SILVICULTURAL OPTIONS IN THE CENTRAL COAST

A REPORT PREPARED FOR THE CENTRAL COAST LAND AND COASTAL RESOURCE MANAGEMENT PLAN BY:

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EXECUTIVE SUMMARY

This report assesses the ecological suitability, sustainability, practicality, utility, and applicability of various silvicultural systems to the Central Coast. We provide recommendations on whether or how to apply the alternative models and practices at the strategic level.

The Central Coast is most like the North Coast and the southern portion of the Kalum Forest District. It has less similarity to Vancouver Island and the southwest mainland coast. We define three ecological subunits within the plan area:

HECATE LOWLAND (hypermaritime)

- a distinctive and consistent landscape, stretching from Johnstone Strait to Prince Rupert
- really nothing else like it in B.C., but some similarities to northern Vancouver Island (n of Port Hardy) and the western fringe of Vancouver Island, as well as parts of Q.C.I.

OUTER COAST MOUNTAINS (maritime)

- probably what most people would consider "typical" B.C. coast; mountainous, wet, thickly forested fiordland
- similar forests occur from Vancouver Island and the North Shore Mountains north to the Nass River
- similar environment to much of the wetter portion of Vancouver Island, especially the windward mountains, including Clayoquot Sound

INNER COAST MOUNTAINS (submaritime or transitional)

- mostly formidable hinterland, probably the most extreme terrain in B.C.
- similar forests occur on southwest mainland (e.g., Squamish-Pemberton area) and some leeward parts of Vancouver Island (because of rainshadow effect, some moisture stress, fire history, and Douglas-fir---at least at lower elevations)
- forests at higher elevations more like those to the north, in Kalum Forest District

The Operating Environment is most similar to that of the North Coast (but there is virtually no experience of partial cutting in that district), not much like that of Vancouver Island. Communities are unusually small and isolated, even compared to the North Coast. The majority of permanent residents are First Nations. Other than logging and fishing, there is little resource development. The operable landbase is a small proportion (12%) of the total. There is a short operating season, and virtually no local processing facilities. Most undeveloped watersheds do not have continuous expanses of productive accessible timber, from valleybottom to ridgetop, as used to be fairly common on Vancouver Island and even in some Q.C.I. drainages. Timber is interrupted (by cliffs, slides, avalanche tracks, wetlands, and other inoperable areas) and patchy, so there are more roads/m^3---except when helicopters are used. Harvesting areas and camps are remote, and often disconnected. Most forests are very old, the rest are juvenile or young; there are few middle-aged and mature (40-210 years old); there is little opportunity for commercial thinning at present. The distribution of timber types (mostly hemlock-amabilis fir and redcedar-leading) is most like that of North Coast, but also quite similar to that of northern Vancouver Island and Clayoquot Sound. Timber quality and recoverable volume/ha are lower than on Vancouver Island. Wood for the next 10-20 years is projected to come primarily from Outer

Coast Mountains and Hecate Lowland, and increasingly from low productivity redcedar-hemlock stands and helicopter-accessible stands (the latter a coast-wide trend but more pronounced in Central Coast). This means that licensees will probably be harvesting stands less valuable and more costly than at present.

Natural disturbances in the Central Coast differ between the Hecate Lowland and Outer Coast Mountains (largely Natural Disturbance Type 1) and the Inner Coast Mountains (largely Natural Disturbance Type 2). In the Hecate Lowland and Outer Coast Mountains, fire is rarely an important natural disturbance agent. Forest stands tend to be very old and structurally complex, uneven-aged with significant amounts of dead wood standing (snags) and on the ground (coarse woody debris). Disturbances in these older stands are small-scale in nature, primarily involving the creation of canopy ‘gaps’ by the death of individual (or small groups of) canopy trees. Younger stands occupy a small percentage of most landscapes, and are produced by blowdown, mass movements, and floods. Insects and disease are generally not important disturbance agents in old-growth stands, though they do kill individual trees or small clumps of trees, and they become more important in second-growth stands. In the Inner Coast Mountains, fires have been important as disturbance agents, and large portions of the landscape---at least at lower and middle elevations---probably have regenerated as even-aged stands on a regular (200-300) year basis. Because the stands are younger and burn more regularly than in NDT1, stand structure will be less complex, with smaller volumes of dead wood in the stands. Still, with time between disturbances, these stands will develop some structural complexity as gap processes are initiated. Windthrow and landslides are generally much less important here, whereas snow avalanches become increasingly important from the Outer to the Inner Coast Mountains.

