forage areas for deer. Activities will be governed by the regional objective to enhance present populations of deer in second growth.

As forest management intensifies, it is most probable that wildlife management will as well. Management activities will become more and more orientated to locations where the most benefits can be derived in terms of deer produced and public recreation.

The data presented earlier (Figures 7 and 10) on capability, demand, and hunting opportunities, form a reasonable basis for deriving priority zones for deer management on Vancouver Island (Figure 11). It is highly unlikely that a significant effort will be made to either enhance or maintain high deer populations in areas of low capability and/or restricted opportunities for use (together comprising approximately 40% of Vancouver Island). Interest in such areas will likely centre on maintaining the distribution of the species. As such, significant deferrals of winter range, provision of spring forage blocks, or active attempts to enhance second-growth deer habitat are not expected.

In the other zones (Figure 11) it can be expected that intensity of activities will coincide with the designated priority (high demand/high capability combinations > high/moderate combinations > moderate/moderate combinations > high/low combinations > moderate/low combinations > low/low combinations). Winter range will not be a necessity below 300 m elevation, or feasible above 1000 m in any of the zones that historically have trends for deep snowfall accumulations (Figure 12). Provision of spring forage areas adjacent to deferred winter ranges will likely be requested in high and moderate priority zones. At present, low priority zones are questionable management zones. Further, silvicultural enhancement of second-growth deer habitat will likely be encouraged only in areas of high demand/high capability, high demand/moderate capability, or high capability/ moderate demand.

The Crown land portion of the high/high zone is expected to receive a much higher priority than the private land portion simply because the Wildlife Section has little input to forestry activities on private land. These priority ratings, however, have not been derived just on the assumption that the Wildlife Section would be the only party involved with deer management in the future. It is expected that private landowners will eventually participate in wildlife management in direct response to a large demand on the east coast of Vancouver Island for deer and other wildlife.
FIGURE 11. Priority zones for deer management on Vancouver Island.
FIGURE 12. Estimated snow depth accumulation patterns on Vancouver Island.
5.3 Forest Management Context

5.3.1 Description of the resource

British Columbia has 815 000 km² of land base of which approximately 70% is forested land. The province itself owns 96% of this forested land, representing close to 17% of Canada's forests. With this forested land base, British Columbia controls 52% of the softwood timber volume on stocked, productive, nonreserved forest land in Canada (Bonnor 1982). The importance of the forest industry to the economy of the province cannot be mistaken, and in particular, the coastal forest region provides a substantial portion of this economy. In the 1960's, it was estimated that 33% of British Columbia's total wood volume (trees 10 in. and above at DBH), in stands of productive and accessible sites, existed in the coastal logging area. In 1973 this figure was revised to 26%.

The coast forest region is essentially coniferous. It consists principally of western redcedar and western hemlock, with Sitka spruce abundant in the north, and coastal Douglas-fir in the south. Amabilis fir and yellow cypress occur widely, and together with mountain hemlock and sub-alpine fir are common at higher altitudes. Western white pine is found in the southern parts, and western yew is scattered throughout the region (Hosie 1975). Comprehensive and current information regarding specific characteristics of the timber resource in coastal forests is difficult and time consuming to obtain.

The well-developed coastal logging industry makes a major contribution to the economic base of most coastal communities. Industrial plant capacity is such that all available timber supplies from public and private lands can be used. One-third of the timber volume goes to finished lumber while the remaining two-thirds end up as pulp products (B.C. Ministry of Environment/Ministry of Forests 1983).

5.3.2 Goals and objectives

The general goals and objectives of the Ministry of Forests are laid down within the Forest Act (see Section 1). Objectives relating more specifically to the coastal logging can be extrapolated from Nyberg (1985).

The primary objective for intensive forest management on Vancouver Island is really a composite which stems from three sources: British Columbia Forest Products Limited (BCFP), MacMillan Bloedel Limited (MB) and the
British Columbia Forest Service (BCFS). Their objectives are taken from Nyberg (1985):

**BCFP** - To maximize merchantable mean annual increments by achieving culmination of mean annual increment at a mean stand diameter of 45 cm DBH.

**BCFS** - To manage even-aged stands for the production of sawlogs. The usual objective is to produce a stand with mean DBH of 45 cm.

**MB** - To maximize merchantable volume produced from even-aged stands, within the constraints of product demand forecasts (e.g. pulpwood vs. sawlogs).

These specific objectives relate only to production goals, but all are recommended under the coastal logging guidelines laid down by the Ministry of Forests in 1972 (B.C. Ministry of Forests 1972)(Section 1).

5.3.3 Forest management activities: current, problems projected

Nyberg (1985) stated that management guidelines for silvicultural activities are really only "best guesses" due to the lack of precision surrounding managed stand yield projections. Table 6 shows pre-commercial thinning standards for the large coastal Tree Farm Licenses, the BCFS, and several companies and government agencies in the U.S. Planting and commerical thinning standards are also shown for the BCFS, BCFP, and MB. The conclusion resulting from this table is that there is no single ideal silvicultural management regime.

Silvicultural regimes include more than planting and thinning. Site preparation activities (burning or scarifying) are followed by either planting or natural seeding, fertilization, weeding, clearing and crop-tree pruning. Intensive management may never occur, or could occur one or two times over the initial stages of young stand growth.

Tables 7 and 8 present basic and intensive silvicultural plans for Vancouver Island Crown land as a 5-year projection from 1 April 1982 (Brand 1981). Prescribed fire will continue to dominate mechanical site preparation. Weeding and cleaning will remain as minor activities. The dominant intensive silvicultural activity will be pre-commercial thinning, with fertilization ranking second. Conifer release programs are expected to be relatively extensive. Site rehabilitation, commercial thinning, and backlog planting are currently estimated to be small operations due to the current economic climate.
<table>
<thead>
<tr>
<th>Agency</th>
<th>Planting</th>
<th>Pre-commercial thinning</th>
<th>Commercial thinning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>With commercial thinning</td>
<td>Without commercial thinning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Douglas-Fir</td>
<td>Hemlock</td>
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<td>B.C. Forest Service</td>
<td>850</td>
<td>1200</td>
<td>750</td>
</tr>
<tr>
<td>B.C. Forest Products</td>
<td>750-800</td>
<td>750-800</td>
<td>Comm. thinning not planned</td>
</tr>
<tr>
<td>MacMillan Bloedel</td>
<td>1100</td>
<td>1700</td>
<td>600-1100⁵</td>
</tr>
<tr>
<td>Crown Zellerbach (Canada)</td>
<td>-</td>
<td>-</td>
<td>700-800</td>
</tr>
<tr>
<td>Canadian Forest Products</td>
<td>-</td>
<td>-</td>
<td>625-800</td>
</tr>
<tr>
<td>Toffee</td>
<td>-</td>
<td>-</td>
<td>625</td>
</tr>
<tr>
<td>Western Forest Products</td>
<td>-</td>
<td>-</td>
<td>700-775</td>
</tr>
<tr>
<td>Crown Zellerbach (U.S.)</td>
<td>-</td>
<td>-</td>
<td>700</td>
</tr>
<tr>
<td>Mayerhauser (U.S.)</td>
<td>-</td>
<td>-</td>
<td>740-860</td>
</tr>
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<td>U.S. Forest Service</td>
<td>-</td>
<td>-</td>
<td>750-950</td>
</tr>
<tr>
<td>Washington State Dept. Natural Resources</td>
<td>-</td>
<td>-</td>
<td>800-1000</td>
</tr>
</tbody>
</table>

