. J. Plant Sci. 39:417-429.

key words: fertilizer, forage, digestibility, palatability, sheep, nutrition.

Compares fertilized and unfertilized hay stands in terms of organic matter, crude protein and nitrogen-free extract.

Tuley, G. 1982. Shelters improve the growth of young trees - 1982 results. Arboriculture Research Note, Report 49 83. Silv. Research and Development Division, Alice Holt Lodge, Surrey, UK. 5 pp.

key words: shrubs, establishment, revegetation.

Describes the use of shelters for the protection of trees up to 5 years of age.

U.S.D.A. 1972. Management and uses of 'Sodar' streambank wheatgrass. USDA Soil Conservation Service ID.7-N-20000-27. 3 pp.

key words: streambank wheatgrass, management, erosion control.

Discusses use of streambank wheatgrass for erosion control.

U.S.D.A. 1979. User guide to vegetation, mining and reclamation in the west. USDA Forest Service Gen. Tech. Rep. INT-64. Intermountain Forest Range Exp. Stn., Odgen, Utah.

key words: user guide, mining, reclamation, revegetation.

A guide to reclamation including species selection, site preparation, planting methods and management.

U.S.D.A. 1983. Snag habitat management: Proceedings of a Symposium. June 7-9, 1983, Flagstaff, Arizona. Rocky Mountain Forest and Range Experimental Station, Forest Service. USDA Forest Service. General Technical Repot RM-99. 226 pp.

key words: special features, snags, avifauna, mammals.

These proceedings include a number of research papers that describe use of snags by wildlife in natural situations and incorporation of snags in wildlife enhancement and reclamation projects.

U.S.F.W.S. 1980. Habitat evaluation procedures (HEP) ESM 102. Div. Ecol. Services, U.S. Fish and Wildlife Service, Washington. n.p.

key words: habitat evaluation, wildlife.

This manual describes the HEP methodology for assessment of wildlife habitat. This method provides a quantitative method for simultaneously assessing the quality and quantity of wildlife habitat.

U.S.F.W.S. 1984a. Snowshoe hare. Pages B1-B12, in: Terrestrial Habitat Evaluation Criteria Handbook - Alaska. USFWS, Anchorage.

key words: snowshoe hare, *Lepus americanus*, food habits, habitat use, spatial behaviour.

Reviews available data pertinent to assessment of snowshoe hare habitat in Alaska.

U.S.F.W.S. 1984b. Beaver. Pages B27-B46, in: Terrestrial Habitat Evaluation Criteria Handbook - Alaska. USFWS, Anchorage.

key words: beaver, Castor canadensis, food habits, habitat use, spatial behaviour.

Reviews available data pertinent to assessment of beaver habitat in Alaska.

U.S.F.W.S. 1984c. Moose. Pages B218-B266, in: Terrestrial Habitat Evaluation Criteria Handbook - Alaska. USFWS, Anchorage.

key words: moose, Alces alces, food habits, habitat use, spatial behaviour.

Reviews available data pertinent to assessment of moose habitat in Alaska.

U.S.F.W.S. 1984d. Spruce grouse. Pages A138-149 in: Terrestrial Habitat Evaluation Criteria Handbook - Alaska U.S.F.W.S., Anchorage.

key words: spruce grouse, Canachites canadensis, food habitats, habitat use, spatial behaviour.

Reviews available data pertinent to assessment of spruce grouse habitat in Alaska.

Van Camp, J. and E.S. Telfer. 1975. Hare habitat and cover relationships in Elk Island National Park. Canadian Wildlife Service, Edmonton. 55 pp.

key words: snowshoe hare, Lepus americanus, habitat use.

Assesses the location and structure of snowshoe hare habitat in Elk Island National Park, with particular reference to ungulate browsing.

Van Dyke, W.A., A. Sands, J. Yoakum, W. Polenz and J. Blaisdell. 1983. Wildlife habitats in managed rangelands - the Great Basin of southeastern Oregon. Bighorn sheep. USDA Forest Service Gen. Tech. Rep. PNW-159. Pacific Northwest Forest Range Exp. Stn. 37 pp.

key words: bighorn sheep, Ovis canadensis, habitat use, spatial behaviour, habitat assessment.

Reviews habitat requirements of bighorn sheep with a view to facilitating management of sheep habitat in the Great Basin area.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:893-901.

key words: habitat evaluation, population density, habitat quality.

Methods of evaluating wildlife habitat for management purposes are discussed in relation to their ability to measure habitat quality in terms of population survival and productivity. In general, density estimates of habitat quality should be use with caution.

Viereck, L.A. and E.L. Little. 1972. Alaska trees and shrubs. U.S. Dept. Agr., Forest Service. Agr. Handbook No. 410, 265 pp.

key words: trees, shrubs, identification.

A key to the trees and shrubs of Alaska.

von Althen, F.W. 1983. Animal damage to hardwood regeneration and its prevention in plantations and woodlots of southern Ontario. Information Rep. O-X-351, Canadian Forestry Service.

key words: damage, control, large mammals, small mammals.

The types of damage to hardwood trees by small and large mammals are reviewed. Methods of control for each type of damage are discussed.

Wallis, C. and C. Wershler. 1979. Literature review of considerations for reclaiming lands as wildlife habitat. Prepared for Cardinal River Coals by Cottonwood Consultants Limited. 43 pp.

key words: reclamation, wildlife, habitat.

This publication provides some baseline information on wildlife populations and habitats in the vicinity of the Cardinal River Coal mine. Recommendations for reclamation of wildlife habitat also are proposed.

Watson, L.E., R.W. Parker and D.F. Polster. 1980. Manual of plant species suitability for reclamation in Alberta. Alberta Land Conserv. Reclam. Council Report RRTAC 80-5. 2 vols. 541 pp.

key words: revegetation, species, selection, reclamation.

Describes the suitability of various tree, shrub and ground cover species to use in reclamation in Alberta.

WECO. 1982. Western Energy Company's alternate reclamation plan. Area E highwall. Western Energy Co., Colstrip, Montana. 21 pp + appendices.

key words: wildlife, reclamation, contouring.

This report outline a plan for the reclamation of a mine end cut as cliff and talus habitat for wildlife.

WECO. 1983. Seasonal range and wildlife demonstration area. Alternate reclamation plan. Volume 1. Western Energy Co., Colstrip, Montana. 22 pp.

key words: wildlife, reclamation, recontouring, revegetation.

Methods are reviewed for the development of a mine end cut for wildlife habitat. Methods for recontouring and revegetation are discussed.

WECO. 1984. A plan for the re-establishment of postmine coulee bottom/upland deciduous shrub-tree habitat type in Area A. Western Energy Co., Colstrip, Montana. 8 pp.

key words: wildlife, reclamation, habitat.

A reclamation plan for re-establishing coulee-bottom habitat for wildlife is proposed.

Weeden, R.B. 1967. Seasonal and geographical variation in the foods of adult white-tailed ptarmigan. Condor 69:303-309.

key words: white-tailed ptarmigan, _Lagopus leucurus_, food habits.

Provides data on food habits (from crop analyses) of white-tailed ptarmigan throughout their North American range, including Alberta.

Welch, C.E. 1980. Relationship between the availability, abundance and nutrient quality of _Typha latifolia_ and _Scirpus acutus_ to summer foraging and use of space by muskrats (_Ondatra zibethica_) in south-central Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 119 pp.

key words: muskrat, _Ondatra zibethicus_, food habits.

Examines foraging and spacing patterns of muskrats in Bowden Lake, south-central Alberta.

Weller, M.W. and L.H. Fredrickson. 1974. Avian ecology of a managed glacial marsh. Living Bird 12:269-291.

key words: waterfowl, muskrat, habitat enhancement.

Methods to improve wetlands for waterfowl are discussed. Integrated use of wetlands by muskrat and waterfowl is recommended in order to maintain good ratios of open water: emergent vegetation.

Westar Mining. 1983. End land use goals for the Balmer minesite. A specific reclamation plan for the Balmer minesite 1984-2004. Westar Mining, Sparwood, B.C. 36 pp + appendices.

key words: wildlife, habitat, reclamation, revegetation.

This report is a combined literature review and reclamation plan for the Westar Mine. Methods of contouring, wetland creation and revegetating that will benefit wildlife are reviewed.

Westmoreland Resources. 1984. Revegetation Plan. Exhibit H-9. Revegetation Plan for the Absaloka Mine. Westmoreland Resources, Hardin, MT. 4 pp. & tables and appendices.

key words: revegetation, Montana.

Describes the revegetation plan for agricultural and wildlife end uses at the Absaloka mine of Westmoreland Resources.

Williams, G.L., K.R. Russell and W.K. Seitz. 1978. Pattern recognition as a tool in the ecological analysis of habitat. Colo. Coop. Unit. Colo. State Univ., Fort Collins, Colo.

key words: habitat assessment, wildlife, key species.

Describes a method of describing and assessing wildlife habitat through use of a key species concept.

Willner, G.R., J.A. Chapman and J.R. Goldsberry. 1975. A study and review of muskrat food habits with special reference to Maryland. Maryland Wildl. Admin., Publ. in Wildl. Ecology No. 1. 25 pp.

key words: muskrat, Ondatra zibethicus, food habits.

Provides a review of muskrat food habits studies.

Windberg, L.A. and L.B. Keith. 1978. Snowshoe hare populations in woodlot habitat. Can. J. Zool. 56:1071-1080.

key words: snowshoe hare, _Lepus americanus_, spatial behaviour.

Details studies of snowshoe hare population dynamics in woodlots associated with agricultural areas near Westlock, Alberta.

Wiseley, A.N. 1979. A review of birds and their habitats in Kananaskis Country. Kananaskis Country Planning Document #2. Alberta Fish and Wildlife Division, Edmonton. 168 pp.

key words: birds, habitat use.

Synthesizes information on breeding status, seasonal occurrence and habitat use of all bird species occurring in the Kananaskis area of southwestern Alberta.

Wishart, W.D. 1958. The bighorn sheep of the Sheep River Valley. M.Sc. Thesis, University of Alberta, Edmonton. 66 pp.

key words: bighorn sheep, _Ovis canadensis_, food habits, habitat use, spatial behaviour.

Presents results of studies on the ecology of bighorn sheep in the Sheep River area, southwestern Alberta.

Wishart, W.D., J. Jorgenson and M. Hilton. 1980. A minor die-off of bighorns from pneumonia in southern Alberta (1978). Pages 229-245, _in_: Proc. Biennial Symposium Northern Wild Sheep and Goat Council, Salmon, Idaho.

key words: bighorn sheep, _Ovis canadensis_, habitat use, disease.

Discusses use of winter range and reviews factors leading to a die-off of bighorn sheep in the Sheep River area, southwestern Alberta.

Wolff, J.O. 1978. Food habits of snowshoe hares in interior Alaska. J. Wildl. Manage. 42:148-153.

key words: snowshoe hare, _Lepus americanus_, food habits.

Reports a study of seasonal food habits of snowshoe hares in Alaska, and compares diet composition with data from other areas.

Wolff, J.O. 1980. Th^ role of habitat patchiness in the population dynamics of snowshoe hares. Ecological Monographs 50:111-130.

key words: snowshoe hare, Lepus americanus, food habits, nutrition, habitat use, spatial behaviour.

Discusses various aspects of habitat use by Alaskan hares in relation to phase of the population cycle.

Wright, M. 1984. Hanlan Robb sour gas plant: mitigation and public participation. Pages 37-48, in: P. Thompson, D. Thompson and S. Stephansson (eds.). Symposium on Environmental Mitigation: Solutions to Problems. The Alberta Society of Professional Biologists, Edmonton.

key words: wildlife, mitigation, sour gas.

Reviews the major effects of sour gas on flora and fauna and examines methods of mitigating these effects. Impacts of pipeline development and mitigation were also discussed.

Wroe, R.A, S. Smoliak, A. Johnston and M.G. Turnbull. 1979. Alberta range pastures. Alberta Agriculture and Alberta Energy and Natural Resources, Edmonton. ENR Report No. 86. 30 pp.

key words: rangelands, forage, vegetation zones, range condition, stocking rates.

Describes Alberta rangelands in terms of vegetation type, forage production and carrying capacity.

Wyoming Game and Fish Department. 1976. Considerations for wildlife in industrial developpment and reclamation. Cheyenne, Wyoming. 65 pp. Cited in Tessman 1982.

Zwickel, F.C., D.A. Boag and J.H. Brigham. 1974. The autumn diet of spruce grouse: a regional comparison. Condor 76:212-214.

key words: spruce grouse, Canachites canadensis, food habits.

Compares fall diets of spruce grouse in north-central Washington with published data from other regions, including the Swan Hills of Alberta.

10.0 APPENDICES

10.1 APPENDIX 1: SELECTION OF KEY SPECIES

The key species for the MFRRP were selected based on the four-step system described below:

10.1.1 Step 1: Identification of Candidate Species

To reduce the initial number of species to a manageable size, we restricted our evaluations to terrestrial aquatic mammals and to waterbirds, upland game birds and raptors. Only those species of mammals and birds whose population ranges, as described by Banfield (1977) and Salt and Salt (1976), respectively, extended well into the mountain and foothills biomes were considered. We did not include other wildlife groups primarily because their habitat requirements cannot be reclaimed easily through manipulation of topographic or vegetation features and, consequently, reclamation plans for these species would not always be applicable to a wide range of other species or to potential post-mine landscapes. Although carnivorous mammals were included in the guilding process, they were not considered as key species because their distributions are primarily affected by prey abundance as opposed to terrain or vegetation parameters. Hence reclamation plans for some herbivores will, in effect, be suitable for some carnivores. Bats (Family Chiroptera) were excluded because of their limited distribution, specialized habitat requirements and the low probability that reclamation areas would be considered specifically for this group. Similarly, most passerine birds have very specialized habitat and dietary requirements and, as a result, do not adequately represent a sufficient number of other wildlife species to be considered as good key or indicator species.

10.1.2 Step 2: Identification of Species Associations

Species associations, consisting of species with similar habitat requirements, were developed separately for birds and mammals. The tabulation of groups with similar habitat requirements was based on division of the major vegetation communities (Section 4.0) into five broad zones or strata including the tree canopy, shrub canopy, ground surface, emergent zone/shoreline and open water. Each species of bird and mammal identified in Step 1 was then listed under vegetation strata that best satisfied food, cover and reproductive requirements (Tables 17 and 18). General habitat data for mammals were obtained from Banfield (1977) and Soper (1964, 1970, 1973) and for birds from Godfrey (1966) and Salt and Salt (1976).

10.1.3 Step 3: Evaluation of Species Significance

The species evaluation system developed by Green et al. (1984) was used in this study, with slight modification, to provide a systematic method of selecting the most appropriate key species from each species association. Four criteria were used to assess the importance of each species, with each criterion consisting of one or two components.

10.1.3.1 Political Importance. Political importance was assessed on the basis of relative abundance and degree of management concern expressed about the species. A value of 0 reflects a high species abundance and low management concerns; 1 represents widespread declining numbers (except in cyclic species), or local rarity and moderate management concerns; and 2 indicates a rare, endangered or threatened species with high management concerns.

10.1.3.2 Economic Importance. Economic importance was based on a species' commercial value (i.e., provides income as a fur species or from guiding) and subsistence value (meat). For both components, values of 0, 1, or 2 were used to reflect importance, 0 being assigned to species of little or no importance, 1 to species that are occasionally utilized, and 2 to species that are frequently utilized.

Table 17. Guilding matrix for the selection of key species of mammals in the mountain and foothills biomes.

Habitat Stratum	Deciduous Forest	Coniferous Forest	Mixed Forest	Shrub	Meadow	Bog	Talus	Lacustrine	Riverine
Tree Canopy	N. Flying Sq. Am. Beaver* Porcupine	Red Squirrel N. Flying Sq. Wood Rat Porcupine Marten* Fisher Mountain Lion* Caribou *	Red Squirrel* N. Flying Sq. Porcupine Marten* Fisher	N/A*	N/A	Red Squirrel* Marten* Fisher	N/A	N/A	N/A
Shrub Canopy	Snowshoe Hare Least Chipmunk Am. Beaver Deer Mouse Wood Rat Red-backed Vole Porcupine Black Bear Grizzly Bear* Marten Mule Deer White-tailed Deer Moose* Elk*	Snowshoe Hare Least Chipmunk Pine Chipmunk Wood Rat Red-backed Vole Porcupine Marten* Caribou * Mule Deer White-tailed Deer Moose* Elk*	Snowshoe Hare Least Chipmunk Pine Chipmunk Am. Beaver Deer Mouse Wood Rat Red-backed Vole Porcupine Black Bear Grizzly Bear* Marten Caribou * Mule Deer White-tailed Deer Moose* Elk*	Snowshoe Hare Least Chipmunk Am. Beaver Deer Mouse Wood Rat Red-backed Vole W. Jumping Mouse Porcupine Black Bear Grizzly Bear* Mule Deer White-tailed Deer Moose* Elk*	Hoary Marmot Columbian Grd. Sq. Elk*	Snowshoe Hare* Deer Mouse N. Bog Lemming Heather Vole Porcupine	Am. Pika* Hoary Marmot*	N/A	N/A

continued...

Table 17. Concluded.

Habitat Stratum	Deciduous Forest	Coniferous Forest	Mixed Forest	Shrub	Meadow	Bog	Talus	Lacustrine	Riverine
Ground Surface	Shrews Snowshoe Hare Least Chipmunk Red Squirrel Deer Mouse Red-backed Vole W. Jumping Mouse Porcupine Coyote Wolf Red Fox Black Bear Grizzly Bear* Weasel Mink Striped Skunk Lynx Bobcat Mule Deer White-tailed Deer Moose* Elk*	Shrews Snowshoe Hare Least Chipmunk Red Squirrel Deer Mouse Red-backed Vole Wolf* Black Bear Weasel Mink Mountain Lion Lynx Bobcat Caribou*	Shrews Snowshoe Hare Least Chipmunk Red Squirrel Deer Mouse Red-backed Vole W. Jumping Mouse Porcupine Coyote Wolf* Red Fox Weasels Mink Striped Skunk Mountain Lion Lynx Bobcat Mule Deer White-tailed Deer Moose* Elk*	Shrews Snowshoe Hare Hoary Marmot Columbian Grd. Sq. Golden Mantled Grd. Sq. Deer Mouse Red-backed Vole Heather Vole Porcupine Coyote Wolf Red Fox Black Bear Grizzly Bear* Weasel Mink Wolverine Am. Badger Lynx Bobcat Mule Deer*	Shrews Am. Pika Hoary Marmot Colombian Grd. Sq. Golden Mantled Grd. Sq. N. Pocket Gopher Deer Mouse Wood Rat N. Bog Lemming Heather Vole Meadow Vole Long-tailed Vole W. Jumping Mouse Coyote Red Fox Black Bear Grizzly Bear* Weasel Wolverine Am. Badger Striped Skunk Mule Deer Elk* Mountain Goat Bighorn Sheep	Shrews Snowshoe Hare* N. Bog Lemming Wolf Red Fox Weasel Mink* Lynx*	Am. Pika Hoary Marmot Wood Rat Heather Vole Grizzly Bear* Wolverine Mountain Goat* Bighorn Sheep*	N/A	N/A
Emergent Zone	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Water Shrew Beaver Muskrat* Rich. Water Vole Mink River Otter Moose*	Water Shrew Beaver Muskrat* Rich. Water Vole Mink River Otter Moose*
Open Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	River Otter Beaver*	River Otter*

able 18. Guilding matrix for the selection of key species of birds in the mountain and foothills biomes.