The bulk of logging in next 10-20 years will be in forests with NDT1 (ecosystems with rare stand-initiating events; gap dynamics prevail; opening sizes typically 1 to a few tree heights in width, or 0.1 to 3-4 ha in size; larger openings occasional). Forest management that approximated such a disturbance regime would call for lots of small openings, a few larger cutblocks, and for more “biological legacies” to be left behind in the openings

Forests in the Central Coast develop much as they do elsewhere in coastal B.C. Successional pathways depend on the nature and intensity of the associated disturbance and on the regeneration cohort; the scenarios play out in reasonably well-understood ways, which foresters can either embrace or try to manipulate.
Except for very large clearcuts (approaching 500 ha) and coppicing, there are no compelling, *a priori*, biological or ecological constraints to any silvicultural system **on an individual stand basis.** But the landscape consequences depend on the rate and extent of harvest, and all sorts of factors enter the picture at the landscape scale; e.g., number of roads required, levels of canopy retention, fragmentation, age class structure. In other words, in some important ways it doesn’t matter as much **how** you log as **how much** you log. Even so, one can generalize that silvicultural systems that retain a certain level or amount of critical stand structure make more ecological sense than those that don’t.

Virtually all silvicultural systems, traditional and non-traditional, could be implemented in the Central Coast. There are no compelling operational (equipment, skilled labour) constraints. The most serious silvicultural constraints centre on windthrow, high-grading, and forest pests and diseases.

We conclude that successful operations in the Central Coast must have harvesting equipment and supporting operations that are relatively mobile and provide broad flexibility. Individual operations are relatively small and short in duration; operators can not afford to retain or import equipment purpose-built for individual situations. They require equipment flexible enough in application to cover virtually all situations.

Comparative analysis of operations in the Central Coast and in similar or comparable ecosystems on Vancouver Island revealed the following distinctive operating conditions in the Central Coast:

- cutblock size is smaller
- merchantable timber volume per unit area is significantly lower
- more helicopter logging
- average haul distance and woods run distance is significantly longer
- isolated operations, requiring camp facilities in virtually all cases
- timber development per unit of road construction is significantly lower
- much more hardrock road construction
- much higher percentage of barge transport required
- additional towing transport required in many cases

These distinctive operating conditions result in the following economic differences:

- All logging cost phases analysed showed higher costs in the Central Coast, especially for timber development (roads and bridges) and administration (overhead and camp costs).
- Timber value production in the Central Coast is marginally higher. Even though average value by species is lower in all cases, operations in the Central Coast produce, on average, a significantly higher percentage of higher value redcedar.
- Average net revenue in the Central Coast is significantly lower.

While our review did observe a number of partial cutting applications, based on an analysis of cutting permit records, there is very little partial cutting being implemented in the Central Coast planning area (almost none in oldgrowth timber types). Use of partial cutting operations in similar ecosystems and forest types outside the planning area appears to be only slightly higher although the trend appears to be increasing, to meet social and market as well as silviculture and biological objectives. The biggest differences appear to be in variety of applications and in documentation of results.