1 Thinning densities are residual (i.e. post-thinning) stocking levels.
2 Good sites.
3 Medium sites.
4 Poor sites.
5 Depends on stand height at which future thinning will occur.
<table>
<thead>
<tr>
<th>Unit</th>
<th>Location</th>
<th>Area denuded (ha)</th>
<th>No treatment (ha)</th>
<th>Site preparation</th>
<th>Planting</th>
<th>Brushing and weeding</th>
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<td>Soward Forest. Isolated blocks in L &amp; M Railway Belt West coast north to Brooks Peninsula</td>
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<td>226</td>
<td>164</td>
<td>21</td>
<td>453</td>
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<td>Cape Scott area, Quatsino Sound south to Brooks Peninsula</td>
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<td>1121</td>
<td>663</td>
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<td>NA</td>
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<td>937</td>
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<td>Sooke, Naka Creek Port McNeill areas</td>
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<td>NA</td>
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^1 Not available
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<th>Unit</th>
<th>Year</th>
<th>Barkbag planting</th>
<th>Site rehabilitation</th>
<th>Site release</th>
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<td>266</td>
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<td>211</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
<td>21</td>
<td>617</td>
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<td>-</td>
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<td>(TFL) 2, Crown</td>
<td>83/84</td>
<td>-</td>
<td>-</td>
<td>21</td>
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<td>-</td>
<td>5</td>
<td>353</td>
<td>310</td>
<td>-</td>
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<td>-</td>
<td>5</td>
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<td>239</td>
<td>190</td>
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</tr>
</tbody>
</table>
It is important to note that most activity with respect to basic and intensive silviculture is expected to take place on the east coast of Vancouver Island north of Ladysmith, as well as south of Nootka Sound on the west coast of Vancouver Island. Potential for silvicultural treatment comparisons between locations of high and low deer capability is promising (see Figure 7).

5.4 Summary of The Problem Definition

The following is a brief summary of the major points made in Sections 4 and 5.

5.4.1 Perspectives

Foresters find it difficult to accept that provision of certain types of forests for deer habitat is an important issue, especially in view of the current scale of predation by wolves.

Deer biologists have provided evidence that current logging practices are depleting winter range for deer. They predict this will cause a severe and long-lasting decline in deer populations, and remain skeptical about the potential for providing winter range in young second-growth forests.

5.4.2 Wildlife ecology context

**Cover**

Deer select and use habitats that approximate thermal neutrality, that help minimize sinking depths in snow, and that provide some cover from sight by potential predators. The extent to which these cover requisites are preference or requirement is unclear. The relative amounts of energy expended to achieve selection of suitable habitat is not known.

**Food**

The important characteristics of food are quantity available, quality (energy and nitrogen content), and digestibility. Food species selected by deer are variable and depend on region, time, and availability. Minimum levels of protein necessary for maintenance have been reported as 6-7%.
Spatial and temporal variation

How deer respond to the spatial and temporal variation of their habitat matrix (food and cover) is unclear. The problem intensifies when these variations are increased by perturbations such as fire or logging practices.

Predation

Predators can regulate and/or limit deer populations. The significance of habitat structure in prey vulnerability is unclear but has been reported as having an effect.

Behaviour

Foraging for food ranges in difficulty from most difficult in the winter, less difficult in the fall and summer, to least difficult in the spring. Learning is a large factor in determining home range selection (at least for females and non-dispersing males). Site fidelity is an important management issue. Deer show some signs of behavioural adaptation to predation, especially to predation by humans.

Population growth

At least two approaches are available for determining the quality of numbers and productivity of deer populations:

1. estimation of ecological carrying capacity; and
2. determining the net energy aquisition and expenditure on an individual animal basis.

The two assessment methods are sound theoretically but difficult to apply primarily because of inventory problems in the former, and lack of energy estimates for activities in the latter.

5.4.3 Wildlife management context

Cover

Thermal cover, if important on Vancouver Island, is expected to be most significant during cold, wet springs.

There are no data to indicate the significance of security cover for deer on Vancouver Island.

The need for cover from deep snow is well documented and research has progressed as far as identifying those forest characteristics most important in providing cover. Current research emphasis is on the implementation of management policies on small-scale test sites in second-growth forests.
Food

Food habit studies have been frequent and indicate that Vaccinium spp., Gaultheria shallon, Thuja plicata, Tsuga heterophylla, Pseudotsuga menziesii, Rubus ursinus, Blechnum spicant, Rubus pedatus, Epilobium angustifolium, Hypochaeris radicata, and arboreal lichens are the most important forage items.

Provision of lichens has tended to be in the centre of the resource conflict because old-growth produces far more lichens as winter forage than do young stands. Many questions have arisen concerning the use of lichens as a forage item and their management for continued availability as forage for deer.

Managers are unclear how forage availability is altered by snowpack accumulation and ablation during winter.

Spatial and temporal variation

The timing and spatial arrangement of habitat perturbations caused by forest harvesting has serious ecological implications for Vancouver Island deer populations (e.g., deer numbers may be concentrated into particular seasonal habitats; or some habitats may become entirely unavailable).

Juxtaposition of habitat types is considered to be a problem unless integrated management becomes a reality.

Managers have identified topographic and climatic gradients as important characteristics of deer habitat quality.

Predators

There are no data to determine the effect that wolves have on habitat selection by deer.

Competition

An overlap between deer and elk does occur in local situations, but there is no evidence of severe competition for resources.

Behaviour

Deer select old growth as winter habitat except where old growth has been harvested, in which case deer will use second growth. There is no information regarding differing rates of survival between deer selecting old-growth and those selecting second-growth stands. Little is known regarding predator avoidance strategies of black-tailed deer.
Population growth

The common method of assessing growth and regulation has been the evaluation of indices of deer abundance (night spotlight counts), deer productivity (fawn/does counts), hunter harvest data, and wolf abundance indices.

The "net energy" approach has been used only in theory and in the form of conceptual models.

Logging activities, fluctuating weather (severe and mild winters), and increases in wolf populations have produced extremely complex and poorly understood changes in Vancouver Island deer numbers.

Limiting factors are believed to be wolves and availability of winter habitat.

The distribution of deer has not changed over recent times, but the area of greatest relative abundance has shifted from north Island to south Island.

Densities of deer can be as high as 20 per square kilometre in productive watersheds. Densities in partially cut watersheds appear highest, followed in order by uncut watersheds and advanced second-growth watersheds.

Demand

Demand for deer hunting on Vancouver Island is expected to increase in the future.

Thirty-five to fifty percent of the recreational hunting days are spent on deer (1960-1980 estimate).

Hunter success has declined from 6 to 8 days required to bag a deer in the 1960's, to 15 to 20 days required in the early 1980's.

Management

Management is largely subjective and extensive. Hunting is monitored by game checks and questionnaires and control is established by altering hunting regulations.

Currently there is no effective regional control over wolf numbers.

Habitat is managed through preservation (protection) strategies, although there is a current push for habitat improvement. Protection of winter range and spring forage areas are of primary concern.

It is unlikely that significant effort should be put into managing deer populations in areas of low capability or restricted access (40% of Vancouver Island).
5.4.4 Forest management context

In 1960, 33% of British Columbia's total wood volume, in stands of productive and accessible sites, existed in the coastal logging area.

Stands of Douglas-fir, western hemlock, and western redcedar provide the basis of a viable forest industry that is the economic base of most coastal communities in British Columbia.

One-third of the timber goes to finished lumber, while the remaining two-thirds end up as pulp products.

Most of the forest industry is committed to intensive silviculture although there is no single silvicultural management regime.

Silvicultural activities can include planting, thinning (the two most widely used), as well as burning, fertilization, weeding, cleaning, and pruning.

Most activities are concentrated on the east coast of Vancouver Island and south of Nootka Sound on the West Coast.

5.4.5 The problem summarized

There appear to be two basic concerns over the management of the deer resource on Vancouver Island, only one of which is directly related to intensive forest management. The short-term, but pronounced, effect of predation on deer by wolves is a management problem of concern to the Ministry of Environment. The longer-term, but perhaps most serious, problem originates from the following conflict in objectives between the ministries of Forests and Environment: Intensive forest management has the potential to cause large-scale changes to deer habitat. Wildlife managers have limited input to where and when the large-scale changes occur. Deer winter ranges are thought to be the current (but long-term) limiting factor to deer population levels, and hence old-growth winter range availability has been the focus of the conflict, although it is by no means the whole conflict.