Habitat Stratum	Deciduous Forest	Coniferous Forest	Mixed Forest	Shrub	Meadow	Bog	Talus/Cliff	Lacustrine	Riverine
:rial				Red-t. Hawk Marsh Hawk Merlin*	Red-t. Hawk Golden Eagle* Marsh Hawk Merlin Kestrel	Marsh Hawk* Hawk Owl		Bald Eagle* Osprey* (combine with open water and shoreline)	Bald Eagle* Osprey* (combine with open water and shoreline)
·ee Canopy	Common G'eye* Barrow's G'eye* Bufflehead* Hooded Merg* Common Merg Goshawk Sharp-sh. H. Cooper's H. Red-t. Hawk Bald Eagle* Osprey* Merlin Kestrel Ruffed Grouse* Solitary Sand. Gr. Horned Owl Gr. Gray Owl Saw-whet Owl	Common G'eye* Barrow's G'eye* Bufflehead* Hooded Merg* Common Merg Bald Eagle* Osprey* Merlin Kestrel Blue Grouse Spruce Grouse Ruffed Grouse Wh.-tailed Pt.* Solitary Sand. Gr. Horned Owl Hawk Owl Pygmy Owl Barred Owl Gr. Gray Owl Boreal Owl Saw-whet Owl	Common G'eye* Barrow's G'eye* Bufflehead* Hooded Merg* Common Merg Goshawk Sharp-sh. H. Cooper's H. Red-t. Hawk Bald Eagle* Osprey* Merlin Kestrel Ruffed Grouse Wh.-tailed Pt.* Solitary Sand. Gr. Horned Owl Hawk Owl Pygmy Owl Barred Owl Gr. Gray Owl	N/A	N/A	Common G'eye* Barrow's G'eye* Bufflehead* Hooded Merg* Common Merg Spruce Gr.* Solitary Sand. Hawk Owl Gr. Gray Owl* Saw-whet Owl	N/A	N/A	N/A
ruh Canopy	Merlin* Ruffed grouse*	Merlin*	Merlin*				White-t. Pt.*	N/A	N/A

continued...

able 18. Continued.

Habitat Stratum	Deciduous Forest	Coniferous Forest	Mixed Forest	Shrub	Meadow	Bog	Talus/Cliff	Lacustrine	Riverine
round Surface	Blue Grouse* Ruffed Grouse* Sharp-t. Grouse	Spruce Grouse* Greater Y'legs* Lesser Y'legs*	Ruffed Grouse*	Canada Goose* Mallard Pintail Green-w. Teal Blue-w. Teal N. Shoveler Marsh Hawk* Sharp-t. Grouse*	Canada Goose* Mallard Pintail Green-w. Teal Blue-w. Teal N. Shoveler Lesser Scaup Marsh Hawk Blue Grouse White-t. Pt.* Sharp-t. Grouse Killdeer Common Snipe Spotted Sand.	Green-w. Teal* Spruce Grouse* Sharp-t. Grouse Common Snipe Greater Y'legs Lesser Y'legs	Golden Eagle* White-t. Pt.*	N/A	N/A
nergent Zone/ noreline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Common Loon Red-n. Grb. Canada Goose* Mallard Pintail Green-w. Teal Blue-w. Teal N. Shoveler Lesser Scaup Common G'eye Barrow's G'eye Bufflehead Harlequin D. Sora Am. Coot Killdeer Common Snipe Spotted Sand. Solitary Sand. Greater Y'legs Lesser Y'legs	Canada Goose* Mallard Blue-w. Teal Green-w. Teal Lesser Scaup Harlequin D. Sora Am. Coot Killdeer Common Snipe Spotted Sand. Solitary Sand. Greater Y'legs Lesser Y'legs

continued...

able 18. Concluded.

Habitat Stratum	Deciduous Forest	Coniferous Forest	Mixed Forest	Shrub	Meadow	Bog	Talus/Cliff	Lacustrine	Riverine
pen Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Common Loon Red-n. Grb. Canada Goose* Mallard Pintail Green-w. Teal Blue-w. Teal N. Shoveler Lesser Scaup Common G'eye Barrow's G'eye Bufflehead Harlequin D. Hooded Merg Common Merg Am. Coot	Canada Goose* Mallard Green-w. Teal Blue-w. Teal Lesser Scarp Common G'eye Barrow's G'eye Bufflehead Harlequin D. Hooded Merg Common Merg Am. Coot

10.1.3.3 Recreational Importance. The degrees of both non-consumptive and consumptive use were considered in the evaluation of species' recreational importance. Species that commonly support high non-consumptive uses (e.g., bird watching, photography) received scores of 2. Similarly, those with high aesthetic value, regardless of the degree of their non-consumptive use also scored highly in this category (e.g., peregrine falcons have a high aesthetic value but are infrequently seen by most people). Under consumptive use, game species were assigned values of 0, 1 or 2, 0 being assigned to non-hunted species, 1 to species of moderate importance to recreational hunting (e.g., snowshoe hares), and 2 to species that are highly important to recreational hunting (e.g., waterfowl, ungulates).

10.1.3.4 Ecological Factors. The ecological criterion consisted of two components. The first, ecological importance, refers to the degree to which a species is involved in or contributes to nutrient cycling, the food chain, and physical maintenance of their respective ecological communities. For example, snowshoe hare in sufficient numbers provide an important food source for a variety of predators (particularly lynx) and may contribute significantly to nutrient cycling through browsing activity. Because all species influence ecosystems to some degree, the lowest score assigned was 1. A score of 2 reflects a high degree of interaction within the system and/or a large role in governing or maintaining the system. For example, because of the direct contribution of beaver and muskrat to the physical maintenance of some wetland areas and their importance as prey species, each of these species would receive a rating of 2.

The second component of the ecological criterion, vulnerability to habitat alteration, was scored as 0, 1, or 2 (low, moderate, and high vulnerability, respectively). This rating was based on the species' dependence on certain habitats and its ability to utilize alternate habitat types in the event of habitat destruction or modification.

10.1.3.5 Additional Scoring Factors. Two additional factors were considered that are entirely artificial, but reflect our ability to adequately and expediently evaluate the habitat suitability for a given species. These factors are self-explanatory. Species for which detailed habitat relationships are known, and for which a habitat model already exists were, for obvious reasons, preferred as evaluation species over those with little existing information or with no existing model.

10.1.4 Step 4: Selection of Guild Representatives

The final step in the selection of key species was based on total importance scores (Table 19 and 20); the highest scoring species from each species association was selected as the representative key species. In the event of a tie, the species considered most appropriate as a key species from an ecological and/or reclamation perspective was selected. Eight mammals and two birds were selected as key species: snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse and white-tailed ptarmigan. Several of the key species represent two or more habitat strata (Table 21).

ble 19. Assignment of importance values for selection of key species of mammals.

	litical Importance: Status and Management	onomic Importance: Commercial Value	onomic Importance: Subsistence Value	creational Importance: Consumptive Use	creational Importance: Non-consumptive Use	ological Aspects: Importance to System	ological Aspects: Vulnerability	dditional Considerations: Availability of Literature	dditional Considerations: Existing Model	otal Score
Masked Shrew	0	0	0	0	0	1	0	0	0	1
Dusky Shrew	0	0	0	0	0	1	0	0	0	1
Water Shrew	0	0	0	0	0	1	1	0	0	2
Arctic Shrew	0	0	0	0	0	1	0	0	0	1
Pygmy Shrew	0	0	0	0	0	1	0	0	0	1
American Pika	1	0	0	0	0	1	2	0	0	4
Snowshoe Hare	0	0	1	1	1	1	0	2	1	7
Least Chipmunk	0	0	0	0	1	1	0	1	0	3
Yellow Pine Chipmunk	0	0	0	0	1	1	0	0	0	2
Hoary Marmot	0	0	0	0	1	1	1	1	0	4
Columbian Ground Squirrel	0	0	0	0	1	1	0	2	0	4
Golden-mantled Ground Squirrel	0	0	0	0	1	1	0	1	0	3
American Red Squirrel	0	1	1	0	1	1	0	2	1	7
Northern Flying Squirrel	0	0	0	0	0	1	1	0	0	2
Northern Pocket Gopher	0	0	0	0	0	1	0	0	0	1
American Beaver	0	2	1	0	1	2	2	2	1	11
Deer Mouse	0	0	0	0	0	1	0	2	0	3
Bushy-tailed Wood Rat	0	0	0	0	0	1	0	0	0	1
Gapper's Red-backed Vole	0	0	0	0	0	1	0	2	1	4
Northern Bog Lemming	0	0	0	0	0	1	1	0	0	2
Heather Vole	0	0	0	0	0	1	1	0	0	2
Muskrat	0	2	2	0	1	2	2	2	1	12
Richardson's Water Vole	0	0	0	0	0	1	1	0	0	2
Meadow Vole	0	0	0	0	0	2	0	2	1	5
Long-tailed Vole	0	0	0	0	0	1	0	0	0	1
Western Jumping Mouse	0	0	0	0	0	1	1	0	0	2
Porcupine	0	0	1	0	1	1	0	1	0	4
Coyote	0	1	0	1	1	1	0	1	0	5
Wolf	1	1	0	0	2	2	0	1	1	8
Red Fox	0	1	0	0	1	2	0	1	0	5
Black Bear	0	1	1	2	2	1	0	1	1	9
Grizzly Bear	1	1	1	2	2	1	1	1	0	10
Marten	0	2	0	0	1	1	1	1	1	7
Fisher	0	1	0	0	1	1	1	0	1	5
Ermine	0	1	0	0	0	1	0	1	0	3
Long-tailed Weasel	0	1	0	0	0	1	0	1	0	3
Least Weasel	0	0	0	0	0	1	0	0	0	1
Mink	0	2	0	0	1	1	2	1	1	8
Wolverine	0	2	0	0	1	1	1	0	0	5
American Badger	0	1	0	0	1	1	1	0	0	4
Striped Skunk	0	0	0	0	0	1	0	0	0	1
River Otter	0	2	0	1	1	1	1	1	0	6
Mountain Lion	2	0	0	1	2	1	1	0	0	7
Lynx	0	2	0	0	2	2	0	1	1	8
Bobcat	1	1	0	0	2	2	0	0	0	6
Caribou	2	0	1	2	2	1	2	2	0	12
Mule Deer	0	0	1	2	2	1	0	2	0	8
White-tailed Deer	0	0	1	2	2	1	0	1	0	7
Moose	0	0	2	2	2	2	1	2	1	12
Elk	1	0	2	2	2	2	1	2	0	12
Mountain Goat	1	0	0	2	2	1	2	2	0	10
Bighorn Sheep	1	0	0	2	2	1	2	2	0	10

Table 20. Assignment of importance values for selection of key species of birds in the mountain and foothills biomes. (Species whose ranges extend only marginally into the mountain/foothills area or for which there are few breeding records were not considered).

	Common Loon	Red-necked Grebe	Canada Goose	Mallard	Pintail	Green-winged Teal	Blue-winged Teal	Northern Shoveler	Lesser Scaup	Common Goldeneye	Barrow's Goldeneye	Bufflehead	Harlequin Duck	Hooded Merganser	Common Merganser
Political Importance															
Status and Management	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0
Economic Importance															
Commercial Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsistence Value	0	0	2	2	2	2	2	1	1	1	0	1	0	0	1
Recreational Importance															
Consumptive Use	0	0	2	2	2	2	2	1	1	1	0	1	0	0	1
Noncomsumptive Use	1	1	2	1	1	1	1	1	1	1	2	1	2	2	1
Ecological Aspects															
Importance to System	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vulnerability	2	1	0	0	0	0	0	0	0	1	1	1	2	1	0
Additional Considerations															
Availability of Literature	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Existing Model	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Score	6	4	8	7	7	7	7	5	5	6	6	6	7	6	5

	Goshawk	Sharp-shinned Hawk	Cooper's Hawk	Red-tailed Hawk	Golden Eagle	Bald Eagle	Marsh Hawk	Osprey	Merlin	American Kestrel	Blue Grouse	Spruce Grouse	Ruffed Grouse	White-tailed Ptarmigan	Sharp-tailed Grouse
Political Importance															
Status and Management	0	0	0	0	2	2	0	2	1	1	0	0	0	1	0
Economic Importance															
Commercial Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsistence Value	0	0	0	0	0	0	0	0	0	0	1	2	2	1	2
Recreational Importance															
Consumptive Use	0	0	0	0	0	0	0	0	0	0	1	2	2	1	2
Noncomsumptive Use	1	1	1	1	2	2	1	2	1	1	2	1	1	2	1
Ecological Aspects															
Importance to System	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vulnerability	0	0	0	0	2	2	0	2	1	0	1	0	0	1	0
Additional Considerations															
Availability of Literature	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1
Existing Model	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Total Score	3	3	3	3	8	8	3	8	5	4	8	9	8	9	7

	Sora	American Coot	Killdeer	Common Snipe	Spotted Sandpiper	Solitary Sandpiper	Greater Yellowlegs	Lesser Yellowlegs	Great Horned Owl	Hawk Owl	Pygmy Owl	Barred Owl	Great Gray Owl	Boreal Owl	Saw-whet Owl
Political Importance															
Status and Management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Economic Importance															
Commercial Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsistence Value	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Recreational Importance															
Consumptive Use	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Noncomsumptive Use	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Ecological Aspects															
Importance to System	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vulnerability	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Additional Considerations															
Availability of Literature	0	1	0	1	0	0	0	0	1	0	0	0	1	0	0
Existing Model	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Score	3	4	1	4	1	1	1	1	3	2	2	2	3	2	2

ble 21. Key species selected in each habitat stratum of the mountain and foothills biomes. The highest scoring carnivore, herbivore, waterbird, raptor and upland game species in each stratum are listed for purposes of comparison. The key species selected for each stratum is underlined.

Habitat Stratum	Deciduous Forest	Coniferous Forest	Mixed Forest	Shrub	Meadow	Bog	Talus/Cliff	Lacustrine	Riverine
ee Canopy	Beaver(11) Tree Ducks(6) Bald Eagle/ Osprey(8) Ruffed Grouse(8)	Mountain Lion/ Marten(7) Caribou(12) Tree Ducks(6) White-t. Pt.(9) Bald Eagle/ Osprey(8)	Red Squirrel(7) Marten(7) Tree Ducks(6) Bald Eagle/ Osprey(8) White-t. Pt.(9)	N/A	N/A	Red Squirrel(7) Marten(7) Tree Ducks(6) Spruce Grouse(8) Great Gray Owl(3)	N/A	N/A	N/A
rub Canopy	Grizzly(10) Moose/Elk(12) Merlin(5) Ruffed Grouse(8)	Marten(7) Caribou/ Moose/Elk(12) Merlin(5)	Grizzly(10) Caribou/ Moose/Elk(12) Merlin(5)	Grizzly(10) Moose/Elk(12)	Elk(12)	Snowshoe Hare(7)	Pika/Hoary Marmot(4) White-t. Pt.(9)	N/A	N/A
ound Surface	Grizzly(10) Moose/Elk(12) Blue/Ruffed Grouse(8)	Wolf(8) Caribou(12) Spruce Grouse(8) Greater/Lesser Yellowlegs(1)	Wolf(8) Moose/Elk(12) Ruffed Grouse(8)	Grizzly(10) Elk(12) Canada Goose(8) Merlin(5) Sharp-t. Gr.(7)	Grizzly(10) Elk(12) Canada Goose(8) Golden Eagle(8) White-t. Pt.(9)	Snowshoe Hare(7) Mink/Lynx(8) Green-w. Teal(7) Marsh Hawk(3) Spruce Grouse(8)	Grizzly(10) Mountain Goat/ Bighorn(10) Golden Eagle (8) White-t. Pt.(9)	N/A	N/A
nergent Zone/ oreline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Muskrat/ Moose(12) Canada Goose(8) Bald Eagle/ Osprey(8)	Muskrat/Moose(12) Canada Goose(8) Bald Eagle/ Osprey(8)
en Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Muskrat(12) Canada Goose(8) Bald Eagle/ Osprey(8)	Muskrat(12) Canada Goose(8) Bald Eagle/ Osprey(8)

10.2 APPENDIX 2: INDIVIDUALS INTERVIEWED FOR THE MFRRP WILDLIFE STUDIES

(Names, affiliations and date of contact of individuals interviewed during the MFRRP Wildlife Studies are listed below:)

18 December	Linda Foubuster	B.C. Fish and Wildlife
20 December	John Dick	B.C. Ministry Petroleum and Mineral Resources
3 January	John Monday	Montana Dep. Fish and Wildlife
3 January	Peter Marten	Montana Dep. Fish and Wildlife
3 January	William Schoekoph	Western Energy, Montana
3 January	John Kirkland	Saskatchewan Dep. of Mines
3 January	Sheldon McLeod	Saskatchewan Dep. of Environment
3 January	Bruce Waege	Western Energy
3 January	Roger Burton	Peter Kewit Incorporated, WO.
7 January	Larry Jones	Idaho Dep. of Game and Fish
7 January	Karen McGordon	Idaho Bureau of Reclamation
7 January	Robert Comer	Thorne Ecological Inst.
7 January	Lowell Adams	Institute of Urban Ecology, Washington, D.C.
7 January	Darrel Svedersky	Univ. of Minnesota, Crookston Mn.
8 January	Michele Mitchell	Westmoreland Mines, MT.
8 January	Gomer Jones	Nat'l. Inst. of Urban Wildlife, MY.
8 January	Marlin Murphy	Gregg River Coal, Alta.
8 January	Gary Amestoy	Administration of Reclamation. MT.
15 January	Burton Poston	CWS, Edmonton, Alberta
15 January	Jeff Bondy	Alberta Forest Service, Edmonton, Alberta
15 January	Rick Ferster	Luscar Mines, Alberta
16 January	Paul Ziemkiewicz	RRTAC, Edmonton, Alberta
16 January	William Wishart	Alberta Fish and Wildlife Division, Edmonton
17 January	Alan J. Kennedy	Esso Resources, Calgary, Alta.
21 January	Karen Natsukoshi	ManAlta Coal Ltd., Calgary, Alta.