Our review included a variety of partial cutting applications as well as the associated documentation. We reviewed steep-slope cable logging on both steep and moderate slopes, with dispersed retention, patch cuts, and strip cuts; helicopter logging for both dispersed and patch retention, on virtually all terrain and slope types; hoeforwarding on moderate to flat ground, for both patch and low-level dispersed retention as well as in combination with cable harvesting systems. Because of operational difficulties, safety concerns, high cost, and innovations in helicopter harvesting, industry staff will be less likely to use cable harvesting systems (particularly those requiring lateral yarding capability) in long-reach, steep-slope applications in

the future. There is a preference to use the latest grapple helicopter technology in these situations to provide the needed flexibility.
From an operational perspective, it appears that retention silviculture systems are sufficiently flexible to successfully implement in oldgrowth forests. Compared to the classical alternative silviculture systems, retention systems require less planning and layout work, and put more control of tree harvest/retention in the hands of the faller. This provides the flexibility required to respond to the variety of operational conditions associated with harvesting oldgrowth forests, including, and most importantly, worker safety.

Establishment of land use planning areas (zones?) with development of flexible management objectives could have a positive effect on timber availability and logging costs. In some (not all) drainages, the potential operational and economic advantages could help justify the expected incremental cost of doing partial cutting. Alternatively, land use planning areas with more ”constraining” management objectives could promote or require use of partial cutting .

Based on a review of documented incremental costs of partial cutting, our field visits, and staff interviews, we conclude that:

- Harvesting costs will increase with an increase in the level of uniform tree retention; cable harvesting systems are the most cost-sensitive. Patch retention is not expected to be as cost-sensitive.
- Based on current and expected future economic conditions, partial cutting doesn’t make economic sense everywhere but could be justified in some drainages and on some sites.
- Depending on management objectives and remaining mindful of the dangers of highgrading, partial cutting could target more valuable log species and grades, thus offsetting the higher incremental harvesting costs; in other words, it could improve the economic margin to the point of making the operation profitable.
- Site-specific rather than average conditions determine logging activity. On the right sites, or in specific drainages given the operational flexibility to harvest the right species and grade profile at the right time, there are economically viable opportunities.

We make the following recommendations:

1. That planners recognize the three ecological subunits, Hecate Lowland, Outer Coast Mountains, Inner Coast Mountains; acknowledge their environmental differences; and use them in strategic planning.

2. That riparian forests get special attention and treatment.

3. That economic margin be considered before implementing partial cutting.

4. At the current rate of cut, we don’t recommend doing partial cutting everywhere, over the entire plan area, because we don’t think that would be ecologically sensible, silviculturally desirable, or economically viable. We also don’t recommend clearcutting everywhere, because it doesn’t make ecological sense, and because it could have some undesirable silvicultural and

economic consequences.

5. Leave more biological legacies, to maintain key elements of forest structure (live trees of varying species, size and condition--including some large stems, multiple canopy layers, canopy gaps, understory patches, snags of varying size and decay class, downed logs. We also recommend that as much attention be paid to what to **leave** as to what to take.

6. Evaluate the ecological consequences of compressing and truncating natural succession in managed forests (and especially on lands designated for an emphasis on timber production), at the landscape scale. Address the problem through: landscape unit planning; successional stage distribution; deployment of a variety of silvicultural systems according to desired similarity to early and late successional stages, including non-traditional retention systems to help retain desired levels of stand structure and biological legacies; longer rotations for some stands.

7. Implement a variety of silvicultural systems, operationally not merely for demonstration purposes. Monitor any associated blowdown and its consequences, not just in or near the treated stands but also in nearby untreated, natural stands.

8. At the site level, use partial cutting in the following applications:
- In general and where circumstances warrant, as variable retention systems.
- To address regeneration delay where it is a problem, either by retaining advance regeneration of preferred species in a variable retention scenario, or by using small patch or strip cuts to protect artificial regeneration.
- As commercial thinning, where and when stand conditions are appropriate.
- To extract some wood from some (not all) riparian forests while maintaining essential forest structure and ecosystem function.
- In Douglas-fir-leading forest types in the Inner Coast Mountains, in particular by using helicopter logging on steep rocky slopes.
- In redcedar/yellow-cedar-leading types in the Hecate Lowland, where several systems (group selection, strip, group and irregular shelterwood, variable retention) could be implemented, most efficiently through hoeforwarding.