The general problem is a lack of integrated and co-ordinated management of a resource that is basic to both the forest industry and to black-tailed deer. There are a number of reasons for this:

1. There is a difference in perspective associated with this resource conflict (Section 5.4.1) and this divergence results in the inability to perceive and plan for specific management activities (both on the side of forest managers and wildlife managers).
2. There is an inadequate understanding of how deer respond to changes in the cover characteristics (thermal, security, and cover from snow) of their habitats, imposed by intensive forest management.

3. Food availability and quality is expected to change due to intensive forest management. This problem is reviewed in greater detail by Nyberg (1985).

4. It is not well understood how deer respond to changes in the juxtaposition of habitat types imposed by intensive forest management, or how altering the ratio of cover to food affects deer.

5. Because of points (2)-(4), there is an inability to recommend second-growth silvicultural practices that would enhance deer production to meet the demand for deer.

6. There is no information regarding the effect of wolves on habitat selection by deer.

7. Individual behaviour of deer is expected to have an influence on the success of habitat management attempts.

8. There is an inability to inventory deer populations, deer harvests, and deer habitat at desired scales and with desired accuracy so that points (2)-(4) can be monitored and point (5) assessed. Although energy values for deer forage have been obtained and energy cost of locomotion through snow has been estimated, much scientific research is necessary before precise estimates of net energy can be used as a means of assessing point (5).

9. There is a lack of area-specific management for deer comparable to the site-specific management of forests.

10. There is an inadequate legislative base to force the modification of land use activities and so manage deer and their habitat.

11. There is a lack of incentive for forest managers to become involved in deer habitat management. That involvement would effectively reduce current levels of timber production and hamper attempts at changing production goals to parallel market fluctuations.

6 INFORMATION NEEDS

The principle problem facing managers is their inability to predict adequately the effects of intensive silviculture on deer populations.
Subsequently, few recommendations can be made for effective integrated forest-wildlife management. This problem is primarily due to an inadequate understanding of how deer respond to the habitats created by forest management activities and regimes, as individuals and as populations. Managers can make general predictions about deer population responses, but only gross changes are detectable with current inventory methods and resources (Harestad and Jones 1981). Thus the manager's problem is predicting both the vegetation or habitat response to silviculture and the deer population response to the changes in habitat, within confidence limits appropriate to management objectives.

6.1 Needs Identified by Defining the Problem

Integrated management can take place only after such time as differences in perspectives have been resolved and policy statements on production objectives have been produced. Forest managers have production objectives firmly in place (e.g., annual allowable cut) but wildlife managers must be explicit, site specific, and more quantitative in stating production goals. In the interim, until recreational objectives are set, there must be a relay of information from research personnel to forestry and wildlife management. Information should be in the form of a simple and concise handbook that explains why habitat is important to deer and how various aspects of a deer's life requisites are linked to habitat. Furthermore, the handbook should describe how silvicultural prescriptions can alter deer habitat. One significant lack of information remains that concerning absolute numbers of deer. Wildlife managers are encouraged to use their "best indices" in the meantime so that integrated management can be viewed as a viable solution to the current resource conflict.

6.1.1. Habitat: physical environment parameters

**Cover**

An understanding of how deer respond to "effective temperature" (radiation, wind, relative humidity) gradients is required to define exactly what a deer's thermal cover requirements are. We assume thermal cover to be important to the deer for conserving energy. Thus, if less heat is lost to the environment, then more energy will be available for other purposes such as locomotion and reproduction. To evaluate habitat suitability in serving as thermal cover, managers require information
about the effect of vegetation on factors affecting heat loss, such as temperature and windspeed. It is important that information concerning deer response to these factors be recorded, since deer can respond both physiologically and behaviourally (Section 5.1.4).

Hatter (1982) indicated that information is needed regarding the effect of intensive silviculture on prey vulnerability to predators. Do isolated blocks of mature timber concentrate deer and increase their vulnerability? How can the important physical characteristics of hiding and escape cover be identified, measured, and therefore incorporated into silvicultural practices?

Cover from deep snow in winter is influenced by the way in which forest canopies intercept and redistribute snow (Bunnell et al. 1985). The characteristics that most old-growth winter ranges have in common are well documented (Bunnell 1985). Manipulative research based upon current understanding of forest/snow interactions (Bunnell et al. 1985) should improve our knowledge of critical components of winter range and of how deer react to such habitat management. Such experiments will also determine our ability to silviculturally manipulate second-growth stands with silviculture, and so mimic old-growth conditions (Nyberg et al. 1985b).

**Nutrients**

Defining the forage resource, quantifying its abundance and quality, and determining how deer respond to changes in forage resources are complex problems. "Forage" includes a large, diverse collection of plant items differing in temporal and spatial distribution and abundance and in chemical composition, size, and form. Vegetation varies in biomass, species composition, and productivity relative to environmental site factors, disturbance, and time.

The most relevant variables to consider for forage species are biomass, current annual growth, cell structural components and cell solubles, digestibility, nitrogen, energy content, and secondary compounds.

The patterns and processes of secondary vegetation succession (either naturally or silviculturally induced) can differ greatly as a function of site factors and predisturbance community structure. The quality of the resultant habitat varies accordingly. Thus, we require quantification of succession vegetation dynamics before we can relate
deer responses to any changes in forage. The effects of silvicultural practices on understory vegetation dynamics needs to be understood generally, in terms of the rate and pathways of secondary succession, and specifically in terms of species composition, biomass, and annual productivity.

Vegetation in both climax and successional plant communities has been studied extensively on Vancouver Island (for a review see Krajina 1965; Packee 1972; Klinka 1976; Nyberg 1985), but it is a complex and difficult endeavour that requires much more intensive work. Ellis (1980) recommended initiation of a major research program on Vancouver Island, involving growth and yield parameters of forest stands and the autecology of understory species. The effects of major silvicultural practices should be stressed in such studies. None of the past studies (Cowan 1945; Gates 1968; Harestad 1979; Rochelle 1980) provide any data on silviculture effects on forage production.

The importance of lichens as winter forage has been documented (see Section 5.2.1.2). Digestibility, nutrient content, and availability of lichens for deer have not been fully evaluated. In addition, the biology of lichens should be investigated to provide knowledge on their management as deer forage. Such investigations should include: dispersal distance of seed sources, growth rates of lichens, growth substrate requirements, litterfall rates, and standing crop inventory techniques (Stevenson 1978).

As well as increasing locomotory costs to deer, snow also limits forage availability. The relationships among snow depth, burial, compression, horizontal and vertical distribution of forage, and resultant forage availability and quality have been investigated to some extent in the Nimpkish Valley (Harestad 1979), but many of the relationships have been developed empirically and need extensive field testing (see Harestad and Bunnell 1979).

**Spatial and temporal patterns**

Managers must consider the characteristics of adjacent stands when providing management proposals. For example, where winter ranges are deemed to be necessary, the questions that should be asked are: How much? Where or what should be the spatial orientation of distribution of such habitat? Will winter range reserves turn out to be predatory traps? The general nature of topography-snowpack relationships and
likely correlation with deer range use are fairly well understood, but current inventory data on regional and local snowfall are lacking for much of Vancouver Island, thus hampering management predictions for winter range on the basis of snowpacks. An up-to-date version of Figure 12 is necessary to delineate priority zones for winter range management.

Orientation of spring forage range and winter range is a topic concerning most deer managers. Managers wish to provide forage areas that will be readily accessible in early spring to deer using adjacent winter ranges. It is not known at what distance from a winter range spring forage will become "inaccessible" due to home range size constraints. Snow conditions fluctuate over time and space, and thus managers need to understand how these changes affect travel costs and, most importantly, habitat selection.