28 January	Lin Callow	Gulf Canada Resources, Calgary, Alta.
29 January	Phil Lulman	TransAlta Utilities, Calgary, Alta.
29 January	Tim Adamson	Union Oil, Hinton, Alta.
29 January	Bill Davidson	Idaho Fish and Game Department
29 January	Gerry Thiessen	Idaho Fish and Game Department
29 January	Tony Milligan	Westar Mining, Sparwood, B.C.
30 January	Vern Betts	MacIntyre Mines, B.C.
30 January	Terry Masyck	Alberta Research Council, Edmonton, Alberta
30 January	Roger Burdussco	Fording Coal, Elkford, B.C.
30 January	Curtiss Brinker	Luscar-Sterco, Coal Valley Mine, Alta.
31 January	John Wisch	Widco, Washington State
31 January	Gerry Acott	Cardinal River Coal, Alta.
31 January	Jim Lant	Crowsnest Resources, Sparwood, B.C.
31 January	Dermot Lane	Fording Coal, Elkford, B.C.
1 February	Brent Densmore	Crowsnest Resources, Sparwood, B.C.
2 April	Bob Logan	Luscar-Sterco (Diplomat Mine), Alta.
23 May	Malcolm Ross	Crownest Resources, Calgary, Alta.

10.3 APPENDIX 3: LIST OF COMMON AND SCIENTIFIC NAMES USED IN TEXT

10.3.1 List of Common and Scientific Names of Plant Species

Common Names	Scientific Names
Grasses	
alpine bluegrass	Poa alpina
Altai wild ryegrass	Elymus angustus
bearded wheatgrass	Agropyron trachycaulum unilaterale
big bluegrass	Poa ampla
bluejoint (marsh reed grass)	Calamagrostis canadensis
Canada bluegrass	Poa compressa
chewings red fescue	Festuca rubra commutata
creeping red fescue	Festuca rubra rubra
crested wheatgrass	Agropyron cristatum
dwarf timothy	Phleum bertolonii
Elbee smooth brome	Bromus inermis
	Festuca saximontana
green needle grass	Stipa viridula
hairy wild rye	Elymus innovatus
hard fescue	Festuca ovina duriuscula
hay timothy	Phleum pratense
inland bluegrass	Poa interior
intermediate wheatgrass	Agropyron intermedium
june grass	Koeleria cristata
Kentucky bluegrass	Poa pratensis
latigume wheatgrass	Agropyron latigume
Magna smooth brome	Bromus inermis
meadow foxtail	Alopecurus pratensis
mountain timothy	Phleum alpinum

continued . . .

Common Names	Scientific Names
Grasses - continued	
northern wheatgrass	Agropyron dasystachyum
orchard grass	Dactylis glomerata
parry oat grass	Danthonia parryi
perennial ryegrass	Lolium perenne
pubescent wheatgrass	Agropyron trichophorum
redtop	Agrostic alba
reed canarygrass	Phalaris arundinacea
rough fescue	Festuca scabrella
Russian wild ryegrass	Elymus junceus
sheep fescue	Festuca ovina
slender wheatgrass	Agropyron trachycaulum
smooth brome	Bromus inermis
spike trisetum	Trisectum spicatum
streambank wheatgrass	Agropyron riparium
tall wheatgrass	Agropyron elongatum
timber oatgrass	Danthonia intermedia
tufted hairgrass	Deschampsia caespitosa
western wheatgrass	Agropyron smithii
(western) porcupine grass	Sporobolus spartea
Legumes	
alfalfa	Medicago falcata
alfalfa	Medicago sativa
alsike clover	Trifolium hybridum
birdsfoot trefoil	Lotus corniculatus
cicer milkvetch	Astragalus cicer
red clover	Trifolium pratense
sainfoin	Onobrychis viciifolia
white clover	Trifolium repens
white sweetclover	Melilotus alba
yellow sweetclover	Melilotus officinalis

continued . . .

Common Names	Scientific Names
Forbs	
ainica	*Arnica* spp.
aster	*Aster* spp.
balsam-root	*Balsamorhiza sagittata*
beard-tongue	*Penstemon* spp.
bistort/smartweed	*Polygorum* spp.
bulrush	*Scirpus* spp.
bunchberry	*Cornus canadensis*
buttercup	*Ramunculus* spp.
Canada anemone	*Anemone canadensis*
cattail	*Typha* spp.
cinquefoil	*Potentilla* spp.
coltsfoot	*Petasites* spp.
coral bells	*Heuchera richardsonii*
crowberry	*Empetrum nigrum*
cut-leaved anemone	*Anemone multifida*
everlasting	*Antennaria* spp.
false dandelion	*Agoseris glauca*
fireweed	*Epilobum angustifolium*
fleabane	*Erigeron* spp.
gaillardia	*Gaillardia aristata*
groundsel	*Senecio* spp.
harebell	*Campanula rotundifolia*
horsetail	*Equisetum* spp.
Indian paint-brush	*Castilleja* spp.
meadow rue	*Thalictrum* spp.
milk vetch	*Astragalus* spp.
moss campion	*Silene acaulis*
narrow leaved dock	*Rumex mexicanus*
northern bedstraw	*Galium boreale*
pink wintergreen	*Pyrola asarifolia*

continued . . .

Common Names	Scientific Names
Forbs - continued	
pondweed	Potamogeton spp.
prairie sagewort	Artemisia ludoviciana
purple saxifrage	Saxifraga oppositifolia
pussy-toes	Antennaria spp.
saxifrage	Saxifraga spp.
sedge	Carex spp.
stonecrop	Sedum lanceolatum
strawberry	Fragaria virginiana
sweet-broom	Hedysarum spp.
three flowered avens	Geum triflorum
vetchling	Lathyrus spp.
water milfoil	Myriophyllum spp.
wild blue flax	Linum lewisii
wild vetch	Vicia americana
wooly	Antennaria lanata
yarrow	Achillea spp.
yellow avens	Geum allepicum var. strictum
yellow pond-lily	Nuphar variegatum
Shrubs	
alpine bearberry	Arctostaphylos rubra
arctic willow	Salix arctica
Barratt's willow	Salix barattiana
beaked hazelnut	Corylus cornuta
beaked willow	Salix bebbiana
bearberry	Arctostaphylos uva-ursi
black elderberry	Sambucus melanocarpa
blueberry	Vaccinium myrtilloides
bog bilberry (blueberry)	Vaccinium uliginosum
bog birch	Betula glandulosa
bog cranberry	Vaccinium vitis-idaea

continued . . .

Common Names	Scientific Names
Shrubs - continued	
bracted honeysuckle	*Lonicera involucrata*
bristly black currant	*Ribes lacustre*
buckbrush	*Symphoricarpos occidentalis*
buffaloberry	*Shepherdia canadensis*
bunch berry	*Cornus canadensis*
choke cherry	*Prunus virginiana*
common juniper	*Juniperus communis*
creeping juniper	*Juniperus horizontalis*
crowberry	*Empetrum nigrum*
dwarf birch	*Betula glandulosa*
green alder	*Alnus crispa*
grey willow	*Salix glauca*
highbush cranberry	*Viburnum trilobum*
labrador tea	*Ledum groenlanicum*
lowbush cranberry	*Viburnum edule*
mountain alder (green alder)	*Alnus viridis*
mountain avens	*Dryas* spp.
mountain mahogany	*Cercocarpus montanus*
mountain heather	*Cassiope mertensiana*
mountain laurel	*Kalmia polifolia*
Oregon grape (creeping mahonia)	*Berberis* spp.
pin cherry	*Prunus pensylvanica*
prickly rose (wild)	*Rosa acicularis*
purple heather	*Phyllococe empetriformis*
red fruit bearberry	*Arctostaphylos rubra*
red osier dogwood	*Cornus stolonifera*
red raspberry	*Rubus strigosus*
rhododendron	*Rhododendron* spp.
river alder	*Alnus tenuifolia*
rock willow	*Salix vestita*

continued . . .

Common Names	Scientific Names
Shrubs - continued	
rocky mountain juniper	Juniperus scopulorum
salmon berry	Rubus parviflorus
saskatoon	Amelanchier alnifolia
scouler willow	Salix scouleriana
shrubby cinquefoil	Potentialla fruticosa
silverberry	Elaeagnus commutata
sitka alder	Alnus sinuata
snowberry	Symphoricarpos albus
snow brush	Ceanothus velutinus
snow willow	Salix nivalis
twinning honeysuckle	Lonicera glaucescens
wavy leaved alder	Alnus sinuata
wild gooseberry	Ribes oxyacanthoides
white avens	Dryas integrifolia
white dryad	Dryas octopetala (D. hookeriana) (D. integrifolia)
white meadow sweet	Spiraea lucida
white mountain avens	Dryas octopetala
white mountain heather	Cassiope tetragona
wood rose	Rosa woodsii
yellow avens	Dryas drummondii
yellow heather	Phyllococe glanuiflora
Trees	
alpine fir	Abies lasiocarpa
alpine larch	Larix lyallii
balsam fir	Abies balsamea
balsam poplar	Populus balsamifera
black hawthorn	Cretaegus douglasii
black spruce	Picea mariana

continued . . .

Common Names	Scientific Names
Trees - continued	
cottonwood	Populus spp.
Douglas fir	Pseudotsuga menziesii
Douglas maple	Acer glabrum
engelmen spruce	Picea engelmannii
Green's mountain ash	Sorbus scopulina
limber pine	Pinus flexilis
lodgepole pine	Pinus contorta
Manitoba maple	Acer negundo interius
paper birch	Betula papyrifera
Ponderosa pine	Pinus pondersa
Sitka mountain ash	Sorbus sitchensis
tamarack	Larix laricina
trembling aspen	Populus tremuloides
western larch	Larix occidentalis
white spruce	Picea glauca
white-bark pine	Pinus albicaulis

10.3.2 Scientific and Common Names of Mammals Occurring in the Mountain and Foothills Biomes of Alberta. (Only those species whose ranges extend well into these biomes are included. Names and ranges based on Banfield [1974].)

INSECTIVORES

Soricidae	
Sorex cinereus	Masked shrew
Sorex obscurus	Dusky shrew
Sorex palustris	Water shrew
Sorex arcticus	Arctic shrew
Microsorex hoyi	Pygmy shrew
Chiroptera	
Myotis lucifugus	Little brown bat
Myotis evotis	Long-eared bat
Myotis volans	Long-legged bat
Lasionycteris noctivagans	Silver-haired bat
Eptesicus fuscus	Big brown bat
Lasiurus cinereus	Hoary bat
Lagomorpha	
Ochotona princeps	American pika
Lepus americanus	Snowshoe hare
Rodentia	
Eutamias minimus	Least chipmunk
Eutamias amoenus	Yellow pine chipmunk
Marmota caligata	Hoary marmot
Spermophilus columbianus	Columbian ground squirrel
Spermophilus lateralis	Golden-mantled ground squirrel
Tamiasciurus hudsonicus	American red squirrel
Glaucomys sabrinus	Northern flying squirrel
Thamomys talpoides	Northern pocket gopher
Castor canadensis	American beaver
Peromyscus maniculatus	Deer mouse
Neotoma cinera	Bushy-tailed wood rat
Clethrionomys gapperi	Gapper's red-backed vole
Synaptomys borealis	Northern bog lemming
Phenacomys intermedius	Heather vole
Ondatra zibethicus	Muskrat
Arvicola richardsoni	Richardson's water vole
Microtus pennsylvanicus	Meadow vole
Microtus longicaudus	Long-tailed vole
Zapus princeps	Western jumping mouse
Erethizon dorsatum	Porcupine
Carnivora	
Canis latrans	Coyote
Canis lupus	Wolf

Carnivora - continued	
Vulpes vulpes	Red fox
Ursus americanus	Black bear
Ursus arctos	Grizzly bear
Martes americanus	Marten
Martes pennanti	Fisher
Mustela erminea	Ermine
Mustela frenata	Long-tailed weasel
Mustela nivalis	Least weasel
Mustela vison	Mink
Gulo gulo	Wolverine
Taxidea taxus	American badger
Mephitis mephitis	Striped skunk
Lutra canadensis	River otter
Felis concolor	Mountain lion
Lynx lynx	Lynx
Lynx rufus	Bobcat
Artiodactyla	
Cervidae	
Rangifer tarandus	Caribou
Odocoileus hemionus	Mule deer
Odocoileus virginianus	White-tailed deer
Alces alces	Moose
Cervus elaphus	Elk
Bovidae	
Oreamnos americanus	Mountain goat
Ovis canadensis	Bighorn Sheep

10.3.3 Scientific and Common Names of Birds Occurring in the Mountain and-Foothills Biomes of Alberta. (Only those species of upland game birds, waterbirds, and raptors whose ranges extend well into these biomes are included. Names and ranges based on Salt and Salt [1976].)

Gaviidae	
Gavia immer	Common loon
Podicipedidae	
Podiceps grisegena	Red-necked grebe
Podilymbus podiceps	Pied-billed grebe
Ardeidae	
Botaurus lentiginosus	American bittern
Anatidae	
Branta canadensis	Canada goose
Anas platyrhynchos	Mallard
Anas acuta	Pintail
Anas crecca	Green-winged teal
Anas discors	Blue-winged teal
Anas clypeata	Northern shoveler
Aythya collaris	Ringed-necked duck
Aythya affinis	Lesser scaup
Bucephala clangula	Common goldeneye
Bucephala islandica	Barrow's goldeneye
Bucephala albeola	Bufflehead
Histrionicus histrionicus	Harlequin duck
Lophodytes cucullatus	Hooded menganser
Mergus merganser	Common merganser
Accipitridae	
Accipiter gentilis	Goshawk
Accipiter striatus	Sharp-skinned hawk
Accipiter cooperii	Cooper's hawk
Buteo jamaicensis	Red-tailed hawk
Buteo swainsoni	Swainson's hawk
Buteo regalis	Ferruginous hawk
Aquila chyrsaetos	Golden eagle
Circus cyaneus	Marsh hawk
Pandionidae	
Pandion haliaetus	Osprey

Falconidae

Falco mexicanus	Prairie falcon
Falco columbarius	Merlin
Falco sparverius	American kestrel

Tetraonidae

Dendragapus obscurus	Blue grouse
Canachites canadensis	Spruce grouse
Bonasa umbellus	Ruffed grouse
Lagopus lagopus	Willow ptarmigan
Lagopus leucurus	White-tailed ptarmigan
Pediocetus phasianellus	Sharp-tailed grouse

Meleagrididae

Meleagris gallopavo	Turkey

Rallidae

Porzana carolina	Sora
Fulica americana	American coot

Charadriidae

Charadrius vociferus	Killdeer

Scolopacidae

Capella gallinago	Common snipe
Actitis macularia	Spotted sandpiper
Tringa solitaria	Solitary sandpiper
Tringa melanoleuca	Greater yellowlegs
Tringa flavipes	Lesser yellowlegs

Phalaropidae

Steganopus tricolor	Wilson's phalarope

Strigidae

Bubo virginianus	Great horned owl
Surnia ulula1	Hawk owl
Glaucidium gnoma	Pygmy owl
Strix varia	Barred owl
Strix nebulosa	Great gray owl
Aegolius funereus	Boreal owl
Aegolius acadicus	Saw-whet owl

10.4 SNOWSHOE HARE HABITAT REQUIREMENTS

10.4.1 General

This is a widely distributed species, occurring throughout the province except for the grassland zone (Soper 1964). Snowshoe hares are absent from higher elevation areas of the mountain biome due to lack of habitat, but are relatively more abundant in the foothills (Preble 1908; Soper 1964, 1970; Salt and Clarke 1979; Mill and Andersen 1980; Holroyd and VanTighem 1983).

10.4.2 Food

Snowshoe hares are largely herbivorous, although some carrion may be eaten when available (Soper 1964). The diet of this species within the province in general consists of grasses and forbs and the foliage, twigs and bark of various trees and shrubs (Soper 1964). Fall and winter diets are composed almost entirely of hardwood and coniferous browse, with a variety of green plant material being used in spring and summer (see review by Green 1979).

Food habits data from the mountain and foothills biomes are lacking except for scattered incidental observations; foods utilized include an array of grasses and forbs, and the leaves, twigs and/or bark of aspen, willow, birch, rhododendron, *Menziesia* and other shrubs, and of lodgepole pine, spruce and fir (Preble 1908; Millar 1953; Fitzmartyn and Holroyd 1978; Salt and Clarke 1979). However as snowshoe hares are opportunistic feeders (Wolff 1978; Pease et al. 1979) the range of food plants used in these biomes is certainly much broader. Preferred or major food species elsewhere (reviewed by Wolff 1978; Green 1979; USFWS 1984a), and that occur in the mountain/foothills biomes, include white spruce, black spruce, larch, Douglas fir, aspen and balsam poplar, paper and dwarf birch, several willows (including the very common *Salix bebbiana*), green and river alder, gooseberry, raspberry, prickly rose, highbush cranberry, beaked hazelnut, red osier dogwood, Labrador tea, bog cranberry, bog bilberry, white spiraea (meadowsweet), balsam-root, arnica, fireweed, horsetails and junegrass. It is noteworthy, however, that some of these (black spruce, Labrador tea) have been found to be unpalatable and little used in studies in north-central Alberta (Keith et al. 1984), as have low-bush cranberry, twining and bracted honeysuckle, and snowberry (Pease et al. 1979; Keith et al. 1984).

During periods of abundance snowshoe hares may utilize up to 100% of the browse available (Wolff 1980), but normally food selection is determined by a combination of factors, including abundance and distribution of individual plant species, and their nutrient content and palatability (Wolff 1978). Winter feeding experiments in the Rochester area indicated a mean individual daily requirement of approximately 300 g of woody browse having a diameter of 4 mm or less; hares could not maintain weight and died if kept on a diet of larger twigs (Pease et al. 1979). In the same area, Keith et al. (1984) defined hare food as browse within 60 cm of ground or snow level and having twig diameters of 4 mm or less, and measured early winter forage biomasses as ranging between 63 and 540 kg/ha. It is noteworthy that snow accumulation can act both to decrease food availability, by burying unused food supplies, or to increase it by providing better access to above snow portions of browse plants.

10.4.3 Cover and Terrain

Snowshoe hares utilize forest and shrub growth for food, and for hiding, reproductive and thermal cover. In the mountains they extend into the subalpine and even the true alpine in the vicinity of suitable shrub cover, but make greatest use of the forested lower slopes and valleys (Soper 1970, 1973). Holroyd and VanTighem (1983) found that of the 26 cover types receiving high use by hares, 19 were closed forests. Cover types used include a variety of conifer forests (composed of lodgepole pine, white spruce, black spruce, Douglas fir), mixed conifer/deciduous woods, aspen poplar forest, spruce bogs, and alder, willow, buffaloberry and silverberry thickets (Soper 1964, 1970, 1973; Nielsen 1973; Fitzmartyn and Holroyd 1978; Salt and Clarke 1979; Holroyd and VanTighem 1983). In the mountains, aspen poplar, balsam poplar, subalpine larch and Engelmann spruce/subalpine fir forests appear to receive relatively low levels of utilization (Holroyd and VanTighem 1983).