9. Establish a process to monitor the effectiveness of different silvicultural systems in meeting social, economic, and ecological goals. Consider adaptive management as a model for this process

10. In groups of individual, often parallel, small drainages (most apparent in Outer Coast Mountains), consider compressed harvesting schedules in some drainages and reduced or no activity in neighbouring ones (in other words, a staggered development schedule).

11. As another approach, consider trial use of multi-pass silvicultural prescriptions, to target species and log grades that would allow operations to work within market cycles ‘normally’ experienced in the lumber and pulp industry.

12. Develop ecosystem restoration projects for some valleys of the Inner Coast Mountains---

something considerably beyond the rather limited scope of "watershed restoration".

13. Continue to allow partial-cut handlogging along parts of the shoreline, with due regard to aesthetics, recreational opportunities, marine resources, and highgrading.

1.0 INTRODUCTION

1.1 Mandate

The Province of British Columbia, Land Use Coordination Office, asked us in Spring 1999 to address the issue of alternative forest harvesting methods and silvicultural systems in the Central Coast area of British Columbia. Here and elsewhere in this report, designed to assist in preparation of the Central Coast Land and Resource Management Plan (CCLRMP), "alternative" refers to alternatives to clearcutting. A variety of alternative forest practices and guidelines have recently been developed or applied elsewhere in B.C; a very few examples exist in the plan area. We attempt to objectively review and assess the ecological suitability, sustainability, practicality, utility, and applicability of these practices to the Central Coast. We are to provide non-binding recommendations on whether or how to apply the alternative models and practices **at the strategic level**---which, we think, means in the form of management recommendations for the strategic plan rather than operational guidelines. Please note that this is not an independent scientific review in the strict sense (Meffe and others 1998), but rather an attempt at an objective technical review.

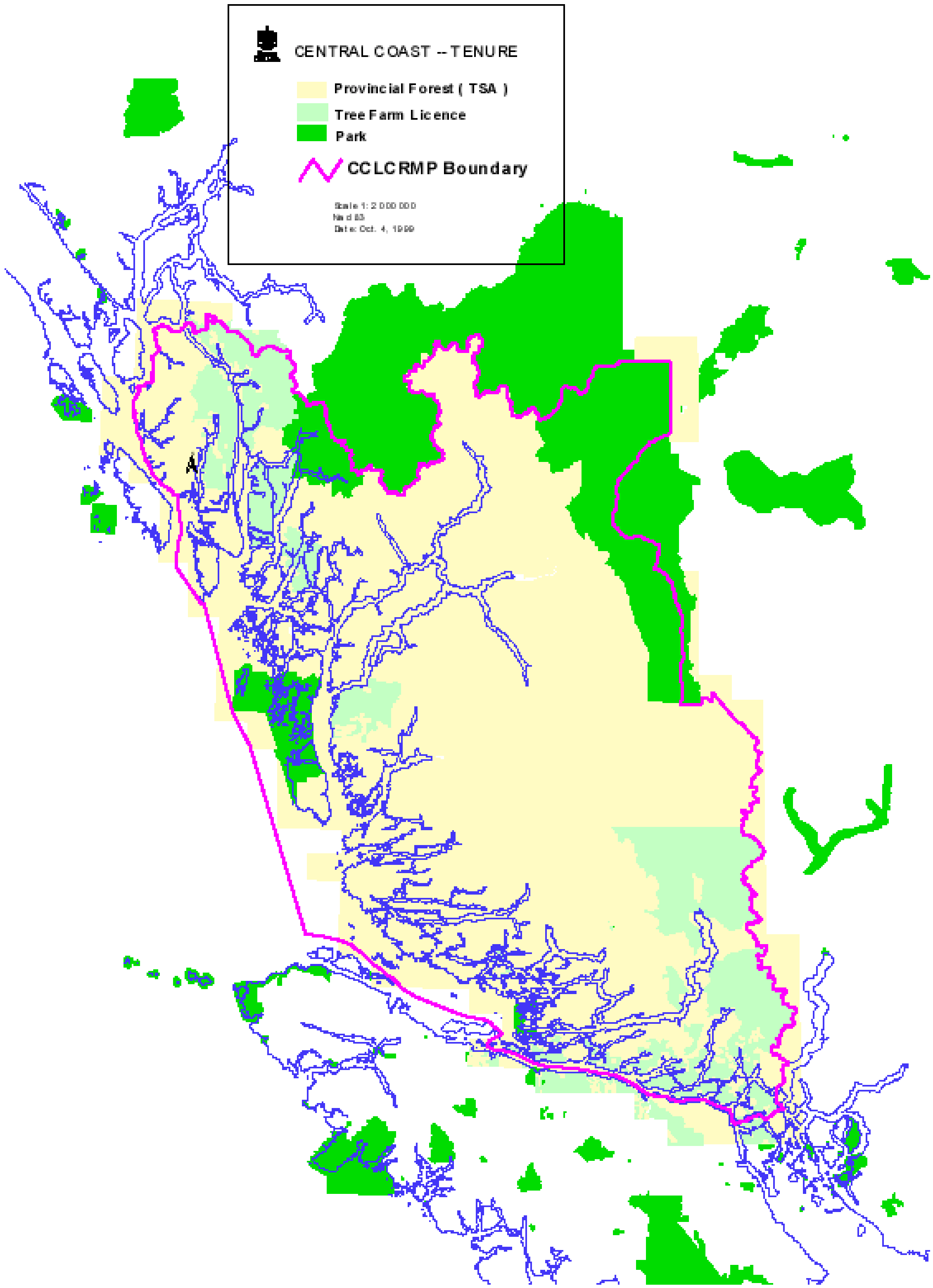
The alternative approaches we consider include MacMillan Bloedel's variable retention model, the recommendations of the Clayoquot Sound Scientific Panel, helicopter and "retention" logging practices of various licensees, and other examples of partial cutting.