Wallmo and Schoen (1980) suggested that old growth forests have a more variable spatial orientation of both forage and snow than other habitats. Old growth could potentially enable reduced locomotion cost and higher amounts of more nutritious forage than other habitats with the comparable "mean" snow depths but less variable accumulation of snow. This topic is currently under preliminary investigation (Bunnell 1984; Nyberg 1985).

Spatial orientation of forage areas to security cover is another area where information is needed. No current research has been planned.

Integration with the Habitat Management Section of B.C. Ministry of Environment will be required when habitat juxtaposition problems are addressed.

6.1.2 Predation and competition

Hatter (1982) outlined 11 questions that need to be addressed to increase understanding of predator-ungulate relationships on Vancouver Island. Most questions focus upon the influence of wolves on deer recruitment, survival, and habitat selection, and upon the potential for snow and silvicultural practices to alter predator impact. What habitat type is required to limit the functional response of predators? How can forest characteristics be measured and incorporated into silvicultural practices?
More information is required to enable integration of wolf management into ungulate-habitat systems. Currently this management entails the reduction of wolf numbers. Longer-term objectives should be to explore the potential of using habitat management to create greater security cover for deer, and to document the level at which Vancouver Island wolf and deer numbers can reach equilibrium. Specific needs are to understand how wolves influence habitat selection, how cutblocks are used seasonally and nocturnally by deer, and what the physical characteristics are of security cover (Hatter 1982).

6.1.3 Behaviour/adaptive strategies: habitat selection

The important question regarding habitat selection is how does a deer respond to its environment and use habitat while meeting its requirements? Answers to this question are necessary for assessment of relative value of habitat components to deer and/or habitat quality.

Many of the major deer-forestry management conflicts revolve around why deer use or select particular habitats. A limitation of investigating habitat selection, however, is that it can only indicate the deer's choice of the available alternatives, but will not necessarily indicate what is the "best" habitat if the latter is unavailable. A similar problem revolves around the issue concerning selection, preference, and requirement. Information is required that will help to resolve the problem of differentiating between what is a preferred habitat and what is required for survival. Thus, in addition to habitat selection data, we need to be able to assess what benefit a deer gains by selecting a particular habitat.

In the high snowfall areas we do not fully understand the functional differences between critical and average winter range. We will need a much greater understanding of the spatial aspects of home range-related behaviour to answer these questions. Current studies using 19 radio-collared deer on Vancouver Island reveal great variation in home range and habitat selection pattern. We also need to know why deer winter in poor ranges when 0.5 km down a valley, snow conditions may be much less severe and ranges adequate. Do deer get trapped on these upper ranges by increasing snow depths during the winter? To what degree does learning enter into habitat selection? Home range fidelity during winter and deer movement in response to snow conditions need more study.
6.1.4 Population growth and regulation

In recent times the economy has endangered the continuity of collecting baseline population trend data. Population reproduction parameters and fawn/doe ratios are currently the only viable techniques that can be used for population productivity estimates and the importance of their continued use needs to be stressed.

The "net energy gain/loss" technique is useful potentially for improving our conceptual understanding and providing "best guesses" for field level management (Potvin and Hout 1983; Section 5.4.2). However, few, if any, researchers have been able to extrapolate "net energy" theory to field management situations. The use of energy as a fundamental measure of population productivity for decision-making in wildlife management is recent (Moen 1973). Generally, knowledge is required that will help make "net energy" theory more applicable for field level management.

The determination of energy and protein requirements for an animal is a costly, difficult, and time-consuming process. It consists of measuring physiological responses at varying nutritional and/or activity levels, and assessing such parameters as survival, weight changes, condition, and reproductive performance. Research involving domestic ungulates has been substantial, lab research on wild ungulates less common, and actual field trials on wild ungulates very rare. Refinement for estimates of these costs will require considerable field research with wild ungulates (activity costs and physiological response); much more data on seasonal and daily activity regimes; and, most importantly, the testing of deer population response to range condition, based on predictive estimates or models of protein/energy needs.

6.2 Needs Identified by the Modelling Approach

Using a modelling approach to understanding the system of deer/intensive forestry interactions has several advantages (Martin 1968):

1. Decisions concerning the future system can be made while the system is still in a conceptual stage.
2. System performance can be simulated and observed under all conceivable conditions (real world and/or hypothetical situations).
3. Results of field system performance can be extrapolated on simulation models for purposes of prediction and hypothesis generation.
4. System trials are speeded up and more cost efficient. The following four models of deer/intensive forestry interactions are discussed:

Conceptual models - 1) energy functions (Harestad et al. 1982) and 2) optimal foraging theory (Hanley 1981); and

Descriptive simulation models - 3) ESSA (McNamee et al. 1981) and 4) STUF (Shank and Bunnell 1982c).

Conceptual models

Harestad et al. (1982) presented a simple conceptual model comparing two energy functions during winter: 1) the relationship between energy (food) availability and snow depth, and 2) the relationship between energy expenditure for movement and snow depth (Figure 13a). The model implies that under shallow snow conditions deer acquire a net benefit because more energy is acquired than expended. The converse is true in deep snow. Contrary to the model, a net energy gain may be possible for deer during spring and summer seasons, but is unlikely during winter for either forage availability or behavioural reasons (Bandy et al. 1970; Nordan et al. 1970; Section 5.1.4). Therefore, the model presented by Harestad et al. (1982) may have more utility for seasons other than winter, and with a locomotion impediment such as logging debris.

Figure 13b depicts the same conceptual model for a winter season, with corrections made for behavioural changes (reduction of forage intake and BMR, and the catabolism of body tissue). This model expresses energy expenditure without consideration of distance travelled and trailing behaviour. Home range studies indicate this distance is usually lower in winter than in other seasons. The energy expenditure function in Figure 13 is well documented by Parker et al. (1984). Very little information is available concerning the energy acquisition function.

Figure 13b implicitly points out that deer select habitats with minimal snow accumulation. Because the net energy is slightly negative during winter, the best habitat for deer must be one that will allow minimum energy deficit. The primary question is whether or not deer select habitat on a "threshold" basis or whether deer respond to snow conditions on a simple energy cost model? Regarding the latter, this may not be the case since deer often remain as high as possible in snow areas and do not appear to be selecting the most snow-free areas or
FIGURE 13. A conceptual model of the influences of snow depth upon energy expenditure (E) and energy acquisition (A) for a wintering deer: a) from Harestad et al. (1982), and b) altered to consider characteristic winter behavior and winter net energy balance.
least snow depths. The models in Figure 13 express energy gains and expenditure in relation only to snow depth, but similar models could be designed for other seasons and other energy costs/benefits.

The second conceptual model of deer and intensive forestry interactions is more specific to habitat selection based on optimal foraging theory (OFT) (Hanley 1981). OFT is based on the premise that deer will harvest food efficiently and that they will choose the most profitable foods relative to the choices available. Further, it is assumed that deer will change feeding areas only when they can do better (i.e., obtain higher intake) by travelling to another habitat. Thus, according to OFT, the optimal allocation of time to a habitat is that which maximizes net rate of nutrient intake. OFT, exemplified by Hanley’s (1981) model of habitat selection and habitat quality, proposes that deer “optimize” and that most aspects of habitat selection can be explained on the basis of foraging theory (Figure 14). This theory suggests that deer only have to move to eat, making foraging the major consideration. Hanley indicates that during winter deer can only last a short time without food, and thus foraging is the driving force behind habitat selection and the best basis for assessing habitat quality. He assumes that optimal allocation of time or the maximizing of net rate of intake is synonymous with habitat quality, and that observed habitat selection (because it is based on time) reflects habitat quality. He further emphasizes that one must consider both food consumption and food processing when discussing foraging efficiency because diet quality determines not only the energy intake per unit time feeding, but also how much time can be spent feeding each day. Thus Hanley reduces the problem of habitat quality and habitat selection (deer’s food acquisition strategies) to a problem of the deer choosing the combination of diet and habitat (foraging availability) that will maximize its foraging efficiency:

- Foraging efficiency is a function of diet and amount consumed.
- Amount of forage available for consumption is a function of the habitat selected.
- Foraging costs are a function of the habitat selected and the amount of time feeding (latter partially a function of diet).