The availability of a dense shrub layer is a key habitat feature for this species. This relationship has been well-documented elsewhere (Keith 1966; VanCamp and Telfer 1975; Wolff 1980) and appears to hold also in the mountain and foothills biomes, where thickets developed in bogs and under forest cover, at the edges of alpine/subalpine meadows, along the borders of streams and lakes, along avalanche tracks and in windfall areas provide major blocks of habitat (Soper 1964, 1970, 1973; Nielsen 1973; Fitzmartyn and Holroyd 1978; Salt and Clarke 1979; Holroyd and VanTighem 1983). Similarly, clearcut areas in the foothills support high populations of snowshoe hares once suitable conifer and shrub cover have developed (Stelfox et al. 1973; Stelfox 1981). Holroyd and VanTighem (1983) suggested that habitat manipulation to favor hares could be achieved by controlled burning of alluvial forests to maintain a young, shrubby forest cover.

Deadfall is also used for cover and bed sites, and may be an important determinant of winter distribution of hares (Fitzmartyn and Holroyd 1978).

10.4.4 Space

Snowshoe hares are relatively sedentary, occupying well-defined but overlapping home ranges that, in various studies, have varied from 7 to 14 ha (Wolff 1980). Data are not available from the mountain/foothills biomes in Alberta, but in the Rockies to the south adult home range size was shown to average 8 ha in spruce-fir forest, the preferred habitat (Dolbeer and Clark 1975).

Snowshoe hare populations undergo cyclic fluctuations, reaching peak densities every 8-11 years (Keith 1963). Although not as well-documented as elsewhere, population fluctuations do occur in the foothills and mountain areas (Soper 1964).

These cycles are important determinants of use of both space and habitat. It has been shown elsewhere that during periods of population expansion, successively less favorable areas are occupied, whereas during low points in the cycle the population retreats into pockets of the most favorable habitat (Keith 1966; Keith and Windberg 1978; Wolff 1980), resulting in a mosaic of hare densities related to habitat quality. This probably explains observations in western Alberta of local abundance of hare in some areas but scarcity or virtual absence in others (Preble 1908; Clarke 1942; Banfield 1958).

During a population high in the early part of the century, peak hare densities in the mountain parks were estimated at 1000 or more per mi2, an equivalent of 3.9/ha (Soper 1947; Banfield 1958), but they subsequently were scarce (Soper 1970). No data are available for the foothills, although in the boreal mixedwood region to the east hare populations have fluctuated between lows of 1.3 to 2.6/ha and highs of 5.9 to 11.8/ha (Windberg and Keith 1978), and up to 18.2/ha in regenerating burned habitat (Keith et al. 1984).

10.4.5 Size and Interspersion of Habitat Units

Interspersion or habitat patchiness appears to be an important component of snowshoe hare habitat, although this factor has not been quantified in western Alberta. Studies in Alaska have shown that patchy habitat (dense black spruce and willow thickets interspersed with open areas) permitted snowshoe hares to feed on herbaceous material and low shrubs in openings in summer, then shift to a browse diet obtained from dense thickets in winter (Wolff 1980). Salt and Clarke (1979) noted that in the Kananaskis area in winter hares kept to dense shrub cover during the day but wandered in the open at night. In addition, dense thickets are important refugia during population crashes (Keith 1966; Wolff 1980).

In mature forests, snowshoe hares may depend on an interspersion of openings (Dodds 1960). Several natural physical processes (wind and water action, fire, avalanches) and human activities (logging) serve to create or maintain openings used as hare habitat in the mountains and foothills, but data on optimum size and interspersion are lacking. Studies on effects of logging in Michigan have suggested that for maximum utility to hares, cut blocks should be small or shaped so that canopy cover is available within 200 - 400 m of all parts of the opening (Conroy et al. 1979).

10.4.6 Habitat Models

Green (1979) and Green et al. (1984) provide detailed reviews of the literature on food habits, habitat utilization and demography of snowshoe hares. A review of habitat requirements and formulation of a habitat model, based largely on data from Alaska, are in preparation (USFWS 1984a).

10.5 BEAVER HABITAT REQUIREMENTS

10.5.1 General

Beavers occupy aquatic habitat throughout the province, with the exception of most of the prairie (grassland) zone (Soper 1964). The major habitat requirements are waterbodies suitable for year-round occupation, and an adjacent supply of food and building materials in the form of deciduous woods or shrublands (Soper 1970; Slough and Sadleir 1977; Todd 1978). The mountain and foothills biomes are considered to be secondary range for this species (Alberta Fish and Wildlife Division 1984), primarily due to the relative paucity of suitable waterbodies. Nevertheless, beavers are widely distributed in these biomes and may be locally abundant under favorable habitat conditions (Soper 1970; Sverre 1972; Wallis and Wershler 1972; Salt and Clarke 1979; Mill and Andersen 1980; Holroyd and VanTighem 1983). Their altitudinal range extends to the upper subalpine (Holroyd and VanTighem 1983).

10.5.2 Food

Food consists primarily of the bark, twigs, leaves and to some extent green wood of willows and aspen (Ashley 1954; Sverre 1972), although balsam poplar, alder, paper birch, dwarf birch, rose, red osier dogwood, silverberry and saskatoon may also be used (Soper 1970; Sverre 1972; Nielson 1973; Salt and Clarke 1979). Herbaceous terrestrial vegetation is utilized during summer, but probably constitutes a small proportion of the total diet (Sverre 1972; Salt and Clarke 1979). Aquatic macrophytes such as yellow pond lily are important seasonal foods in some areas (e.g., reviews by Todd 1978; Searing 1979; Allen 1983) and are probably used in the mountain/foothills biomes, but documentation is lacking.

Woody vegetation is harvested and stored for winter use in the form of aquatic food caches (Soper 1970, 1973). However, in the Porcupine Hills, and possibly elsewhere subject to mild winter conditions, beavers forage onshore during winter and do not construct food caches (Sverre 1972).

10.5.3 Cover and Terrain

Beavers occupy a variety of aquatic habitats, ranging from ponds and small streams to the larger lakes and rivers (Soper 1970, 1973; Sverre 1972; Holroyd and VanTighem 1983). Minimum water depths of 0.9 to 1.5 m are required under Alberta climatic conditions (Todd 1978), mainly to enable travel beneath ice. Marginal habitat may be improved by blocking outflow areas or slow-flowing streams with dams constructed of sticks and mud (Soper 1970; Sverre 1972; Nielsen 1973; Salt and Clarke 1979; Mill and Andersen 1980). Streams with gradients of up to 13% are occupied, although dams tend to be constructed on sections with somewhat lower gradients (e.g., 5 to 7%: Sverre 1972). Gentle to moderate slopes (as opposed to steep slopes) adjacent to waterbodies facilitate foraging and limit erosion (Sverre 1972).

Mud and stick lodges, with entrances under water, are constructed by beavers and provide thermal, escape, resting and reproductive cover (Soper 1970; Sverre 1972; Nielsen 1973). Bank dens also are used in some foothills and mountain areas (Millar 1953; Soper 1970, 1973; Nielsen 1973). Clay soils are preferred for construction purposes (Sverre 1972).

In addition to aquatic sites providing adequate water depths and stability, beavers require a nearby source of food and building materials. Woody plants are generally cut close to shore, but foraging may extend inland 100 m or more, depending on topography and availability (Soper 1970; Sverre 1972). Aquatic sites occupied in the mountains may be surrounded by forest, shrub or herbaceous cover, but vegetation near the water's edge is usually willow, poplar or other deciduous growth (Holroyd and VanTighem 1983). In the foothills all of 60 active beaver colonies surveyed had willow present (forming the primary cover at 47 sites, and secondary cover at 10), 37 had aspen present (forming primary cover at 3 and secondary cover at 17 sites), 22 had balsam poplar present (forming primary cover at 4 sites), 21 had conifers present (forming primary cover at 3 sites) and 18 had birch present, forming the primary cover at 1 site (Sverre 1972).

At a subsample of four of the above sites, willows comprised 85.6% of total stems cut by beavers and aspen 9.0%; 92.1% of willow stems cut were 5 cm or less in basal diameter as were 67.3% of cut aspen stems, although aspen was felled even when greater than 25 cm basal diameter. Willow density averaged 204.0 x 10^2 stems/ha, with a mean biomass of 152.6 x 10^2 kg/ha, while aspen density averaged 38.9 x 10^2 stems/ha with a mean biomass of 113.8 x 10^2 kg/ha (Sverre 1972).

Willow is probably the most important plant component of beaver habitat throughout the mountain and foothills biomes as a whole, forming an edaphic climax in many riparian situations and regenerating after browsing (Sverre 1972; see also Slough and Sadleir 1977). Conversely, aspen occurs in fire subclimax stands that generally produce only one crop, and that are replaced by willows (Sverre 1972) or conifers (Slough and Sadleir 1977) when removed by beavers. Nevertheless aspen stands provide important habitat where they occur (Sverre 1972; Holroyd and VanTighem 1983), and perpetuation of aspen habitat has been proposed by Slough and Sadleir (1977) as a powerful beaver management tool. By contrast, conifers are little used for either food or construction materials (Sverre 1972; see also review by Allen 1983) and beavers may be forced to forage over wider areas where conifers dominate the cover near shore (Soper 1970).

Exhaustion of food supply appears to be a relatively common cause of site abandonment (Ashley 1954), other factors being silting up of ponds and winter mortality (Sverre 1972).

10.5.4 Space

Beavers occur in colonies consisting of a monogamous pair of adults, subadults and young of the year, with an average colony size of five (reviews by Sverre 1972 and Allen 1983). Colonies occupy distinct and non-overlapping territories, and use of space is determined by social as well as by habitat factors.

Except for long-distance dispersal movements undertaken by subadults, beavers appear to remain within relatively confined home ranges, foraging a maximum 245 m (but usually 30 m or less) inland, and up to 800 m along shore from the lodge or cache (reviews by Todd 1978; Searing 1979; Allen 1983). Few data are available from the mountain or foothills biomes, apart from Soper's (1970) and Sverre's (1972) observations of beavers foraging up to 100 m inland.

Population densities of 0.16 colonies/km of stream, or 0.07 colonies/km^2 of total study area, have been documented in the southern foothills (Sverre 1972), but density data apparently are not available for other areas of the mountain/foothills biomes. Favorable habitat elsewhere in North America supports 0.4 to 0.8 colonies/km^2 (review by Allen 1983).

10.5.5 Size and Interspersion of Habitat Units

Sverre (1972) calculated a mean beaver pond size of 0.63 ha in the Porcupine Hills, which may provide an approximation of minimum water area required; much larger lakes are occupied elsewhere in Alberta. Sverre (op. cit.) also calculated that .08 ha of forest/shrub habitat could supply the annual food requirements of a colony, based on a combined willow/aspen dry weight biomass of 260 x 10^2 kg/ha, and 50% utilization. It is noteworthy here that Allen's (1983) habitat model assumes that a minimum of 0.8 km of stream channel or 1.3 km^2 of lake/marshland habitat needs to be available to be suitable for occupation by beavers.

Todd's (1978) description of Class 1 beaver habitat in Alberta, based partly on work in the northern foothills, succinctly summarizes the size, interspersion and other physical characteristics of good beaver habitat:

1. streams: "average drainage density about 1.8 km of stream per square km of land surface area or more; about 50% of stream length is permanent streams of the following description: low gradient (< 3%), meandering streams generally 1.5 to 7.5 m wide and 0.9 to 1.5 m or more deep; discharge ranging from 6 to 2832 L/S. Valley width greater than 45 m with a variably broad, mesic floodplain covered with willow and alder. Aspen and possibly balsam poplar available within 90 m of stream edge on gently to moderately sloping (<25%) valley slopes. Ideal valley alignment is basically

east-west because aspen is most apt to occur on south-facing slopes at more northerly latitudes. Accessible poplar woods are not altogether necessary, however, provided that a broad expanse of willow/alder adjoins the stream. Tributary intermittent creeks will provide additional colony sites. The soil type on the stream banks must be sufficiently heavy-textured to support dam construction."

2. lakes/potholes: "lakes with numerous islands and highly irregular shorelines (e.g., 3.2 km of shoreline per square km of surface area) may provide excellent beaver habitat provided that water depths are adequate, mud substrates are available for lodge construction, and suitable deciduous tree or shrub food sources are available. High density complexes of small, irregular lakes and potholes may also provide ideal beaver habitat."

Beavers are tolerant of human activities, but transportation corridors and land clearing adjacent to waterways may adversely affect habitat suitability (Slough and Sadleir 1977). Conversely, beavers may become problem animals by flooding roads and other developments (Mill and Andersen 1980; Alberta Fish and Wildlife n.d.).

10.5.6 Habitat Models

Sverre (1972), Slough and Sadleir (1977), Todd (1978), Searing (1979), Allen (1983), Green et al. (1984), Nietfeld et al. (1984) and USFWS (1984b) provide detailed reviews of beaver habitat requirements.

Todd (1978) outlines criteria for assessing and mapping land capability for beaver production in Alberta, based on a minimum map unit size of 2.5 km^2. IEC Beak (1984a) provide a quantitative model for assessing beaver habitat suitability in each of 278 habitat subregions (homogeneous land units) in Alberta, as discerned from 1:500 000 scale Landsat imagery.

Slough and Sadleir (1977) provide a land capability classification system for beaver, based on multiple regression models of beaver-habitat relationships in British Columbia, and applicable to small, discrete units of potential habitat (lakes and stream sections of uniform gradient). Allen (1983) also provides a mathematical model applicable to determining habitat suitability of individual wetland units.

10.6 MUSKRAT HABITAT REQUIREMENTS

10.6.1 General

Muskrats are distributed throughout the province (Soper 1964). They are rare in the mountains, where suitable aquatic habitat is very limited, but are relatively more abundant and well-distributed in the foothills (Soper 1947, 1964, 1970; Wallis and Wershler 1972; Salt and Clarke 1979; Mill and Andersen 1980).

10.6.2 Food

No specific information on food habits is available from either the mountain or foothills biomes. However, judging from habitat occupancy (see below), food habits are likely similar to those documented elsewhere. Muskrats feed primarily on aquatic vegetation (Willner et al. 1975), but agricultural crops and animal matter are used in some situations (Errington 1961). Cattails and bulrushes are the most important forage species within the North American range (Willner et al. 1975; Allen and Hoffman 1984). Although a number of studies have identified a preference for cattail over bulrush (review by Allen and Hoffman op. cit.), a strong preference for *Scirpus acutus* has been documented in southern Alberta (Welch 1980). Submergents are locally and/or seasonally important food sources (Fuller 1951; Stevens 1955; Welch 1980).

10.6.3 Cover and Terrain

In the mountains and foothills, muskrat habitat is restricted to valley bottoms where standing waterbodies and slow-moving streams, or backwaters along major rivers, have developed (Soper 1964, 1970, 1973; Holroyd and VanTighem 1983). Primary requirements are aquatic and semi-aquatic plant growth sufficient for food and cover requirements, and water depths adequate for year-round foraging.

Suitable vegetation includes submergent beds of water milfoil and pondweed, emergent stands of sedge, grasses (bluejoint, tufted hairgrass), cattail and bulrush, and seasonally flooded shrublands composed of willows, dwarf birch and shrubby cinquefoil (Soper 1970; Holroyd and VanTighem 1983). Muskrat habitats in these biomes, as elsewhere, are dependent on periodic flooding to retard plant succession (Holroyd and VanTighem op. cit.). Beaver ponds often are used (Banfield 1947; Soper 1970; Salt and Clarke 1979; Sverre 1972), and the local range of muskrats may closely parallel the distribution of beaver habitat (Soper 1973; Mill and Andersen 1980).

Where suitable vegetation is available, muskrats construct houses for thermal and hiding cover and for raising litters; along streams and elsewhere lacking emergents, dens are constructed in stable banks, with the entrances under water (Soper 1970, 1973; see also reviews by Todd (1978), Searing (1979) and Allen and Hoffman (1984)). Banks suitable for denning feature a relatively steep drop-off from shore, permitting access under ice (Todd 1978). Riparian vegetation contributes to bank stability and traps an insulating layer of snow, which may limit ice development over burrow entrances (reviews by Todd 1978 and Searing 1979).

Specific data on water depth requirements are not available for the mountain and foothills biomes. A review of data developed elsewhere in western Canada suggests that optimum depths (i.e., permitting both development of emergents and travel beneath ice in winter) range between 0.9 and 1.8 m (Todd 1978).

10.6.4 Space

Dispersion of muskrats within blocks of suitable habitat is dependent on both habitat quality (distribution and abundance of food, cover and water) and social factors. They generally remain within home ranges of 200 m or less in diameter, part of which area may be defended as breeding territory. This subject is reviewed in detail by Searing (1979); data specific to western Alberta are not available.

Excellent quality habitat units in Alberta would be expected to sustain in excess of 40 active houses/km^2 (Todd 1978).

10.6.5 Size and Interspersion of Habitat Units

Todd's (1978) land capability classification for Alberta furbearers, developed partly from data obtained from the northern foothills zone, outlines the following size and interspersion characteristics of areas with very high to moderately high capability for muskrat production:

1. units comprised almost entirely of irregular lakes and/or marshes with adequate water depths, and extensive offshore emergents well interspersed with submergents throughout. Percent of area covered by emergent stands may vary from 10 to 60+%.

2. units where numerous small (0.4 to 16 ha), irregular sloughs cover more than 50% of the area, with abundant emergents throughout and well-developed emergent stands offshore, or with shoreline development suitable for bank dens.

3. shallow lakes less than 10 km^2 in size, with regular shorelines suitable for burrowing and abundant submergents throughout, or moderately high density sloughs and potholes as in (2) above.

10.6.6 Habitat Models

Todd (1978) and Green et al. (1984) summarize habitat requirements of this species, and Todd (op. cit.) details a system for rating present capability of land units for muskrat production in Alberta. Searing (1979) and Allen and Hoffman (1984) provide thorough reviews of muskrat habitat requirements based on the world literature; the latter also provides a quantitative habitat suitability index model.

10.7 ELK HABITAT REQUIREMENTS

10.7.1 General

The current distribution of elk in the province is limited primarily to the mountain and foothills biomes, and to a few outlying areas such as the Cypress Hills and the region surrounding Elk Island N.P. (Soper 1964; Alberta Fish and Wildlife Division 1984). Prime elk range is concentrated in the southwestern part of the province, south of the Clearwater River (Alberta Fish and Wildlife Division 1984).