Despite the emphasis on diet, habitat quality can be assessed on the basis of an intake function (such as net energy) and a cost
FIGURE 14. A conceptual model of habitat selection based upon vegetation biomass where energy expenditure (E) and energy acquisition (A) are hourly energy functions (from Hanley 1981).
function -- habitat quality being the difference between the two functions. Changes in forage availability and quality will change the acquisition function, while changes in environmental costs such as thermal environment or locomotion difficulties in snow will change the expenditure function. Some factors such as snow, which bury forage and increase travel costs, will change both functions.

Both conceptual models ignore predation or the possible need for cover, both of which may influence use of a feeding area. Further, both models assume that non-foraging activities and use of habitat for same, are not very important in assessing habitat quality and habitat selection. The models assume that any time a deer uses a habitat, it is attempting to maximize net gain (Hanley's model) or minimize net loss (Figure 13). Do deer always optimize? Can habitat quality and observed habitat selection be evaluated on this basis? At present, we simply do not have sufficient deer movement or habitat use data to evaluate these theories.

Descriptive models

Two models that attempt to clarify conceptual understanding of black-tailed deer/intensive forest management interactions by the simulation approach are the ESSA and STUF models.

The first model was formulated in 1981 through a workshop approach (McNamee et al. 1981), the objectives of which were to:
1. develop a framework for co-operation and communication between wildlife and forestry interests;
2. develop a conceptual framework, in the form of a computer simulation model, to use as a guide in developing a research plan for IWIFR;
3. develop a set of hypotheses about important processes in the system under study;
4. develop a framework for testing hypotheses, and provide a basis for evaluating the relative importance of different processes; and
5. resolve the question of the level of detail for research in the program.

Elk, deer and their predators are the only wildlife species considered.

The second model took form at the University of British Columbia (UBC) (Shank and Bunnell 1982c). It was named STUF to reflect the focus on snow, trees, ungulates, and forage, this model was developed to:
1. guide research directions concerning deer/intensive forestry interactions, and providing a dynamic synthesis of research results;
2. identify relevant processes in the system under consideration;
3. create an understanding of sectors of strength and weaknesses in the system leading to a sharper conceptual image of the perceived interactions; and
4. develop a sense of which processes and parameters might be most important.

The model explicitly ignores predator influence in the system and considers only deer.

The following discussion attempts to answer five questions concerning results of the two modelling efforts:
1. Is the model sufficiently simple that the basic concepts presented are understood?
2. Do the logical assumptions introduce potential confounding and/or unreliable synthesis?
3. Are the important issues of the system (based on current knowledge) all incorporated?
4. What questions are raised by the model? Where is knowledge lacking?
5. Can we extract the relative significance of each problem issue in the system?

Producing these general models necessitates decisions concerning choices of specific subroutines. For some particular subroutines, many modelling choices already exist in the current literature.

6.2.1 The ESSA deer submodel

The ESSA deer submodel presents a hypothetical situation in which a watershed is divided into one hundred 80-ha blocks. The deer submodel loops over three seasons and deer are assigned to habitat "blocks" on a relative basis according to the value of the particular "block habitat." The value of each "block habitat" depends upon winter range value, escape cover value, and food value, which are all variable characteristics of each block. Sections 2.2 and 2.6 of the McNamee et al. (1981) report clarified the particular parameters involved and the interaction matrix for the modelling exercise.
Because the ESSA model was created with the intent of developing a research plan for IWIFR, it is therefore directly related to research concerning deer/intensive forestry interactions. Research recommendations resulting from the exercise include hypotheses concerning:

Snow
- the effect of snowfall frequency on food supply and energy costs.
- the effect of tree canopy characteristics on snow interception.
- the relationship between snow depth and food availability.

Movement
- the selection of winter habitat as guided by fidelity and snowfall patterns.
- the components relating to value of a site as deer habitat and subsequent description of the utility of the site as winter range escape cover, and foraging habitat.
- the seasonal range size of a deer.

Foraging
- the preference that deer have for various food types.
- intra-specific competition for food resources.

Survival and reproduction
- winter mortality as the only other source of mortality besides hunting and predation,
- the influence of winter and spring energy intake on reproduction.
- the compensatory and/or additive natures of winter mortality and predation mortality.

While the ESSA model incorporates all of the issues concerning deer/intensive forest management interactions, it does so at the expense of being vague and unreliable. The unreliability stems primarily from the numerous and confounding assumptions that are used. Weighting factors employed with limited empirical knowledge create many basic assumptions (e.g. security cover indices, restrictions on seasonal movement patterns, searching efficiency ratios). Assumptions and "guesses" end up as concurrent tests in the model.

No confidence can be placed in judging the relative significance of information needs even though the information needs are clearly represented in the ESSA model. Perhaps the most effective use of the ESSA model are its assumptions. Many of the these (represented by the list of research recommendations made earlier) require further baseline field knowledge so
that less complex subroutines could be run. The intent would be to formulate prediction hypotheses from each subroutine to guide specific research projects.

6.2.2 The UBC STUF model

The simulation model STUF consists of three major submodels: 1) a snowpack subprogram, 2) a subprogram describing forage availability and use, and 3) a subprogram describing energy costs of deer locomotion through snow. The current emphasis on refining the model is to improve the realism of the snow submodel.

The time period for the model is 1 day and is restricted primarily to the winter and spring seasons. The model is not site-specific but operates on point estimates that exhibit various site factors such as canopy cover, slope, aspect, and elevation. A complete interaction matrix is given in Table 1 of Shank and Bunnell (1982c). The major differences between STUF and the ESSA deer submodel are that:

1. the time step is 1 day as opposed to one season;
2. the spatial cell is 20 m on a side rather than 80 ha in area;
3. the deer are allowed to move from one cell to another without time constraints;
4. model refinement is an ongoing procedure as data become available to evaluate and test model assumptions.

Currently, only the snow subprogram operates with sufficient predictive capabilities to be tested. Information needs identified by model operation thus far are:

- daily measurements are needed (instead of monthly or weekly) before refinement of the snow melt subroutines can take place.
- management for uniform, intermediate canopy covers may encourage uniform destruction of the forage throughout winter and early spring under extreme conditions.
- reasonable values for the interaction between distance moved and energy expended by deer.
- "real world" canopy cover - forage biomass relationships.
- development of more sophisticated decision-functions for deer choice of feeding areas.
small-scale spatial variability patterns.

STUF does not incorporate all the issues concerning deer/intensive forest management interaction nor is it a finished product. However, it is a simple model that is conceptually clear. Its assumptions are explicit and conform to the data driving the model. Unvalidated assumptions are not incorporated but are identified as information needs instead.

6.3 Summary of Information Needs

This section provides a short list of study topics that could lead to better evaluations and definitions of how intensive forest management affects the selection and use of habitats by deer. Some of these topics are listed below even though they may replicate the results of Hatter (1982), Nyberg (1985), and Nyberg et al. (1985b). Emphasis, however, is placed on topics concerning only deer response to habitat and habitat conditions. At the same time, it must be emphasized that there is a need to clarify the relative importance of predation by wolves and humans and of habitat (primarily winter range) to deer populations and their management on Vancouver Island.

Habitat characteristics

1. We need to test both our abilities to manage second-growth stands to produce winter range conditions for deer, and to test our models of snow interception by forest canopies. This is a logical progression of Priority 1 of Nyberg (1985). These tests will also help demonstrate and transfer knowledge to foresters.

2. We need to quantify succession vegetation dynamics and to provide realistic canopy cover-forage biomass relationships. The relationships would provide a scale on which to evaluate deer response to forage changes imposed by silvicultural practices. This is stated as Priority 2 of Nyberg (1985) and is currently being undertaken by the IWIFR program as well as at UBC.

3. We need to find a means of managing lichens as a key winter forage item that might not otherwise be produced in second-growth winter ranges. Nyberg (1985) noted this in Priority 1. This need is currently undergoing a problem analysis (Stevenson 1985).

4. We need to quantify the change in availability of winter forage items as snowpacks accumulate and ablate. This need is stated in Nyberg (1985), Priority 1, and is currently being undertaken in the IWIFR program as
well as at UBC. The purpose is to improve predictions on forage availability during winter.

5. We need to quantify the physical characteristics of security cover in different habitats (Hatter 1982). This is also Priority 3 of Nyberg (1985). Nyberg (1985) alluded to the fact that the need for such cover should be determined before emphasis is placed on studying how intensive forest management altered security cover.

6. We need to quantify how forest variables modify "effective temperature" gradients in forest stands. This is Priority 4 of Nyberg (1985). Determining the response of deer to "effective temperature" should probably take place prior to studying the influence of forest variables on "effective temperature".

7. We need to know the integrated effects of climate, topography, and vegetation as they relate to snowfall patterns and conditions on Vancouver Island. This need was not identified as such by Nyberg (1985), but it would help determine winter range management regions and priorities for winter range management on Vancouver Island.

Responses of deer to habitat and habitat conditions

1. Habitat suitability model: We need a short, simple document that describes how habitat components satisfy the various life requisites of deer. Wildlife managers would be required to make evaluations of optimum habitat carrying capacity and to express relationships in terms and expressions regularly used by foresters. The document would help relieve the perspective divergence between foresters and wildlife managers and to provide a basis for integrated management (see "Perspectives", Section 5.4.1).

2. Thermal cover: We need to quantify how deer respond to "effective temperature" gradients. The purpose is to identify conditions that may present thermal stress and extreme losses of energy for deer (see point (6) above and "Thermal cover", Section 6.2).

3. Security cover: We need to document how deer respond to the elimination or severe alteration of security cover, to determine if security cover is a requisite of deer, and if further study is required to define the characteristics of security cover (see point (5) above and "Security cover", Section 5.4.2).

4. Locomotion in snow: We need to clarify the effects of snow characteristics on sinking depths of black-tailed deer and further, we
need reasonable values of the interaction between distance moved and energy expended by deer. The purpose is to enable extrapolation of the findings of Parker et al. (1984) to the situation in coastal British Columbia and, further, to map energy expenditure functions into existing models of habitat quality that are based on "net energy balances" (see Section 6.2).

5. Juxtaposition of habitat types: We need to study deer response to varying juxtapositions of habitat types. Particular emphasis should be placed on: i) proximity of spring forage to winter ranges; and ii) the number and position of winter ranges in watersheds. The purpose of such study is to allow more area-specific (e.g. watershed level) management plans (see "Spatial and temporal variation", Sections 5.4.2 and 5.4.3).

6. Predator influence: We require information that will help our understanding of the influence that wolves impose on habitat selection and use by deer. The purpose is to help to determine the relationships between wolves, deer, and habitat selection by deer, and further, to evaluate these relationships in varying conditions of security/cover (see Section 5.4.2).

7. Site fidelity: We require information concerning the response of deer to our attempts at managing second-growth forests for winter range. The purpose is to determine the significance of site fidelity and other behavioural issues thought to affect the use of managed winter ranges by deer (see Sections 5.4.2 and 5.4.3).

8. Decision functions: We require seasonal decision functions for a deer's choice of habitat types (feeding and cover); and an estimate of probability of survival parallel to the decision functions. Eventually, we will need to understand decisions made at a finer level of detail (e.g. forage selection, micro-habitat selection).

9. Distance of movement: We need documentation of seasonal range sizes and seasonal linear travel for deer so that this information can be mapped into seasonal energy expenditure functions (see Section 6.2).

10. Winter-spring energy acquisition and expenditure: We require information concerning the influence of winter and spring energy intake and expenditures on reproductive success of deer. This information as well would be mapped into energy-based models of habitat assessment.

11. Simulation modelling: We need to collate existing habitat selection, energy acquisition, and energy expenditure data for deer, and to model
(as simply as possible) the interaction of the life requisites of deer. The purpose of the modelling exercise is to provide an estimate of the relative importance of each of the life requisites for deer and to integrate findings from points (2)-(6) and (8)-(10) above (response of deer to habitat and habitat conditions). The results would enable more confidence in defining where research priorities should be placed in the future and would add support to point (1) above.

7 RESEARCH TOPICS
7.1 Setting Research Priorities

Within the following discussion, information needs are assigned priorities. The 11 topics on deer response to habitat and habitat conditions (Section 6.3) were ranked according to their individual importance, using 16 criteria (Table 9). Each information need (henceforth called a potential research topic, Table 10) was given a simple rank (high, medium, or low) for each specific consideration (Table 11). The first seven criteria were used to identify the relevance of a particular research topic to IWIFR's mandate. A joint report from the ministries of Environment and Forests (B.C. Ministry of Environment and Ministry of Forests 1983) and Section 6.3 of this report indicate that most topics have a high ranking for at least these first seven criteria and therefore only the last nine were assigned points (High=3, Medium=2, and Low=1). Priority was based upon point totals. The result was that the potential research topics identified in Section 6.3 could be listed in order of priority (Table 12).

Aside from the priority ranking system described in Table 10 and used to generate Tables 11 and 12, there must be some thought given to how the various research topics relate to each other. Topics 4 and 10 rank evenly in Table 12, but their relation to each other dictates a difference in priority. Available data bases have yet to be fully explored concerning: 1) deer locomotion in snow (work in progress at UBC) and 2) availability of forage during winter and spring (work in progress at UBC and the habitat component of IWIFR). It would be logical to pursue these issues before putting much emphasis on topic 10 - winter and spring energy acquisition and expenditure functions, and their relation to the reproduction success of deer.

To continue the above "critical path" approach, it would seem logical to know how deer proportion their time in individual habitats before topic 10 is
TABLE 9. Criteria used to assess priority of information needs

<table>
<thead>
<tr>
<th><strong>Is the topic within the realm of the organization?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Legislative responsibilities</td>
</tr>
<tr>
<td>2) Agency priorities and policy</td>
</tr>
<tr>
<td>3) Public concern</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Is the topic of major concern to the organization?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>4) Extent of the problem location, region</td>
</tr>
<tr>
<td>5) Timber values involved</td>
</tr>
<tr>
<td>6) Wildlife values involved</td>
</tr>
<tr>
<td>7) Timber and wildlife production opportunities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Are there current management actions available to solve the problem?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>8) Is new information essential?</td>
</tr>
<tr>
<td>9) Consequences of no research</td>
</tr>
<tr>
<td>10) Attitudes and social systems (i.e. management &quot;climate&quot;)</td>
</tr>
<tr>
<td>11) Need for demonstrations and technical transfer plan</td>
</tr>
<tr>
<td>12) Are there models available to generate effective research?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>What are the cost-benefit details?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>13) Cost of research</td>
</tr>
<tr>
<td>14) Probability of success and risk</td>
</tr>
<tr>
<td>15) Independence of the results from research: can they be implemented?</td>
</tr>
<tr>
<td>16) Timeframe of the research activities and benefits</td>
</tr>
</tbody>
</table>
### TABLE 10. Short title list for the potential research topics identified from "information needs"