10.7.2 Food

Elk in the mountain and foothills biomes subsist primarily on gramineous plants (Flook 1964; Salt and Clarke 1979; Morgantini and Hudson 1983). Browse is generally a relatively minor dietary constituent in winter (Cowan 1947; Flook 1964; Table 22), but increases in importance during summer-fall and on some midsummer ranges may provide the bulk of the diet (Flook 1964; Morgantini and Hudson 1983). Forbs are little used during any season (Table 22). Depredations on haystacks and greenfeed occur on ranches within and

Table 22. Food species used by Elk in the mountain and foothills biomes.

	Reference, Area and Diet Composition[1]						
	Berg 1983 (upper Oldman R. area)[2]	Salter and Hudson 1980 (upper Red Deer R. area)[3]	Morgantini and Hudson 1983 (YaHa Tinda Ranch, Banff N.P.)[4]	Morgantini and Russell 1983 (upper Red Deer R. area)[5]	Morgantini and Russell 1983 (upper Clearwater R. area)[6]	Morgantini and Russell 1983 (upper Blackstone R. area)[7]	Morgantini and Olson 1983 (Wolf Creek-Brazeau R. area)[8]
Trees and Shrubs							
Amelanchier spp.	-	-	-	1.2%w	0.1%w	-	-
Artemisia spp.	0.2%w	-	-	0.4%w	1.3%w	-	-
Browse spp.	-	-	2.2w/s,0.2%s	-	-	1.0%w	25.5%w
Juniperus spp.	0.4%w	-	-	1.0%w	-	-	-
Pinus contorta	-	22%w	-	-	-	-	-
Pinus spp.	-	-	-	0.7%w	2.4%w	3.8%w	-
Picea spp.	0.1%w	xw	-	1.6%w	0.8%w	6.8%w	-
Pseudotsuga spp.	3.7%w	-	-	-	0.3%w	-	-
Rubus spp.	<0.1%w	-	-	-	-	-	-
Salix spp.	<0.1%w	19%w	1.5w/s,88.6%s	8.1%w	7.2%w	11.6%w	-
Shepherdia canadensis/ *Elaeagnus commutata*	<0.1%	xw	-	2.4%w	1.0%w	1.4%w	-
Vaccinium spp.	-	-	-	-	-	0.6%w	-
Graminoids							
Agropyron spp.	0.2%w	-	-	-	-	-	-
Agropyron/*Elymus*.	-	-	-	2.5%w	3.7%w	6.2%w	-
Agrosti scabra	-	-	-	-	-	-	-
Bouteloua spp.	0.2%w	-	-	-	-	-	-
Bromus spp.	0.1%	-	-	-	0.1%w	-	-
Carex spp.	2.6%w	9%w	-	19.4%w	16.6%w	19.2%w	-
Cyperaceae spp.	-	-	4.2w/s,2.4%s	-	-	-	40.3%w
Danthonia intermedia	-	1%w	-	0.2%w	0.2%w	1.2%w	-
Danthonia spp.	4.8%w	-	-	-	-	-	-
Deschampsia spp.	-	-	-	-	1.6%w	8.5%w	-
Eleocharis spp.	-	-	-	0.1%w	-	-	-
Elymus innovatus	-	19%w	0.6w/s,1.7%s	-	-	-	-
Elymus spp.	<0.1%w	-	-	-	-	-	-

continued...

Table 22. Continued

	Reference, Area and Diet Composition[1]						
	Berg 1983 (upper Oldman R. area)[2]	Salter and Hudson 1980 (upper Red Deer R. area)[3]	Morgantini and Hudson 1983 (YaHa Tinda Ranch Banff N.P.)[4]	Morgantini and Russell 1983 (upper Red Deer R. area)[5]	(upper Clearwater R. area)[6]	(upper Blackstone R. area)[7]	Morgantini and Olson 1983 (Wolf Creek-Brazeau R. area)[8]
Festuca spp.	85.2%w	21%w	88.2w/s,0.4%s	52.8%w	60.5%w	20.3%w	-
Gramineae spp.	<0.1%w	-	0.9w/s,0.5%s	-	-	-	13.4%w
Juncus spp.	-	-	-	0.2%w	0.3%w	1.2%w	-
Koeleria cristata	0.3%w	xw	-	0.6%w	0.8%w	1.4%w	-
Poa spp.	0.9%w	-	0.2w/s,1.3%s	1.9%w	1.4%w	1.6%w	-
Schizachne purpurascens	-	xw	-	-	-	-	-
Stipa spp.	1.0%w	-	-	0.6%w	-	-	-
Forbs							
Astragalus spp.	-	xw	-	-	-	0.3%w	-
Compositae spp.	<0.1%	-	-	-	0.1%w	-	-
Delphinium spp.	-	-	-	0.1%w	<0.1%w	0.3%w	-
Draba spp.	-	-	-	-	-	0.3%w	-
Forb spp.	-	-	2.0%w/s,3.2%s	-	-	-	3.9%w
Galium spp.	-	-	-	0.6%w	-	-	-
Lupinus spp.	<0.1%w	-	-	-	-	-	-
Mertensia spp.	-	-	-	-	-	0.6%w	-
Petasites spp.	-	-	-	-	-	-	-
Potentilla/Geum spp.	-	2%w	-	-	-	-	-
Saxifraga spp.	-	-	-	-	0.1%w	-	-
Stellaria spp.	-	-	-	-	0.1%w	-	-
Vicia spp.	-	-	-	-	0.1%w	0.4%w	-
Horsetails, Club-mosses and Mosses							
Equisetum spp.	-	<1%w	-	4.8%w	1.1%w	11.0%w	15.8%w

continued...

Table 22. Concluded

	Reference, Area and Diet Composition[1]						
	Berg 1983 (upper Oldman R. area)[2]	Salter and Hudson 1980 (upper Red Deer R. area)[3]	Morgantini and Hudson 1983 (YaHa Tinda Ranch Banff N.P.)[4]	Morgantini and Russell 1983 (upper Red Deer R. area)[5]	Morgantini and Russell 1983 (upper Clearwater R. area)[6]	Morgantini and Russell 1983 (upper Blackstone R. area)[7]	Morgantini and Olson 1983 (Wolf Creek-Brazeau R. area)[8]
Lycopodium spp.	-	-	-	0.2%w	-	-	-
Moss spp.	-	-	-	-	0.1%w	-	-
Selaginella spp.	-	-	-	0.2%w	-	1.1%w	-
Lichens	-	xw	-	-	-	0.4%w	-

1 x = present in diet; w = winter (October-March, or part thereof); s = spring-summer-fall (April-September, or part thereof). All diet compositions determined from identification of plant cuticular fragments in composite fecal samples.

2 fecal samples collected during winter (months not specified).

3 fecal samples collected January, February, March.

4 fecal samples collected monthly on winter range (December-May: w/s) and summer range (July-August: s).

5 fecal samples collected November, December, January, March.

6 fecal samples collected monthly November-March.

7 fecal samples collected December and March.

8 fecal samples collected monthly December-March, in each of 2 years. Browse in diet consisted mainly of Salix spp. Equisetum spp. includes minor amounts of other genera.

adjacent to the outer foothills (Banfield 1947; Alberta Fish and Wildlife Division n.d.).

Fescues and sedges are by far the most important gramineous species in elk diets in the mountain/foothills region as a whole, although hairy wild rye and horsetails are locally important constituents (Holroyd and VanTighem 1983; Morgantini and Hudson 1983, 1985; Table 22). Willows are the most widely used and important browse species, but others such as pine, spruce, silverberry, buffaloberry and aspen may be locally and/or seasonally important (Banfield 1947; Flook 1964; Salt and Clark 1979; Morgantini and Hudson 1983; Table 22).

Forage selection during the growing season appears to be related to protein content (Morgantini and Hudson 1983), whereas during winter food selection may be related more to dry matter digestibility (Morgantini and Hudson 1985).

10.7.3 Cover and Terrain

Elk are an opportunistic and highly adaptable species, occupying a broad range of habitat conditions even within a localized area. Habitat selection patterns are therefore difficult to generalize. Nevertheless, elk habitat can be categorized on a coarse scale as consisting of grasslands and shrublands interspersed with forested areas, and located in valley bottoms and on adjacent slopes and benches (Flook 1964; Soper 1970, 1973; Fitzmartyn and Holroyd 1978; Mussell 1982; Holroyd and VanTighem 1983). The altitudinal range of elk habitat in the mountain/foothills biomes extends from the outer (eastern) part of the foothills zone to the lower alpine.

Observational and dietary data indicate that open and sparsely treed grassland communities provide the major foraging habitat (Morgantini 1979; Salter and Hudson 1980; Berg 1983; Morgantini and Russell 1983). Alpine tundra receives relatively less use (Holroyd and VanTighem 1983), but provides seasonally important and perhaps essential foraging habitat to local elk populations, due to the high protein content and digestibility of alpine plants (Morgantini and Hudson 1983; Morgantini 1984). Shrublands and a variety of deciduous, coniferous and mixedwoods forests also are used for feeding to some extent (Nielsen 1973; Telfer 1978a; Morgantini 1979; Salter and Hudson 1980; Berg 1983; Morgantini and Olsen 1983). Both forest cover and hilly terrain are used for escape and shelter (Flook 1964; Stelfox and Taber 1969; Soper 1970; Telfer 1978a; Morgantini 1979; Holroyd and VanTighem 1983).

Natural disturbances such as fire and avalanching appear to be important in the maintenance of elk habitat (Flook 1970; Holroyd and VanTighem 1983). Elk also utilize logged areas once suitable forage cover and shelter have developed (Stelfox 1981), and make some use of seeded grasslands (Stelfox and Warden Service 1974; Sullivan and Stelfox 1974) and other reclaimed areas (Kuhn and Martens 1980).

Elk are associated primarily with gently to moderately sloping terrain (i.e., slopes of 30% or less), although steeper, vegetated slopes also are used (Morgantini 1979; Salter and Hudson 1980; Strong and Vriend 1980; Berg 1983). Predominant use occurs on west-south and east exposures (Nielsen 1973; Stelfox and Warden Service 1974; Strong and Vriend 1980; Berg 1983), with use shifting from westerly aspects in winter to east aspects in spring (Berg 1983).

During winter elk concentrate in areas of reduced snow depth, generally avoiding sites with accumulations of more than 50-60 cm (Telfer 1978b; Holroyd and VanTighem 1983). West to south-facing grassland slopes and valley bottoms, where snow accumulations are reduced or periodically removed by wind and sun action, are particularly important winter habitats (Flook 1970; Telfer 1978b;

Morgantini 1979; Salter and Hudson 1980; Strong and Vriend 1980; Morgantini and Russell 1983).

10.7.4 Special Habitat Features

Elk in the mountain/foothills biomes make use of natural mineral licks (Cowan and Brink 1949; Carbyn 1975; Holroyd and VanTighem 1983), but their importance is poorly understood and they may not be essential features of habitat (Skovlin 1982). Other mineral sources, such as salt grounds established for cattle and drillhole seepages at mine sites, also are used (Kuhn and Martens 1980; Berg 1983).

10.7.5 Space

Elk exhibit seasonal shifts in habitat use related to snow depth, floral phenology and nutritional factors (Flook 1964; Soper 1970, 1973; Nielsen 1973; Strong and Vriend 1980; Morgantini and Hudson 1983). In the mountains seasonal movements may involve round-trip travel distances of up to 138 km, and total vertical movements of 2000 m (Flook 1964; Morgantini and Hudson 1983; Morgantini 1984). Overnight, vertical movements of 600 m over a linear distance of 9 km have been documented, but most movement occurs as a gradual shift between restricted winter range and more widely dispersed summer range (Morgantini and Hudson 1983). Valley bottoms appear to be the major movement corridors (Banfield 1947; Morgantini and Hudson 1983).

Some elk populations, or segments of populations, apparently forego altitudinal migrations (Flook 1964; Strong and Vriend 1980), satisfying habitat requirements by remaining in areas of high vegetational heterogeneity (Morgantini and Olsen 1983).

10.7.6 Size and Interspersion of Habitat Units

Good elk habitat consists of open forage-producing sites interspersed with forest areas and/or geomorphic features providing escape and thermal cover. Winter ranges receiving highest use in southern Alberta consist of 60-75% foraging area, with thermal and hiding cover comprising the remainder (Strong and Vriend 1980). Forage:cover ratios of 60:40 have been described as optimal elsewhere (Black et al. 1975). Also in southern Alberta, Berg (1983) characterized key elk range sits as being small (probably <25 ha each, but sites may be contiguous) often snow-free, and in open grassland adjacent to grass/conifer range.

Use of foraging areas varies with distance to cover and with disturbance factors (Morgantini 1979; Berge 1983; Morgantini and Russell 1983). Berg (1983) found that almost all elk activity (100% of observations, 99.6% of pellet groups) occurred within 250 m of tree or shrub cover, and that elk on grassland range were most likely to react to disturbance when 100-250 m from cover. Morgantini (1979) and Morgantini and Hudson (1980) documented a redistribution of elk in relation to severe disturbance (vehicular and human activity during a special winter hunting season) that resulted in a 70% decrease in grassland use; a corresponding shift in forage intake resulted in increased use of browse and forest grasses, and decreased diet digestibiltiy (Morgantini and Hudson 1985).

Considering the dependence of elk on limited, traditional wintering area, Telfer (1978b) suggested that road networks and other disturbances (e.g., logging) in the foothills be sited to avoid key winter ranges, and if possible be screened by topographic features.

10.7.7 Habitat Models

Elk habitat requirements are reviewed in detail by Skovlin (1982) and are highlighted by Nietfeld et al. (1984). IOEC Beak (1984b) provides a model for rating habitat suitability of broad-scale land units for elk in Alberta. Leege (1984) outlines a tabular method for estimating quality of elk summer habitat in northern Idaho, and for evaluating effects of land management activities.

10.8 MOOSE HABITAT REQUIREMENTS

10.8.1 General

Moose occur throughout Alberta with the exception of the grassland and most of the aspen parkland region (Soper 1964). The mountain and foothills biomes are classed as prime range, supporting on average 1 - 2 moose/km^2 (Alberta Fish and Wildlife Division 1984).

10.8.2 Food

Moose are primarily browsers, the preferred species being characteristic largely of successional and riparian communities (Peek 1974). In the western part of the range willows are considered to be the most important browse species (Kelsall and Telfer 1974; Peek 1974), and this generalization appears to hold true for the mountain and foothills biomes as indicated both by habitat selection and food habits (Table 23). *Salix arbusculoides* and *S. macallania* are considered to be preferred over the little-used *S. glauca* (Millar 1953; Flook 1964), but preference/avoidance of other willow species has not been documented for this area. Browse (including leaf buds, leaves, twigs and sometimes bark) is utilized throughout the year (Millar 1953; Flook 1964; Salt and Clarke 1979), although where available aquatic plants are used in summer (Millar 1953; Flook 1964; Soper 1970; Salt and Clarke 1979; Holroyd and VanTighem 1983). Forbs and gramineous plants appear to form only a small proportion of the total diet, although a fall stomach sample examined by Millar (1953) contained almost 100% gramineous material, suggesting that graminoids may be seasonally important at least to some animals. Salt and Clarke (1979) reported that in the Kananaskis area grasses are a staple food in winter.

Table 23. Food species used by Moose in the mountain and foothills biomes.

	Reference, Area and Diet Composition[1]				
	Clarke 1972 (Jasper N.P.)[2]	Millar 1953 (Rock Lake)[3]	Flook 1964 (Jasper/ Banff)[2]	Fitzmartyn and Holroyd 1978 (Lake Louise)[2]	Salt and Clarke 1979 (Kananaskis)[2]
Trees and Shrubs					
Abies lasiocarpa	x	0.6%w	-	-	-
Abies spp.	-	xs	-	xw	x
Alnus crispa	-	0.9%w,xs	-	-	-
Anelanchier alnifolia	-	-	x	-	-
Betula glandulosa	x	0.3%w,xs	x	-	-
Cornus stolonifera	-	-	x	-	-
Juniperus spp.	-	xw	-	-	-
Menziesia glabella	-	-	-	-	x
Picea spp.	-	-	-	xw	x
Pinus contorta	-	3.2%w	-	xw	-
Populus balsamifera	-	0.7%w,xs	-	-	-
P. tremuloides	-	1.9%w,xs	x	-	-
Prunus virginiana	-	-	x	-	-
Rhododendron spp.	-	0.1%w	-	-	x
Ribes spp.	-	xw	-	-	-
Rosa spp.	-	xw	-	-	-
Salix arbusculoides	-	xw	-	-	-
S. glauca	-	xw	xw	-	-
S. maccalliana	-	xw	xw	-	-
Salix spp.	x	90.8%w,xs	x	xw	x
Shepherdia canadensis	-	1.3%w,xs	-	-	-
Graminoids					
Carex spp.	-	xs	xw,xs	-	x
Elymus spp.	-	xs	-	-	-
Gramineae	-	xw,xs	xw	-	x
Juncus spp.	-	xs	-	-	x
Typha spp.	-	-	-	-	x

continued...

Table 23. Concluded

	Reference, Area and Diet Composition[1]				
	Clarke 1972 (Jasper N.P.)[2]	Millar 1953 (Rock Lake)[3]	Flook 1964 (Jasper/ Banff)[2]	Fitzmartyn and Holroyd 1978 (Lake Louise)[2]	Salt and Clarke 1979 (Kananaskis)[2]
Forbs/Horsetails/Aquatics					
Epilobium spp.	-	xs	-	-	-
Equisetum spp.	-	-	xs	-	-
Galium boreale	-	xs	-	-	-
Hippurus vulgaris	-	xs	xs	-	-
Lathyrus spp.	-	xs	-	-	-
Mertensia spp.	-	xs	-	-	-

1 x = present in diet; w = winter; s = spring-summer-fall (i.e., snow-free period).

2 presence in diet based on general observations.

3 dietary data based on browse plots, stomach samples and general observations.

Studies in the Streeter Basin and Hinton areas have shown strong correlations between level of moose utilization of a site and the weight per unit area of winter browse available (Telfer 1978b). Browse production in areas used by moose varied between about 25 kg/ha (lowest use) and 425 kg/ha (highest use). Wide variation in use of areas with low browse production suggested that use may also have been related to other factors such as earlier bud bursting or later leaf fall (Telfer op. cit.).

10.8.3 Cover and Terrain

Moose use a variety of cover and terrain types, but are most strongly associated with areas where active processes such as alluvial and wind action, avalanches, impeded drainage, fire or logging have set back or arrested forest development.