**Responses of deer to habitat conditions and components**

1. Habitat suitability model  
2. Thermal cover  
3. Security cover  
4. Locomotion in snow  
5. Juxtaposition of habitat types  
6. Predator influence  
7. Site fidelity  
8. Decision functions  
9. Distance of movement  
10. Winter-spring energy acquisition and expenditure  
11. Simulation modelling
TABLE 11. Ranking of potential research topics (from Table 10)

<table>
<thead>
<tr>
<th>Criteria consideration</th>
<th>Research topic&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Is the topic within realm of organization?</td>
<td></td>
</tr>
<tr>
<td>Legislative responsibility</td>
<td>H&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Agency priority</td>
<td>H</td>
</tr>
<tr>
<td>Public concern</td>
<td>H</td>
</tr>
<tr>
<td>Is the topic of major concern to the organization?</td>
<td></td>
</tr>
<tr>
<td>Extent of problem location</td>
<td>H</td>
</tr>
<tr>
<td>Wildlife value</td>
<td>H</td>
</tr>
<tr>
<td>Timber and wildlife production</td>
<td>H</td>
</tr>
<tr>
<td>Are there current management actions available?</td>
<td></td>
</tr>
<tr>
<td>Minimal information required</td>
<td>L</td>
</tr>
<tr>
<td>Implications of no research</td>
<td>L</td>
</tr>
<tr>
<td>Management &quot;climate&quot;</td>
<td>L</td>
</tr>
<tr>
<td>Minimal technical transfer</td>
<td>M</td>
</tr>
<tr>
<td>Model availability</td>
<td>H</td>
</tr>
<tr>
<td>What are the cost benefit details?</td>
<td></td>
</tr>
<tr>
<td>Low cost of research</td>
<td>L</td>
</tr>
<tr>
<td>Probability of success</td>
<td>M</td>
</tr>
<tr>
<td>Independent results</td>
<td>M</td>
</tr>
<tr>
<td>Short term time frame</td>
<td>M</td>
</tr>
</tbody>
</table>

<sup>1</sup> Research topics are identified by short title in Table 10.

<sup>2</sup> Ranks are H=high, M=medium, and L=low.
<table>
<thead>
<tr>
<th>Priority ranking&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Project No.&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Re-ranked&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,2,9</td>
<td>1,2,9</td>
</tr>
<tr>
<td>2</td>
<td>4,10</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>7,8</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>3,11,6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

1 Overall priority is based upon totals accumulated for each project, where points of priority (High = 3, Medium = 2 and Low = 1) were assigned to each of the 16 criteria considered for every project (see Table 11).

2 For project short titles see Table 10.

3 Re-ranking occurred to make projects fit a more logical flow of information gathering (refer to the discussion in Section 7.1).
undertaken. We expect there to be a significant difference between energy acquisition and energy expenditure based on broad habitat characteristics and differences. Habitat selection in different seasons is a subject of topic 8 - "decision functions", and already has a substantial data base for Vancouver Island (deer component of IWIFR and others). The topic of vegetation succession dynamics should be given higher priority than the other half of topic 8, "decision functions", which deals with forage selection decisions by deer.

Because this problem analysis has been generated simultaneous to field research, a body of data already exists which is relevant to several of the potential research topics. In particular, topic 1 is already in its first draft phase; topic 2 is ongoing at UBC; and adequate data have already been collected to evaluate topic 9 (Table 10). Topics 1, 2, and 9 are exempted from the priority ranking since they have been funded and/or are nearing completion. In addition, preliminary data have been collected which support topics 4, 7, 8, and 10.

7.2 Research Framework

The IWIFR deer project must be integrated with all components of the IWIFR program. A proposed integration of research topics and priorities is provided in Table 13. Note that these topics only relate to the response of deer to habitat and habitat conditions. Not included are topics concerning the direct effects of intensive forest management on habitat per se and on the interrelations between wolves and deer. A general research framework is depicted in Figure 15. The effects of predation (by wolves and humans) on deer populations would be logically appended to Figure 15 if a broader research framework was to be envisaged.

8 RECOMMENDATIONS
8.1 The Need for an Adaptive Management Approach

The problem of black-tailed deer/intensive forest management has been a high priority research endeavour for 15 years. Many of the studies, have been descriptive in nature. Most initial attempts at research have a similar phase of baseline data collection. Certainly, the knowledge gained over the 15 years has generated a considerable understanding of the Vancouver Island deer resource (Section 5.2). With this understanding, a number of
TABLE 13. A recommended framework for studying the research topics outlined in Table 10

<table>
<thead>
<tr>
<th>Research topic</th>
<th>Priority (1 – 8)</th>
<th>Timeframe (short/medium/long)</th>
<th>Proposed methodology</th>
<th>IWIFR group responsible (deer/habitat/UBC/MOE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Habitat suitability model</td>
<td>1</td>
<td>short</td>
<td>concise, clear word### model of current management hypotheses</td>
<td>All</td>
</tr>
<tr>
<td>2. Thermal cover</td>
<td>1</td>
<td>medium</td>
<td>scientific research###</td>
<td>UBC</td>
</tr>
<tr>
<td>3. Security cover</td>
<td>7</td>
<td>long</td>
<td>problem analysis</td>
<td>Deer</td>
</tr>
<tr>
<td>4. Locomotion in snow</td>
<td>3</td>
<td>short</td>
<td>collation and analysis### of existing data</td>
<td>Deer/UBC</td>
</tr>
<tr>
<td>5. Juxtaposition of habitat types</td>
<td>6</td>
<td>long</td>
<td>modelling followed by adaptive management on watershed scale</td>
<td>All</td>
</tr>
<tr>
<td>6. Predator influence</td>
<td>8</td>
<td>long</td>
<td>problem analysis attempt manipulative scientific research</td>
<td>UBC/AOE</td>
</tr>
<tr>
<td>7. Site fidelity</td>
<td>5</td>
<td>medium</td>
<td>data review followed by adaptive management</td>
<td>Deer</td>
</tr>
<tr>
<td>8. Decision function</td>
<td>2</td>
<td>short</td>
<td>analysis of data collected### collation of other data sets followed by modelling</td>
<td>Deer/UBC</td>
</tr>
<tr>
<td>9. Distance of movement</td>
<td>1</td>
<td>short</td>
<td>analysis and write-up of data collected</td>
<td>Deer</td>
</tr>
<tr>
<td>10. Winter-spring energy acquisition and expenditure</td>
<td>4</td>
<td>medium</td>
<td>modelling</td>
<td>Deer/UBC</td>
</tr>
<tr>
<td>11. Simulation modelling</td>
<td>7</td>
<td>long</td>
<td>adaptive modelling###</td>
<td>Deer/UBC</td>
</tr>
</tbody>
</table>

### Projects that are currently in progress.
FIGURE 15. A general research framework recommended for the IWIFR deer project.
progressively detailed research topics has been developed (Section 7.2). However, as Macnab (1983) pointed out, little can be learned from natural systems by following their dynamics at equilibrium even if that equilibrium is upset by environmental perturbation. Manipulation needs to be included as a component of IWIFR research.

With the research of the past 15 years, managers now have adequate information to make management prescriptions. The important point is that these prescriptions for the most part not based on incomplete knowledge. The need for tests predominates. Testing management prescriptions on a small scale can provide confidence for managers and opportunities for experimental perturbation for researchers. The intent is to subject management hypotheses to the traditional scientific method (i.e., "adaptive management"; Holling (editor) 1978; Figure 16).

The role of research must be emphasized as a continual influx of "cause and effect" knowledge to the system. This process-level knowledge continually refines the management hypotheses. The paired, "control" and "manipulated or perturbed" comparison must be emphasized as well. Without controls, the perturbation experiment is often unbalanced and factors are confounded. Equally important is the necessity for monitoring results, which should be directed at measuring the control or unperturbed system, the source or active management implementation, and the effects on the manipulated system.

Changes to the current project implied by adoption of the adaptive management approach centre around reducing the effort spent on describing animals' use of habitat and to measuring changes in use, as well as other indices of deer response before and after system perturbation. Another change is the clear separation (but tight co-operation/communication) of management hypotheses testing and traditional research hypotheses testing.

Above all, manipulative and response variables should be clearly identified. Each particular research topic will have different variables associated with it but, nevertheless, the overall response variable should always be survival and productivity of deer. Deer response is expected to be difficult to assess and predict. Net energy is likely to be the best assessment method but is the farthest from field application and use. Condition indices are only now starting to become field applicable but still have inherent problems. Night counts and productivity counts are indices that allow assessment of carrying capacity and productivity directly in the
FIGURE 16. The adaptive management system.
field. Which method is chosen to assess deer response may vary according to the particular research topic.

8.2 Research Recommendations

The priority ranking scheme of Section 7.1 and the framework scheme of Section 7.2 lead to the following recommendations (topic numbers identify projects as listed in Table 13):

**Short-Term Recommendations (1 year)**

**Topic 1** - A habitat suitability model should be prepared specifically to establish a basis for integrating management and to provide a simplified view of IWIFR research directions and research hypotheses. The model should be clear, concise and adaptable to new research findings.

**Topic 9** - The activity and movement data that have been collected during the first phase of the IWIFR deer project should be collated, analyzed, and final reports written and submitted to scientific journals. Results will be mapped into Topics 10 and 4 below.

**Topic 8** - The habitat selection data that has been collected during the first phase of the IWIFR deer project should be collated, analyzed, and final reports written and submitted to scientific journals. Results will be mapped into Topics 10 and 7 below.

**Topic 4** - A detailed review and synthesis of locomotion costs for deer moving through snow should be prepared. The intent should be to link energy cost functions reported by Parker et al. (1984) to sinking depth of deer in coastal British Columbia. The results will be mapped into Topic 10 below.

**Medium-Term Recommendations (2-3 years)**

**Topic 2** - The thermal studies ongoing at UBC should continue so that we gain an understanding of the relevance of thermal cover to deer.

**Topic 10** - An attempt must be made to bring together winter-spring energy expenditures and energy acquisition functions and to show their connection with reproductive success and survival of deer. The attempt should be in the form of a modelling exercise based on the results of Topics 1, 2, 4, 8, and 9 above, as well as data from other information sources such as Vancouver Island studies in Nimpkish, Sayward, Northwest Bay, and Cowichan Valley. The
results of this study will allow progression of Topic 1. Depending on the results, a field study may be necessary before confidence can be placed on the resulting model.

Topic 7 - An analysis should be made of data that provide information on site fidelity patterns in deer. Based on this analysis a field study should be proposed that would provide information concerning deer response to provision of "new habitat matrices". Results would be required for Topic 5.

Long-Term Recommendations (3-5 years)

Topic 5 - Tests should be made, at an operational scale, to determine how deer respond (behaviourally as well as reproductively) to large-scale changes in habitat juxtaposition imposed by integrated forest and wildlife management. The recommendation for this topic is made with the assumption that a satisfactory atmosphere for integrated management will be accomplished and that models of habitat and deer response to intensive forest management will be operational and relatively complete. Implementation of this topic as a field study could be used as a demonstration as well as a test of integrated forest and wildlife management.

Topic 3 - A short problem analysis should be prepared that details the problem of security cover for deer. Hypotheses would be mapped into Topics 5 and 11.

Topic 11 - A detailed mathematical model (in the fashion of UBC's STUF - see Section 6.2) should be prepared and updated as functional relationships are found and tested. This model would be more complex than Topic 1 and should be used to help structure verification tests of the habitat suitability model.

Topic 6 - A short problem analysis should be prepared that details the influence of predators on habitat selection and use by deer. Hypotheses would be mapped into Topics 5 and 11.

The reader is reminded that these topics are only general recommendations for research when animal- and habitat-related objectives are undertaken. Specific proposals for research should be prepared as required.
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(¹ Indirect solicitation of problem analysis.)
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PUBLIC INTEREST GROUPS

Nanaimo Fish and Game Protective Association:

Various members
APPENDIX 2. GLOSSARY

Animal condition: a measure of the physical health and fitness of an individual (Hatter 1982); used here to connote potential for survival and successful reproduction of viable offspring.

BMR: Basal Metabolic Rate (BMR) is the minimum rate of metabolism measured under resting conditions at a temperature where the animal is not required to expend energy for extra heat production or cooling (Krebs 1978).

Carrying capacity (K): ecological carrying capacity is the maximum population that a given environment can support indefinitely (Keeton 1972); an equilibrium resulting from all natural factors (Leopold 1933). Ecological K is interpreted here as being influenced by all ecological factors and is necessarily a dynamic equilibrium. More specific definitions are provided in Table 3 of Section 5.

Compensatory predation: the killing of prey animals by predators that would not survive and reproduce in the absence of predation (Hatter 1982).

Cutover: a logged area still in an initial seral stage (Hatter 1982).

Density dependence: an inverse relationship between rate of population growth and population density (Hatter 1982).

Density independence: an unpredictable relationship between rate of population growth and population density (Hatter 1982).

Ecosystem: biotic community and its abiotic environment (Krebs 1978).

Escape cover: those habitat features, vegetative or topographic, that allow a prey animal advantage in moving away from pursuit by predators (Hatter 1982).

Habitat: the range of environments in which a species occurs (Krebs 1978).

Hiding cover: those habitat features, vegetative or topographic, where an animal can rest from predators or hunters, in an unstressed condition (Hatter 1982).

Home range: that area traversed by an animal in its normal activities of food gathering, mating, and caring for young, over a specified period of time (Hatter 1982).

Immature forest: any stage before a tree, crop or stand is mature (Nyberg 1985).

Limiting factor: a combination of density dependent and density independent processes that limits population size, and if removed, results in population growth (Hatter 1982).

Mature forest: the stage at which a tree, crop, or stand best fulfills the main purpose for which it was maintained (Nyberg 1985).
Multiple use: management of the different surface resources in a combination that will meet the various needs or demands of society.

Old-growth forest: a natural forest, uninfluenced by human activity, and beyond the mature stage, typified by very large trees, an uneven age structure and high structural diversity both horizontally and vertically (Nyberg 1985).

Optimal foraging theory: the assumption that an animal will maximize its efficiency of food intake through its particular foraging behaviour.

Prey vulnerability: encompasses all physical and biological conditions that make one individual more likely to fall prey than another (Hatter 1982).

Proximate cause of mortality: the proximate cause of mortality refers to the immediate agent of mortality (e.g. predation), whereas ultimate causes refer to those factors, usually environmental, which are primarily responsible for deaths (e.g. food shortage, severe weather) (Hatter 1982).

Recreation-days: one recreation day is equivalent to one person recreating in the environment for all or part of one day.

Regulating factor: density dependent factors that can limit or expand (i.e. regulate) population growth.

Second-growth forest: forest growth that has come up naturally or artificially after some modification of the previous forest crop (e.g. wholesale cutting, fire or insect attack) (Hatter 1982).

Silvicultural treatments: forestry activities undertaken to enhance production of commercially valuable tree species, including thinning, silvicultural fertilization, highsite conversion, and commercial thinning (Hatter 1982).

Sustained yield: implies continuous production with the aim of achieving, at the earliest practicable time, an approximate balance between net growth and harvest, either by annual or somewhat longer periods.

Tree Farm Licence (TFL): Crown land leased to forest companies for the specific purpose of practising sustained yield forest management.

Winter range: area that animal uses during winter months, often characterized by south-facing slopes, low elevation, and particular forage resources or overstory cover types (Nyberg 1985).

Young-growth forest: forest stands or crops that have not yet reached the old-growth stage (Nyberg 1985).