In the mountains, subalpine shrublands are used both summer and winter (Millar 1953; Flook 1964; Stelfox and Taber 1969; Nielson 1973; Soper 1973; Holroyd and VanTighem 1983), but moose are rare (Soper 1970) or absent (Telfer 1978a) in the alpine zone, their altitudinal range being limited by excessive snow depths and lack of woody plants at high altitudes (Kelsall and Telfer 1974).

A variety of forest types are used for escape and thermal cover, and for foraging where suitable browse has developed (Millar 1953; Stelfox and Taber 1969; Soper 1970, 1973; Nielsen 1973; Telfer 1978a; Salter and Hudson 1980; Holroyd and VanTighem 1983). Use of forests is probably related more to understory vegetation and proximity to feeding areas than to overstory composition (Holroyd and VanTighem 1983) and as a consequence deciduous woods, mixed woods and several types of conifer woods are used.

Alluvial shrublands are probably the most important year-round habitat in both the mountain and foothills areas (Millar 1953; Salter and Hudson 1980; Mussell 1982; Holroyd and VanTighem 1983) due to their production of extensive stands of willow and other browse. Moose also will utilize clear-cut areas provided that browse plants and escape cover are available (Telfer 1978b; Stelfox 1981; Tomm et al. 1981).

Moose can tolerate greater snow depths than other cervids (Clarke 1942; Flook 1964; Telfer and Kelsall 1979) permitting them to winter in deep snow areas if good browse is available (Kelsall and Telfer 1974). Shifts to lower elevation areas in winter may be more in response to forage availability than snow depth (Holroyd and VanTighem 1983). Snow depths encountered during a study in the foothills (up to 87 cm in open habitats) did not appear to restrict moose activities (Telfer 1978b); similarly, in the mountains highest track densities were found in the 70-80 cm snow depth range, and tracks were found in snow as deep as 120 cm (Holroyd and VanTighem 1983). Most winter use occurs in flat areas, although south to west-facing slopes also are used (Stelfox 1978; Salt and Clarke 1979).

10.8.4 Special Habitat Features

In summer lakes and streams are used for refuge from biting flies (Flook 1959, 1964) and high temperatures (Kelsall and Telfer 1974). Summer movements to higher altitudes may serve the same purposes in some areas (Millar 1953).

Natural mineral licks are widely used in summer (Banfield 1947; Cowan and Brink 1949; Millar 1953; Best et al. 1977; Holroyd and VanTighem 1983), probably to satisfy sodium requirements (Millar 1953; Best et al. 1977). These may be an especially important feature of habitat in areas where other sources of sodium, such as aquatic vegetation, are not available (Best et al. 1977), and trips of from 1.5 to 16.5 km to visit licks have been documented (Millar 1953; Best et al. 1977). Moose also will eat soil that has been artificially impregnated with sodium chloride (Millar 1953), and they make some use of artificial salt licks (Holroyd and VanTighem 1983).

Pawings and rutting wallows are found in riparian shrublands and at the heads of draws at higher altitudes, suggesting that mating occurs primarily in these areas (Millar 1953).

10.8.5 Space

Moose undertake seasonal shifts between summer and winter range, apparently in response to forage availability. Data on home range size are not available from the mountains, where irregular altitudinal movements to higher ridges in summer and downward into sheltered valleys in winter occur (Millar 1953; Soper 1970). In the Swan Hills home range sizes as determined from radiotelemetry (Lynch 1976) averaged 28.2 km^2 for yearlings (2.4-48.3 km^2), 9.6 km^2 for adult males (less than 1.0-24.9 km^2) and 25.2 km^2 for adult females (less than 1.0-121.6 km^2). Summer and fall home ranges tend to be larger than home ranges during winter (Lynch 1976), when loose concentrations occur in favorable areas (Millar 1953; Telfer 1978b; Holroyd and VanTighem 1983).

10.8.6 Size and Interspersion of Habitat Units

Extensive mature forests produce little browse (Stelfox et al. 1973) and provide poor moose habitat; moose are associated primarily with forest openings (and, in the mountains, with shrublands above timberline), and avoid penetrating heavy forests to any distance (Millar 1953). Nevertheless, moose are sensitive to human and mechanical disturbance(Soper 1964; Tomm et al. 1981) and require escape cover and shelter in proximity to foraging areas (Millar 1953; Stelfox and Taber 1969). Tomm et al. (1981) found that the use of cutblocks by moose in the foothills was related to the size and interspersion of the cuts with residual blocks of mature timber, and to levels of harassment. Moose favored cutblocks 41 to 80 acres (16.6 to 32.4 ha) in size, and buffered from adjoining openings by a 221 to 402 m width of residual forest, although blocks larger than 80 acres were used under low levels of harassment. Tomm et al. (op. cit.) concluded that cutblock widths of 322 to 402 m and residual buffer widths of 101 m were compatible with moose production in areas of low harassment, but recommended that in areas of uncontrolled access and disturbance cutblock widths should be reduced to 121 to 161 m and priority placed on providing suitable cover. In a long-term study in the Hinton area, residual blocks 101 x 101 m in size and interspersed throughout the clearcuts were shown to provide important escape cover and shelter for moose (Stelfox 1981). Conversely, if cutblocks are too large or if residual cover is removed moose avoid or use only the edges of cleared areas (Stelfox et al. 1973; Telfer 1978b; Tomm et al. 1981).

Studies on effects of logging in the foothills have shown that logging results eventually in an increased yield of browse, and provided that suitable cover is available, increased utilization by moose (Stelfox 1981). Manipulation of browse production can be used to influence local distributions of moose (Telfer 1978b), but the size of area required for increases in browse production to be reflected in actual increases in moose populations is unknown. Telfer (1978b) suggested that if treatments are scattered throughout an area of 100 km^2 or more regional moose populations should increase.

10.8.7 Habitat Models

General reviews of habitat requirements, incorporating data from elsewhere in North America, have been prepared by Haywood and Shackleton (n.d.), Rolley and Keith (1979), Thompson et al. (1980), Green et al. (1984) and Nietfeld et al. (1984). IEC Beak (1984c) provides a mathematical model for use in rating habitat suitability of land units in Alberta. A detailed summary of habitat requirements of moose in Alaska is currently in preparation and is available in draft form (USFWS 1984c).

10.9 CARIBOU HABITAT REQUIREMENTS

10.9.1 General

Caribou have a limited distribution in Alberta, occupying a discontinuous range in the mountains and over the northern half of the province. In the mountains they occur from the northern part of Banff National Park through Jasper N.P. to the British Columbia border, extending out into the foothills only between the Athabasca and Wapiti Rivers (Bloomfield and Sword 1981). The area occupied was formerly much broader (Soper 1964), but numbers have declined as a result of habitat loss, disturbance and over-hunting (Soper 1964, 1970; Bloomfield 1980).

10.9.2 Food

Caribou food habits vary seasonally, the major feature being a switch from arboreal lichens in winter to new growth of vascular plants in spring (Stelfox et al. 1978). The switch to new growth probably reflects selection for increased protein levels, as has been documented in interior British Columbia (Bergerud et al. 1984).

Year-long diets include a variety of graminoids, forbs, deciduous shrubs and dwarf shrubs, and both terrestrial and arboreal lichens (Stelfox and Taber 1969; Soper 1970; Stelfox et al. 1978; Bloomfield et al. 1981; Holroyd and VanTighem 1983). Major food plants identified during a detailed study in Jasper N.P. are listed in Table 24.

10.9.3 Cover and Terrain

In western Alberta caribou are associated mainly with the alpine and subalpine zones (Stelfox and Taber 1969; Soper 1970; Stelfox et al. 1978; Holroyd and VanTighem 1983). On a broad scale, their distribution is correlated with the distribution of mature conifer forests and alpine tundra ranges with broad valleys, traversable passes, and scattered summer snowfields (Stelfox et al. 1978).

Important habitats are alpine tundra, lower elevation meadows and shrublands (including delta/shoreline alluvial communities) and mature conifer forests (Stelfox and Warden Service 1974;

Table 24. Food species used by caribou in the mountain biome.

Species	Reference, Area and Diet Composition[1] Stelfox et al. 1978 (Jasper N.P.)
Trees and Shrubs	
Abies lasiocarpa	0.71%
Arctostaphylos uva-ursi	0.07%
Betula glandulosa/Betula spp.	2.55%
Cassiope mertensiana	1.05%
C. tetragona	1.43%
Dryas integrifolia	3.80%
D. octopetala	2.20%
Empetrum nigrum	0.37%
Ledum groenlandicum	0.44%
Menziesia glabella	-
Phyllodoce empetriformis	0.67%
P. glanduliflora	0.94%
Potentilla nivea	1.90%
Salix arctica	0.33%
S. nivalis	0.44%
Senecio resedifolius/Senecio spp.	2.09%
Solidago multiradiata	0.32%
Vaccinium vitis-idaea	1.18%
Graminoids	
Bromus marginatus	0.06%
Carex albo-nigra	1.25%
C. concinna	1.90%
C. scirpoidea	1.91%
C. spectabilis	1.30%
Festuca brachyphylla	0.18%

continued . . .

Table 24. Continued.

Species	Reference, Area and Diet Composition[1] Stelfox et al. 1978 (Jasper N.P.)
Graminoids - continued	
Phleum alpinum	0.18%
Trisetum spicatum	0.13%
Forbs	
Caltha leptosepala	1.00%
Linnaea borealis	1.90%
Pedicularis arctica	3.80%
Trollius albiflorus	0.74%
Valeriana sitchensis	1.90%
Zygadenus elegans	0.65%
Horsetails, Club-mosses and Mosses	
Equisetum scirpoides	4.27%
Dicranum scoparium	0.34%
Lucobryum glaucum	0.65%
Pleurozium schreberi	3.80%
Polytrichum piliferum	2.85%
Ptilium crista-castrensis	0.65%
Rhacomitrium canescens	0.65%
R. lanuginosum	5.70%
Lichens	
Alectoria glabra	0.65%
Cetraria nivalis	1.10%
C. pinastri	0.65%
Cladina arbuscula	1.90%

continued . . .

Table 24. Concluded.

Species	Reference, Area and Diet Composition[1] Stelfox et al. 1978 (Jasper N.P.)
Lichens - continued	
Cladonia cornuta	0.65%
C. deformis	0.65%
Peltigera apthosa	1.98%
Stereocaulon paschae	0.65%

[1] Percent yearlong diets estimated from range transects as % canopy cover x % utilization.

Stelfox and Bindernagel 1978; Stelfox et al. 1978; Bloomfield et al. 1981; Holroyd and VanTighem 1983). Black spruce muskeg is a major caribou habitat in the northeastern part of the province (Fuller and Keith 1981) and may be important in the foothills biome. Altered habitats (avalanche paths, burns, man-made grasslands) are little used or avoided (Stelfox et al. 1978).

Habitat use varies seasonally with floral phenology and forage availability. During the growth period areas of new plant growth are actively sought, mainly in open (non-forested) habitat types (Stelfox et al. 1978). Conversely, mature or over-mature forests are important for over-winter survival, although windswept ridges and meadows adjacent to forest cover also are used at this time (Stelfox et al. 1978; Bloomfield et al. 1981). Engelmann spruce - subalpine fir forests are preferred over the younger lodgepole pine forests (Stelfox et al. 1978; Holroyd and VanTighem 1983; Kaye and Roulet n.d.), but in some areas lodgepole pine and lodgepole pine-white spruce are the major forest habitats used (Bloomfield et al. 1981). Selection of forest cover is strongly related to forage availability, particularly of arboreal lichens (Bloomfield et al. op. cit.). Forests are also used for escape cover (Stelfox and Taber 1969), and possibly for thermal cover. Closed forests are important during winter, but forests used during summer feature mainly open canopies and shrubby understories (Holroyd and VanTighem 1983).

Caribou make use of all exposures on a year-long basis (Stelfox et al. 1978), depending on cover type and slope inclination (Stelfox et al. op. cit.; Bloomfield 1979a). In Jasper, caribou make greatest use of southwest, south and northwest exposures year-long, of northwest and northeast exposures during winter, of north slopes during spring, and of south, southeast and north exposures during summer (Stelfox et al. 1978), preferring rolling till plains and inclined till slopes (Holroyd and VanTighem 1983). East of the park, caribou appear to favor flat to moderate slopes of south, east and west aspects during winter (Bloomfield et al. 1981).

South-facing alpine slopes may be critical calving areas, providing bare ground for foraging, a dark background against which females are cryptic, and proximity to rugged escape terrain (Bergerud et al. 1984). Bergerud et al. (op. cit.) demonstrated that in the Spatsizi area of British Columbia calving females sought such high elevation areas in spring even though doing so meant foregoing foraging in the most nutritious plant associations.

Caribou can utilize deep snow winter ranges, their large hoof areas and relatively low foot loads (Telfer and Kelsall 1971) easing travel through snow, and their large hooves permitting efficient pawing for herbaceous vegetation beneath the snow surface (Stelfox et al. 1978; Bloomfield et al. 1981). Stelfox et al. (1978) found caribou in areas with snow depths of up to 130 cm. Caribou also make use of areas with reduced snow depth, such as windswept alpine ridges (Stelfox et al. 1978), and can switch to a diet of arboreal lichens under forest cover when conditions are unfavorable for cratering (Bloomfield et al. 1981; Holroyd and VanTighem 1983).

10.9.4 Special Habitat Features

Alpine snowfields or snow patches are an important feature of summer habitat, being used for thermoregulation and escape from insects (Stelfox et al. 1978; Holroyd and VanTighem 1983; Kaye and Roulet n.d.).

Caribou utilize natural mineral licks (Cowan and Brink 1949; Holroyd and VanTighem 1983) and also lick salt from roads (Bloomfield et al. 1981; Holroyd and VanTighem 1983) but the importance of licks to this species is not well understood.

10.9.5 Space

In the mountain and foothills biomes caribou undertake generalized shifts between low elevation (mainly winter use) and high elevation summer use areas (Clark 1942; Soper 1964, 1970; Bloomfield et al. 1981; Kaye and Roulet n.d.). They are highly traditional in their area use patterns, using established, learned travel routes and calving, rutting and feeding grounds (Bloomfield 1980; Holroyd and VanTighem 1983; Kaye and Roulet n.d.). They avoid areas subject to human or mechanical disturbance (Soper 1970; Bloomfield 1980), and apparently can be displaced from feeding grounds by elk and horses (Stelfox and Bindernagel 1978; Kaye and Roulet n.d.).

Annual home range sizes are poorly documented in western Alberta,but have been estimated at between 630 and 1205 km^2 (Bloomfield et al. 1981). Highest densities occur on breeding grounds and late winter ranges; in the Berland area late winter densities are 1/27 km^2 (J. Edmonds pers. comm. cited by Nietfeld et al. 1984). These figures compare well with data from the north-eastern part of the province, where studies of radio-collared animals documented late winter densities of 1 caribou/24 km^2, and mean annual home range sizes from 539 km^2 for females to 1196 km^2 for males (Fuller and Keith 1981).

10.9.6 Size and Interspersion of Habitat Units

Caribou rely primarily on climax plant communities, ranging from extensive areas of alpine tundra to mature or over-mature conifer forests, for their food and cover requirements. In general activities that reduce the extent of climax communities, such as logging and fire, are considered to reduce carrying capacity for caribou (Bloomfield 1980; Kaye and Roulet n.d.).

Although open (non-forested) areas are an extremely important feature of caribou habitat, proximity to forest cover may be a major determinant of their use. During spring and summer caribou show some preference for alpine areas and subalpine meadows adjacent to mature forests (Bloomfield et al. 1981), and forest edges and adjacent meadows are important winter habitats (Bloomfield et al. op. cit.; Holroyd and VanTighem 1983). Bloomfield (1980) has suggested that forest openings created artificially (e.g., through logging) should mimic the size of natural openings used by caribou. Conversely, stands of protective cover (as along migration routes) should be at least 400 m wide (Bloomfield 1979b).

Use of shrublands by caribou may be limited by anti-predator considerations. In interior British Columbia, caribou use only low shrublands where they have good visibility (low dwarf birch, and willow stands less than 19 cm tall); tall stands of willow are used only along the edges (Bergerud et al. 1984).

10.9.7 Habitat Models

Habitat requirements and population dynamics of caribou inhabiting forested areas are reviewed in detail by Thompson et al. (1980). Nietfeld et al. (1984) also review key habitat requirements of woodland/mountain caribou as part of a model developed for habitat suitability rating in Alberta (IEC Beak 1984d).

10.10 MOUNTAIN GOAT HABITAT REQUIREMENTS

10.10.1 General

In Alberta mountain goats are confined to high, rugged terrain along the east slopes of the Rockies, where they occupy a discontinuous range from Waterton Lakes in the south to the Grand Cache area in the north (Soper 1964; Alberta Fish and Wildlife Division 1984). The total provincial population has been estimated at 2000 to 2500 animals, with half or more of these being found in Banff and Jasper N.P. (McFetridge 1977a).

10.10.2 Food

Mountain goats consume a varied diet consisting of alpine grasses and forbs and the leaves and twigs of several tree and shrub species (Soper 1964; Kerr 1965; McFetridge 1977a; Salt and Clarke 1979) (Table 25). Diet quality varies seasonally (McFetridge 1977a), but only gross trends in seasonal species composition can be discerned from available data. Deciduous browse and forbs together dominate reported monthly diets. Grasses are used throughout the year and during summer may comprise up to 54% of monthly diets (McFetridge 1977a) and 80% of individual stomach contents (Kerr 1965). Gramineous species used include wheatgrasses, bromes, sedges (including Carex nardina), rough fescue, hairy wild rye and june grass (Salt and Clarke 1979). Among browse species the Elaeagnaceae (silverberry and possibly also buffaloberry) appear to be particularly important and constant dietary constituents, both on a seasonal and area to area basis (Soper 1964; Kerr 1965; McFetridge 1977a). Coniferous browse is generally used in trace or very minor amounts, although exceptionally individual goats may take quantities of subalpine fir (Kerr 1965).

10.10.3 Cover and Terrain

Mountain goats occur primarily in the upper subalpine and alpine zones, where they are found in association with mosaics of grass/forb meadows and tundra, low shrublands, and broken, steep slopes and cliffs (Banfield 1947; Flook 1964; Soper 1964, 1970, 1973; Nielsen 1973; McFetridge 1977a; Holroyd and VanTighem 1983). They also make some use of open forest (both deciduous and coniferous) at timberline, and travel along well-defined routes through subalpine and montane forests to reach mineral licks (Soper 1964, 1970, 1973; McFetridge 1977a; Holroyd and VanTighem 1983). The use of sandstone/shale bluffs by a goat population along Pinto Creek (east of the main mountain ranges) appears to be anomalous, but may be indicative of some plasticity in habitat use by this species; in this area goats are confined to a narrow belt about 200 yards (183 m) wide on each side of the creek, consisting of low shrubland,

Table 25. Food species used by Mountain Goats in Alberta.

Species	Reference, Area and Diet Composition[1] Kerr 1965 (Smoky R. area)[2]	 McFetridge 1977a (Smoky R. area)[3]
Trees and Shrubs		
Abies lasiocarpa	0-1.3%w,xs	-
Alnus spp.	1.7-5.7%w,xs	-
Amelanchier alnifolia	3.9-52.4%w	-
Arctostaphylos uva-ursi	xw,xs	x
Betula spp.	-	x
Coniferae	-	1.4%w,0-1%s
Elaeagnaceae	-	1-34%w,4-46%s
Elaeagnus commutata	17.5-31.6%w,xs	-
Lonicera spp.	0-0.5%w	-
Pinus contorta	0-0.5%w	-
Populus tremuloides	6.5-31.3%w	-
Ribes spp.	xw	-
Rosa spp.	2.3-30.9%w	-
Rubus spp.	0-0.3%w	-
Salix spp.	tr-5.0%w,xs	1%w,0-6%s
Shepherdia canadensis	xw	-
Symphorocarpus albus	0-3.6%w	-
Viburnum edule	0-3.9%w	-
Graminoids		
Cyperaceae	-	1-3%w,0-5%s
Gramineae	xw,xs	26-43%w,10-54%s

continued...

Table 25. Concluded

Species	Reference, Area and Diet Composition[1] Kerr 1965 (Smoky R. area)[2]	McFetridge 1977a (Smoky R. area)[3]
Forbs/Horsetails		
Arnica spp.	-	x
Equisetum spp.	-	0-1%w
Erigeron spp.	-	x
Forb spp.	xw,xs	35-64%w,26-73%s
Leguminosae	-	x

1 x = present in diet; w = winter; s = spring-summer-fall.

2 percent winter diets determined from browse use along range transects Mt. Hamell and Pinto Creek (percentages refer to total winter diets each area). Additional presence/absence data from stomach samples collected December (n=2) and June-August (n=4).

3 percent diets determined from fecal fragments analysis on feces collected each month May-August (summer) and October, November and February (winter). Percentages refer to range of monthly values. Forb class includes some browse.

grassland and cliffs bordered above by white spruce-lodgepole pine forest (Kerr 1965). Proximity to escape terrain in the form of steep slopes or cliffs is a key determinant of habitat use in all areas (Kerr 1965; Stelfox and Taber 1969; McFetridge 1977a; Holroyd and VanTighem 1983). Cliffs also are important as bedding and kidding areas (McFetridge 1977b).

Burned subalpine meadows and slopes provide foraging areas with relatively high plant biomass production, and may be of particular importance to nursery groups (McFetridge 1977a). Although fire-produced habitats are possibly of less significance to goats than to other ungulates (Flook 1964), in general fire suppression is believed to result in habitat deterioration and reduction in carrying capacity for goats (Johnson 1977). The use of avalanche paths (Flook 1964; Holroyd and VanTighem 1983) may similarly be related to selection for the secondary vegetation occurring in such areas.

Suitable habitat is most restricted during winter, when goats are concentrated on areas of steep, broken terrain where wind and sun action reduce snow depths and leave potential forages exposed (Banfield 1947; Kerr 1965; Holroyd and VanTighem 1983). Most winter ranges are located on south to west-facing slopes or ridgetops (Kerr 1965; Stelfox 1978; Holroyd and VanTighem 1983).

Spring-summer-fall range is more extensive (Kerr 1965) and most use of alpine meadows and forested areas is made at this time (Hall 1977; Holroyd and VanTighem 1983). Most use occurs on steep slopes (>45°), but moderate and even gentle slopes (<30°) are used, the latter primarily for feeding (McFetridge 1977a). Predominant use of east, south and north slopes has been documented for the spring to fall period (Nielsen 1973; McFetridge 1977a).

During summer goats use well-established bedding grounds exposed to sun and wind (Kerr 1965) and may lie-out on snowbanks (Holroyd and VanTighem 1983), but also use overhangs and small caves for shade (Holroyd and VanTighem op. cit.). Sheltered areas are sought during rain and snow flurries (Kerr 1965). Use of old mine portals for shelter has been documented in British Columbia (McCrory et al. 1977).

10.10.4 Special Habitat Features

Natural mineral licks are widely used in spring and summer (Cowan and Brink 1949; McCrory 1969; Salt and Clarke 1979; Holroyd and VanTighem 1983), apparently as a source of sodium (Hebert and Cowan 1971). Kerr (1965) suggested that mineral licks were not a necessary requirement of goat range, but well-documented treks to lick areas (McCrory 1969; Soper 1970, 1973; Holroyd and VanTighem 1983), often through heavy forest and at considerably increased risk of predation, suggests a strong motivation for lick use.

Mountain goats can contact contagious ecthyma, which in bighorn sheep has been linked to prolonged use of areas where salt has been provided artificially (Samuel et al. 1975).

10.10.5 Space

Mountain goats are relatively sedentary, and except for movements of up to several km to mineral licks they remain year-round withinrestricted home ranges (Soper 1964, 1970). Although seasonal movement patterns are not well understood (Hall 1977) they appear to consist mainly of short-range altitudinal shifts, and wintering ranges may overlap or be included within summering ranges (Banfield 1947; Stelfox and Taber 1969; Holroyd and VanTighem 1983). Kerr (1965) noted a downward shift in spring that was probably a response to new vegetation growth, followed by a gradual upward movement through the summer (again following new growth) and a downward shift back to winter range initiated by the first snowfalls, all within a maximum horizontal distance of about 4.8 km. There appears to be some sexual segregation, with adult males found in summer in different areas than females and immatures (Banfield 1947; Soper 1973; McFetridge 1977a; Salt and Clarke 1979).

Home range size data apparently are not available for Alberta, although McFetridge (1977a) speculated that individual goats may remain within areas no larger than 25 km^2 during their entire lifespan. This agrees well with mean yearly ranges of 21.5 km^2 for male and 24.0 km^2 for female goats in Montana (Rideout 1974).

10.10.6 Size and Interspersion of Habitat Units

Habitat use by mountain goats is circumscribed primarily by the distance they will travel from secure escape terrain. Studies in the Grande Cache area (McFetridge 1977a) suggest that most use (80% of his observations) can be expected to occur within 200 m of escape terrain, and virtually all use (95% of observations) within about 400 m. As goats do not normally forage beyond this limit the interspersion of escape terrain within forage producing habitat, rather than forage production *per se*, can be considered the critical determinant of carrying capacity for this species.

Proximity of development activities and human access have recently become increasing concerns in management of goat habitat. Increased road access and overhunting have been implicated in population declines in several areas of Alberta and British Columbia, and concern has been expressed about the effects of increasing levels of resource exploitation in mountain goat areas (McFetridge 1977a, 1977b; Pendergast and Bindernagel 1977). Reviewing the situation in North America in general, Johnson (1977) concluded that logging and mining activities contributed both to direct destruction of goat habitat and to disturbance of goat populations, resulting in movement away from traditional use areas. Habitat destruction has not been identified as an important factor in known declines in British Columbia, but may be a factor in attempts to re-establish populations post-mining (Pendergast and Bindernagel 1977). Conversely, reclamation of goat ranges could at least potentially result in habitat improvement by expanding refuge areas (McFetridge 1977a).

10.10.7 Habitat Models

Habitat requirements of mountain goats are reviewed by Nietfeld et al. (1984) as part of a model prepared for use in habitat suitability rating in Alberta (IEC Beak 1984e).

10.11 BIGHORN SHEEP HABITAT REQUIREMENTS

10.11.1 General

In Alberta bighorn sheep are confined to the Rocky Mountains, where they occupy a long, narrow strip of habitat centering on the subalpine and alpine zones (Soper 1964; Alberta Fish and Wildlife Division 1984). A potential habitat area estimated at 35,000 km^2 is populated by approximately 9000 sheep, with both habitat and sheep numbers about equally divided between the mountain national parks and adjacent provincial lands (Stelfox 1971, 1976a, 1978; Alberta Fish and Wildlife Division n.d.). Bighorn sheep occupying this area are subject to periodic die-offs initiated by over-use of winter ranges (Stelfox 1976a).

10.11.2 Food

Bighorn sheep utilize a variety of gramineous, forb and low shrub species, depending on range composition and time of year (Table 26). Grasses and shrubs are used year-round, whereas forbs are used mainly during late spring-early fall (Stelfox 1976a) when in some areas they may become the most important forage component (Wishart 1958). There appears to be a negative correlation between range condition and forb and shrub utilization, with most forb and shrub use occurring on heavily grazed ranges (Stelfox 1976a). Stelfox (op.cit.) reported average diet compositions of 74% gramineous plants, 23% forbs and 4% shrubs on six major ranges in the national parks, confirming results of an earlier, more limited study which estimated that grasses and sedges comprised 83% of the winter diet in Jasper (Cowan 1947). Subsequent studies in Banff have reported winter diets averaging 94% grasses and sedge (Shank 1982).

Table 26 . Food species used by Bighorn Sheep in Alberta.

Species	Reference, Area and Diet Composition[1] Wishart 1958 (Sheep R. area)[2]	Stelfox 1976a (Jasper, Banff, Waterton N.P.)[3]	Shank 1982 (Banff N.P.)[4]
Trees and Shrubs			
Alnus tenuifolia	xs	-	-
Amelanchier alnifolia	xs	xw,xs	-
Arctostaphylos uva-ursi	xs	0-11.1%s,xw	-
Cornus stolonifera	-	xs	-
Elaeagnus commutata	xs	-	-
Picea glauca	xs	-	-
Picea spp.	-	-	0.6%w
Populus tremuloides	xs[H]	-	-
Potentilla fruticosa	xs	0-42.8%s,xw	-
Prunus spp.	-	xw,xs	-
Ribes setosum	xs[H]	-	-
Rosa acicularis	xs	0-4.5%s,xw	-
Salix spp.	xs[H]	xw,xs	-
Sambucus spp.	xs	-	-
Shepherdia canadensis	xs	xs	-
Graminoids			
Agropyron spp.[5]	xs[H]	0-23.3%s,xw	-
Agrostis spp.	xs	-	-
Bromus pumpellianus	-	0-2.9%s	-
Bromus spp.	xs	xs	4.1%w
Calamagrostis spp.	-	0-4.3%s,xw	-
Carex spp.	xs[H]	xw	9.2%w

continued...

Table 26. Continued.

Species	Reference, Area and Diet Composition[1] Wishart 1958 (Sheep R. area)[2]	Stelfox 1976a (Jasper, Banff, Waterton N.P.)[3]	Shank 1982 (Banff N.P.)[4]
Graminoids - continued			
Danthonia spp.	-	xw,xs	-
Elymus innovatus	xs	0-2.9%s,xw	-
Elymus spp.	-	-	2.8%w
Festuca idahoensis	-	0-17.2%s	-
F. scabrella	xs[H]	0-80.1%s	-
Festuca spp.	-	xw,xs	71.4%w
Juncus spp.	-	xw,xs	-
Koelaria cristata	xs[H]	0-14.5%s,xw	4.6%w
Phleum pratense	xs	-	-
Poa spp.	-	0-4.7%w	1.9%w
Forbs			
Achillea millefolium	-	xs	-
Agoseris spp.	xs	-	-
Aremone spp.	xs	xs	-
Artemisia frigida	-	xw,xs	-
Aster spp.	-	0-13.6%s	-
Astragalus spp.	xs[H]	xs	0.6%w
Campanula rotundifolia	-	0-7.0%s	-
Castilleja spp.	xs	-	-
Cirsium spp.	xs[H]	-	-
Compositae	-	-	0.7%w

continued...

Table 26. Continued.

Species	Reference, Area and Diet Composition[1] Wishart 1958 (Sheep R. area)[2]	Stelfox 1976a (Jasper, Banff, Waterton N.P.)[3]	Shank 1982 (Banff N.P.)[4]
Forbs - continued			
Delphinium spp.	xs[H]	-	-
Dodecatheon cusicki	xs	-	-
Equisetum spp.	xs	-	-
Erigeron spp.	-	xs	-
Forb spp.	-	-	1.2%w
Fragaria glauca	xs	-	-
F. virginiana	-	0-1.4%s	-
Galium boreale	-	0-9.1%s	-
Hedysarum spp.	xs[H]	xs	-
Hieracium spp.	-	xs	-
Oxytropis spp.	xs[H]	xs	-
Phacelia sericea	-	0-1.4%s	-
Potentilla spp.	xs	-	-
Senecio spp.	-	xs	-
Silene parryi	-	xs	-
Smilacina spp.	xs	-	-

continued...

Table 26. Concluded.

Species	Reference, Area and Diet Composition[1] Wishart 1958 (Sheep R. area)[2]	Stelfox 1976a (Jasper, Banff, Waterton N.P.)[3]	Shank 1982 (Banff N.P.)[4]
Forbs - continued			
Solidago spp.	-	0-11.1%s	-
Taraxacum officinale	-	xs	-
Trifolium spp.	-	xs	-
Zygadenus spp.	xs	-	-

1 x = present in diet; w = winter; s = spring-summer-fall.

2 diet composition determined from range transects examined April-September. Species receiving high to moderate use during any season are marked with the superscript H.

3 percent diet composition estimated from plant utilization along range transects July-early August; additional data obtained from transects examined during spring, fall and winter. Percentages refer to range of values from six separate areas.

4 percent diet composition determined from fecal fragments analysis on feces collected November-April.

5 includes *A. dasystachyum*, *A. trachycaulum* and *A. spicatum*.

Fescues, wheatgrasses, june grass and sedges are probably the most important gramineous species in sheep diets on a provincial range-wide basis, although others are utilized (Table 26). Forb selection is more difficult to generalize, but it is noteworthy that the Compositae and Leguminosae are well represented in known diets.

10.11.3 Cover and Terrain

On a broad scale, bighorn sheep are associated with grasslands and rocky escarpments throughout the year (Flook 1964; Stelfox and Taber 1969; Stelfox 1976a; Holroyd and VanTighem 1983). Seasonal habitat use spans a number of plant associations and physiographic situations, from open valley bottoms and isolated grasslands within the coniferous forest (montane) zone, to grass, forb and heath-dominated subalpine/alpine meadows and slopes (Wishart 1958; Flook 1964; Soper 1964, 1973; Stelfox and Taber 1969; Nielsen 1973; Holroyd and VanTighem 1983) to artificially seeded grasslands (as along highway aprons: Sullivan and Stelfox 1974). They also make some use of moist open forests of subalpine fir, larch and Engelmann spruce, of open Douglas fir and mixed conifer forests, of deciduous forests, and of upper subalpine shrub communities on avalanche slopes and colluvial aprons (Wishart 1958; Flook 1964; Nielsen 1973; Morgantini 1979; Holroyd and VanTighem 1983). Forests are used primarily along the edges, for limited feeding and for thermal cover. Steep, broken terrain and talus slopes are key habitat features used for bedding, escape and lambing (Wishart 1958; Stelfox and Taber 1969; Nielsen 1973; Morgantini 1979; Holroyd and VanTighem 1983).

Periodic fire appears to be an important feature of sheep habitat, functioning both in increasing the extent of grassland area (or setting back forest encroachment on existing grasslands) and recycling nutrients into new forage growth (Flook 1964; Soper 1973; Stelfox 1976a, 1978; Bentz 1981).

Habitat use during the spring-summer-fall period is strongly related to forage quality. Wishart (1958), Stelfox and Taber (1969) and Stelfox (1978) outlined the following generalized pattern: during April and May sheep concentrate on low, south-facing slopes and valley bottoms where the first new plant growth occurs; in May and June they forage upward along south and east slopes to subalpine and alpine grasslands (with females moving to rugged escarpments on south and east exposures for lambing); in July and August foraging is concentrated on south and west slopes at high elevation and along alpine valley bottoms, following receding snowfields; in late August and September foraging shifts to north-facing grasslands and semi-open forests, again following snow-melt and seeking the most succulent vegetation; in September and October, subsequent to the first frosts and snowfall, a downward drift to wintering areas begins.

During winter bighorns are confined largely to steep south or west-facing slopes where sun and wind action keep forages exposed (Flook 1964; Soper 1964; Geist 1971; Stelfox 1971, 1978; Geist and Petocz 1977) although in Waterton Lakes N.P. the major winter use occurs on north and northeast-facing slopes (Nielsen 1973; Stelfox 1978). Windblown tundra and alpine meadows also are used (Holroyd and VanTighem 1983), but flat areas are avoided (Stelfox 1978). Sheep generally avoid snow depths in excess of 30 cm, and this greatly restricts the extent of available winter range (Stelfox 1976a). They also move away from south and west-facing slopes into more sheltered areas, including caves and thick stands of subalpine timber, to avoid major storms (Soper 1964; Stelfox 1976a) and appear to make use of altitudinal thermoclines, which provide higher ambient temperatures and reduced temperature fluctuations (Geist 1972; Stelfox 1976a).

10.11.4 Special Habitat Features

Bighorn sheep make frequent use of natural mineral licks, primarily during summer (Cowan and Brink 1949; Wishart 1958; Soper

1964, 1970, 1973; McCrory 1969; Stelfox 1978; Wishart et al. 1980; Holroyd and VanTighem 1983). Lick use appears to be related to the lambing and moulting periods (Stelfox 1978), and although use has been variously attributed to a need for sodium (Wishart 1958) or copper, calcium and phosphorous (Stelfox 1978) the nutritional significance of licks remains poorly understood.

Bighorns also make use of other mineral sources, such as salt blocks, highway salt and minerals spilled from trains (Wishart 1958; Stelfox 1978). Use of artificially provided salt has been linked with the spread of contagious ecthyma, a potentially debilitating disease (Samuel et al. 1975; Stelfox 1976b; Lance 1980).

10.11.5 Space

As noted above bighorns undertake seasonal altitudinal movements between summer and winter range, and also make periodic visits to mineral licks, some of which may be in heavily forested areas well away from normal foraging habitat (Soper 1964, 1970; Stelfox 1976a; Morgantini 1979). Wishart (1958) documented seasonal movements of between 8 and 25 mi (13 to 40 km) between summer and winter ranges, although in some cases seasonal ranges overlap. Rams also undertake long-distance movements related to the rut; these may be 15 mi (24 km) or more in extent (Geist 1971).

Sheep are loyal to their home ranges on a year-to-year basis and movements between them are predictable (Geist 1971). Geist (op. cit.) identified up to seven seasonal home ranges occupied by individual rams and up to four seasonal ranges used by individual ewes, with minimum range sizes of approximately .5 mi (.8 km) diameter in midwinter, and maximum home range sizes up to 3.7 mi (6.0 km) in diameter in spring and fall.

The sexes remain segregated for much of the year, even when occupying spatially contiguous ranges (Soper 1964; Geist 1971;

Nielsen 1973; Geist and Petocz 1977; Morgantini and Hudson 1981; Shank 1982).

10.11.6 Size and Interspersion of Habitat Units

Bighorn sheep require open, primarily non-forested habitat for foraging and adjacent steep, broken terrain for escape, bedding, lambing and refuge from deep snow cover. Adjacent forests may be used to some extent for foraging and for thermal cover, and are passed through during seasonal movements, but adequate areas of open, secure terrain are the major feature of habitat required by this species. The interdependence of traditional summer and winter ranges may limit the gross distribution of bighorn sheep (Soper 1970).

Proximity to escape terrain appears to be a major determinant of habitat use. Although quantitative data are not available from Alberta, information reviewed by VanDyke et al. (1983) indicates that cliffs should be at least 8 m high by 200 m long for escape, bedding and thermal use, and should cover at least 2 ha to serve as a lambing area. Bighorn sheep in Jasper have been observed feeding up to .5 mi (.8 km) from escape terrain (Flook 1964); in general they make primary use of forage areas within .8 km and are not seen further than 1.6 km from potential escape areas (VanDyke et al. 1983). Further indirect evidence for the importance of escape terrain is the observation that heart rate (and thus, presumably, level of stress) is lower in bighorns feeding on slopes of 10 to 34° than in open meadows of 0 to 6° slope, or passing through forest (McArthur et al. 1982), and Wishart's (1958) and Geist's (1971) observations that migrating sheep show extreme caution when crossing flats or entering timbered areas.

Carrying capacity of foraging habitat (and thus size of area required by a given herd) varies with floral composition and period of use, as well as with interspersion of escape terrain.

Stelfox (1976a) calculated grazing capacities of 3.2 to 5.9 sheep-months/ha on national park ranges.

Bighorn sheep are sensitive to human disturbance (Soper 1964; Morgantini 1979; McArthur et al. 1979, 1982; Wishart et al. 1980) and are considered to be one of the least adaptable species to habitat disruption (Anonymous 1972). As a result, concern has been expressed about the effects of coal-mining and associated activities on Alberta sheep ranges (Anonymous 1972; Etter 1972, 1973). Although bighorns habituate to humans in areas protected from hunting (Soper 1964; Geist 1971) and to some extent to vehicular traffic, at least when more than 200 m away (McArthur et al. 1979, 1982), they are traditional in their area use patterns and cannot withstand destruction of critical habitat by moving elsewhere.

Etter (1972, 1973) discusses the critical importance of winter range to this species and outlines preliminary approaches to habitat reclamation. He suggests establishment of grasses and forbs on south-facing slopes and of shrubs and trees on north-facing slopes, with priority given to southerly slopes of 10 to 20°. However, south-facing slopes of up 35°, with appropriate areas of steeper, broken escape terrain, may more closely mimic both natural grassland habitat (Stelfox 1976a) and slopes actually used by bighorns (Morgantini 1979; McArthur et al. 1982).

10.11.7 Habitat Models

Nietfeld et al. (1984) review the North American literature as part of a model prepared for rating habitat suitability for bighorns in Alberta (IEC Beak 1984f). Habitat requirements also are reviewed in detail by VanDyke et al. (1983), with a view primarily to facilitating habitat management in the Great Basin region.

10.12 SPRUCE GROUSE HABITAT REQUIREMENTS

10.12.1 General

Spruce grouse are locally resident in coniferous forest areas throughout western and northern Alberta (Salt and Salt 1976). The foothills and mountain biomes comprise a major part of their range within the province.

10.12.2 Food

Conifer needles are the most important foods on a year-long basis, and comprise virtually the entire diet during the period of snow cover, when feeding activity is confined largely or exclusively to conifer trees (Pendergast and Boag 1970; Salt and Salt 1976; Keppie 1977). Lodgepole pine is the major food species in western Alberta (Table 27), although white spruce is seasonally important, and new leaders of this species are actively selected by incubating hens (Pendergast and Boag 1970; McCourt et al. 1973; Herzog 1978). White spruce and larch are major dietary constituents elsewhere, species selection apparently varying at least in part with availability (Zwickel et al. 1974; USFWS 1984d).

Ground vegetation, primarily leaves, flowers and fruit of <u>Vaccinium</u> spp., provides a major part of the diet during the snow-free period (McCourt 1969; Pendergast and Boag 1970; McCourt et al. 1973; Herzog 1978). Arthropods are eaten to some extent by adults and appear to be particularly important to young broods (McCourt 1969; Pendergast and Boag 1970).

Potential food supply for this species is virtually unlimited in conifer-dominated habitats (Pendergast and Boag 1971). Lodgepole pine needles, the major dietary component, feature high gross energy values, but their low crude protein content and low digestibility (Boag and Kuceniuk 1968; Pendergast and Boag 1971) probably necessitate a large intake in order to meet nutritional requirements.

Table 27. Food species used by Spruce Grouse in the foothills biome.

Species	Reference, Area and Diet Composition[1] Pendergast and Boag 1970 (Swan Hills)[2]
Trees and Shrubs	
Betula spp.	0-0.1%s
Cornus canadensis	0-trs
Picea spp.	1.4%w,3.8-21.7%s
Pinus contorta	97.5%w,7.7-57.1%s
Rubus chamaemorus	0-0.3%s
Vaccinium membranaceum	0-31.9%s
V. myrtilloides	0-trs
V. vitis-idaea	13.1-20.5%s
Graminoids	
Carex spp.	0-2.8%s
Gramineae	trs
Forbs	
Streptopus amplexifolius	0-2.2%s
Taraxacum officinale	trs
Tiarella trifoliata	0-0.8%s

continued...

Table 27. Concluded.

Species	Reference, Area and Diet Composition[1] Pendergast and Boag 1970 (Swan Hills)[2]
Horsetails, Clubmosses, Mosses and Fungi	
Equisetum spp.	0-2.5%s
Fungi spp.	0-2.0%s
Musci spp.	0-3.4%s
Arthropoda	0-0.7%s

1 w = winter, s = spring-summer-fall.

2 percent winter diets determined from crop contents (n=22) of birds over 5 months of age collected December-February. Percent spring-summer-fall diets determined from crop contents of birds over 5 months of age collected March-May (n=24 crops), June-August (n=33) and September-November (n=20); percentages refer to range of values over the three periods. All percentages refer to dry weights.

10.12.3 Cover and Terrain

In western Alberta spruce grouse are found primarily in lodgepole pine forest, a fire-induced disclimax (McCourt 1969; McLachlin 1970; Pendergast and Boag 1971; Sharp 1973; Boag et al. 1979, 1984), but also in white spruce and other conifer-dominated forests, in spruce bogs, mixed woods and deciduous woods, and in grasslands, shrublands and subalpine meadows in the vicinity of suitable forest cover (McCourt 1969; McLachlin 1970; Sharp 1973; Stelfox et al. 1973; Wisely 1979; Holroyd and VanTighem 1983). In the mountains they are found mainly in valley bottom forests (Holroyd and VanTighem 1983) but extend into the subalpine (Sharp 1973; Holroyd and VanTighem 1983).

Studies in the foothills west of Turner Valley have shown that there are sex, age and seasonal differences in occupation of cover types, and occupation of sites within a cover type. In this area males were found primarily in lodgepole pine forest and secondarily in white spruce forest and older mixed forest, but never in meadow or marsh (McLachlin 1970). Although lodgepole pine forest was the major available cover type only 28% of it was occupied by resident males, suggesting active selection for certain habitat features. This occupied area differed structurally from peripheral areas (used to some extent by wandering yearlings) comprising the remainder of the forest in having greater overstory cover (mainly in the 25 to 50% and 50 to 75% canopy cover classes), lower middlestory cover (generally <25%), greater stem density (mean 6600 stems/ha) and canopy height (mean 8.2 m), and lower slope of the forest floor (mean 6.6°). Unoccupied areas were generally the upper slopes of the hills where greater exposure, drainage and thinner soil contributed to differences in vegetation cover. Display areas were in more open parts of the home range, where lower overstory cover, lower stem density and an absence of smaller trees facilitated display flights (MacDonald 1968; McLachlin 1970). By contrast moulting males tended to select denser vegetation (McLachlin 1970; Herzog and Boag 1978), as reflected by greater white spruce cover and greater middlestory cover of willow, alder and all species combined (McLachlin 1970).

In the same study area, females used 40% of the available pine forest, but only 5% of the spruce forest and 8% of the poplar forest (McCourt 1969). Like males, they selected areas of greater overstory canopy cover (mainly in the 25 to 50 and 50 to 75% classes), lower middlestory cover (generally <25%), greater stem density (mean 4954 stems/ha) and canopy height (mean 8.06 m), and lower slope values (mean 6.95°) than in the forest as a whole. Females with broods tended to occur in parts of the occupied area featuring a relatively light overstory but heavy middlestory, while females without broods were found in areas where both the overstory and middlestory were relatively heavy.

This species nests on the ground, most commonly within 10 cm of the base of a single tree or between closely adjoining trees, but also under willow clumps, juniper mats or horizontal logs (Keppie and Herzog 1978). Nest site selection is poorly understood, and although nest success is positively correlated with extent of concealment, concealment varies widely among different females (Keppie and Herzog 1978; Redmond et al. 1982). Shrub cover may be important in providing concealment against predators; Boag et al. (1984) found that nests were less vulnerable to predation when shrub canopy cover was 10% or more within a 2 m radius of the nest.

10.12.4 Space

Use of space is dependent on sex, age and time of year (McCourt 1969; McLachlin 1970; Herzog and Boag 1978). Spacing behaviour of adults appears to regulate breeding densities, which may as a consequence vary little from year to year (Boag et al. 1979). Over 10 years of study in the foothills density of birds in the spring population varied between 10.5 to 19.3/km^2 (Boag et al. op. cit.).

Maximum spacing occurs during the breeding season, when adult males occupy uniformly spaced, aggregated territories averaging 1.0 ha (range 0.3 to 1.9 ha) in suitable blocks of habitat, and females occupy uniformly spaced territories averaging 2.3 ha (0.6 to 3.9 ha) peripheral to the central aggregate of males (Herzog 1977; Herzog and Boag 1978). Both male and female yearlings wander widely in early spring (mean home ranges 39.6 ha [10.0 to 58.4 ha] and 15.4 ha [5.3 to 37.8 ha]), during which time they presumably learn the locations of adult territories and locate unoccupied habitat (Keppie 1975; Herzog 1977a; Herzog and Boag 1978; Boag et al. 1979). Yearling females then either establish territories similar to those of adults or are forced to emigrate; similarly some yearling males establish territories and some emigrate, although most occupy large areas (mean 8.6 ha, range 2.3 to 14.8 ha) peripheral to the established males and overlapping several female territories (Herzog and Boag 1978).

The size and shape of female breeding territories appear to be strongly influenced by the availability of food resources (Herzog 1978), particularly mature white spruce trees which are a preferred food source during incubation (Pendergast and Boag 1970; McCourt et al. 1973; Herzog 1978). Nesting usually occurs near the periphery of the territory (Herzog and Boag 1978) averaging 39 to 123 m away from feeding sites (Herzog 1978). Subsequent to hatching female home ranges expand and begin to overlap extensively, areas occupied by females with broods averaging 29.0 ha (20.6 to 5.1 ha) and those without broods 16.8 ha (7.4 to 37.7 ha) (Herzog and Boag 1978).

All sex and age groups tend to be rather sedentary in winter, home ranges of adult males averaging 2.1 ha (single sample), adult females 2.0 ha (0.8 to 3.0 ha), yearling males 6.8 ha (1.9 to 14.7 ha) and yearling females 3.6 ha (0.6 to 7.0 ha) (Herzog and Boag 1978). Both adult and yearling females are known to spend up to several days associated with small blocks of habitat or even with single trees during winter (Herzog and Boag op. cit.).

Local populations may include both resident and migratory birds. Herzog and Keppie (1980) found that 39% of their study population was migratory, moving up to 9.5 km between breeding and wintering sites each year. The remainder of the population was resident in the same general area year-round (Herzog and Boag 1978; Herzog and Keppie 1980).

10.12.5 Size and Interspersion of Habitat Units

Minimum size of suitable habitat blocks may be set in part by social factors, such as the tendencies for male territories to be clumped together, for females to consort with males during the breeding season, and for yearling males to occupy territories adjacent to established males (McCourt 1969; McLachlin 1970; Herzog and Boag 1978). Areas of apparently suitable habitat, but smaller than normal home ranges, are not used by resident males (McLachlin 1970). Reoccupation of vacated territories occurs rapidly in large blocks of habitat (McLachlin 1970; Herzog and Boag 1978; Boag et al. 1979), but apparently less rapidly or not at all in smaller areas (McLachlin 1970).

Recent work in the Adirondack Mountains of New York indicates that patterns of occupation and extinction in patchy habitats can be predicted quantitatively on the basis of size and arrangement of habitat units and demographic characteristics of spruce grouse (Fritz 1979). In that area, unoccupied patches were significantly smaller and significantly further from occupied patches than were other occupied sites. Occupied patches ranged from 28 to 591 ha in size (average 157 ha) whereas unoccupied patches were 20 to 118 ha, and averaged 56 ha in size (Fritz op. cit.).

Within blocks of suitable habitat, features such as openings in the forest, high hills, streambeds and change in vegetation type may form natural boundaries for resident male home ranges, but not for those of yearlings (McLachlin 1970). Females with broods are known to use open, treeless areas (Sharp 1973) but there are no data on optimum opening sizes.

Spruce grouse are vulnerable to habitat disruption and hunting pressure (Salt and Salt 1976) and disappear with logging of white spruce and lodgepole pine forests in the foothills (Stelfox et al. 1973).

10.12.6 Habitat Models

A review of habitat requirements of Alaskan spruce grouse, including a habitat suitability index model, is currently available in draft form (USFWS 1984d).

10.13 WHITE-TAILED PTARMIGAN HABITAT REQUIREMENTS

10.13.1 General

The distribution of white-tailed ptarmigan in Alberta is limited to high altitude areas of the Rocky Mountains (Salt and Salt 1976). Populations are resident in the mountains but there is some vertical movement between summer and winter habitat (Salt and Salt 1976; Herzog 1980).

10.13.2 Food

Leaves and fruits of a variety of alpine plants provide the diet of this species. Within the North American range as a whole (Colorado through Alberta and British Columbia to Alaska), common spring and summer foods are willow and buttercup leaves, dryad flowers, grass and sedge seeds and bistort fruits; autumn foods are willow buds, twigs, and leaves, and *Draba*, bistort, crowberry and *Vaccinium* fruits; and winter foods are willow, alder and birch buds and twigs, depending on lcoation (Weeden 1967).

Only fragmentary data are available on food habits in Alberta. Weeden (1967) reported white dryad leaves and flowers, willow leaves, and buttercup leaves to be the major constituents in three crops collected in Banff and Waterton Lakes N.P. during May to July, and Herzog (1977b) observed females with broods in the Kananaskis area feeding repeatedly on the flowers and leaves of Smelowskia calycina, an alpine Cruciferae. Young birds are known to feed on insects (Salt and Salt 1976). Leaf buds, mainly of willow, are the primary winter food (Salt and Salt 1976; Herzog 1980; Holroyd and VanTighem 1983), but weed seeds and waste grain around human habitations may be used during severe winters (Salt and Salt 1976).

Water appears to be an integral part of summer habitat, but whether free water is actually required for drinking is unknown. Chicks can obtain moisture from dew (Salt and Salt 1976).

10.13.3 Cover and Terrain

White-tailed ptarmigan are found during spring and summer mainly on open rocky slopes and in alpine meadows above treeline (Salt and Salt 1976; Herzog 1977; Holroyd and VanTighem 1983), but also in krummholz and fir/alpine larch cover types (Sharp 1973). Key habitat features apparently are an abundance of rocks suitable for cover (>30 cm diameter) and sufficient moisture for plant growth (Herzog 1977b; Holroyd and VanTighem 1983).

Herzog (1977b) analysed sightings made during July to August in the Kananaskis area and found that rocks comprised nearly 50% of the ground cover in occupied habitats; low willows, mosses, grasses, sedges, saxifrage, groundsel, cinquefoil and everlasting were the major plant species. Large expanses of dry alpine tundra with vegetation cover of heath, heather and mountain avens were not used. Few ptarmigan were located more than 25 m from a snowfield, stream or lake (mean distance 7 m). Willows or conifers were usually in the vicinity of ptarmigan sightings (mean distances 12 and 14 m) but hiding and thermal cover appeared to be provided mainly by rocks.

Nesting occurs on the ground, concealment being provided by short grasses and willows (Salt and Salt 1976). Females with broods remain on the breeding range, as described under spring and summer habitat above (Sharp 1973; Herzog 1977b; Holroyd and VanTighem 1983), or move downslope along stream courses, even penetrating below treeline (Herzog 1977b).

Habitat use in winter appears to be dependent largely on snow cover (Herzog 1980). During winters of low snow accumulation, when food (mainly willow) is available above snow, ptarmigan may remain in the same alpine cirques as occupied during summer (Herzog op. cit.), but otherwise move downward into shrubby areas and open conifer forests (Sharp 1973; Wisely 1979; Herzog 1980; Holroyd and VanTighem 1983), and occasionally into the vicinity of valley bottom ranches and settlements (Salt and Salt 1976). Herzog (1980) provides the following structural description of winter habitats:

1. "alpine cirque (2400 to 2600 m elevation): open tundra with scattered clumps of willow 5 to 30 cm in height.

2. treeline krummholz (2300 to 2500 m): widely spaced dwarf conifers, primarily alpine fir, Engelmann spruce and whitebark pine, with occasional patches of willow up to 50 cm in height.

3. subalpine forest (2000 to 2400 m): open forest of spruce fir and alpine larch, with scattered clumps of willows, dwarf birch and juniper.

4. stream course (1900 to 2100 m): drainageways through subalpine forest dominated by willows 2 to 3 m in height at lower elevations".

10.13.4 Space

Both sexes occupy common breeding areas, but males and broodless females may move to higher elevation basins by midsummer; the cause and extent of such movements are unknown (Herzog 1977b). Downslope movements of 2.5 to 7.5 km have been documented during winter, the extent of movement apparently being related to food availability as influenced by snow cover (Herzog 1980). There is some evidence that males remain closer to the summer range in winter than do females, but whether this is related to territorial, nutritional or other considerations is unknown (Herzog op. cit.).

10.13.5 Size and Interspersion of Habitat Units

Minimum area requirements of white-tailed ptarmigan have not been documented. In Alberta, small alpine basins with rock slides and rocky stream courses, and adjacent shrublands and subalpine forest for alternate winter food and cover, provide the year-round habitat requirements (Herzog 1977b, 1980).

10.13.6 Habitat Models

No formal models describing habitat use by this species were found.