The Central Coast plan area (Fig. 1) corresponds roughly to the Mid-Coast Forest District, a southern segment of the North Coast Forest District, the mainland portion of the Kingcome Timber Supply Area (part of the Port McNeill Forest District), and the mainland portion of the Strathcona Timber Supply Area (part of the Campbell River Forest District). The area extends from the top of Princess Royal Island in the north to Johnstone Strait in the south. "The boundaries of the Plan Area are not ecologically based, but instead largely correspond (by default) to other administrative and/or land use planning boundaries" (Lewis and others 1997). We have been informed that the boundaries of the Plan Area are intended to approximate First Nations traditional territories.

1.2 Context: Sustainability

1.2.1 Background

Sustainability has become a buzzword in the current discourse of conservation biology and resource management, as have biological diversity, ecosystem health, and ecological integrity. Ecologists and other scientists have been enlisted in efforts to put the notion of sustainability on sound, scientific footing. The Ecological Society of America established the Sustainable Biosphere Initiative as the ecological research agenda for the 1990s and the new millennium (Lubchenco and others 1991). The journal *ECOLOGICAL APPLICATIONS* published a special forum, prefaced by an editorial that characterized sustainability as *"the central environmental issue facing us"* (Levin 1993). More recently, an independent scientific committee established by the U.S. Agriculture Secretary produced a report intended to review and evaluate the U.S. Forest Service's planning process for land and resource management, and to identify changes that might be required. This interdisciplinary committee, which included representatives from landscape ecology, silviculture, fire ecology, wildlife biology, economics, sociology,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planning, environmental law, range management, and fisheries, concluded that ecological sustainability is the fundamental basis for economic and social sustainability (Dale and others 1999). They stated that ecological sustainability should become the principal goal in managing the national forests, not to the exclusion of human values and uses but because these uses of the forest and its resources could be impaired without ecologically sustainable systems.

The Agriculture Secretary endorsed the report, and the U.S. Chief Forester is to act on its recommendations. Not surprisingly, not everyone has agreed to this approach. A panel of the Society of American Foresters produced its own report, arguing that selecting any single criterion as the sole management goal would inevitably preclude some forest uses, and the American people through Congress should make those sorts of decisions (Mann & Plummer 1999; Sedjo 1999). The same sorts of arguments occur in British Columbia, although currently with a rather different mix of participants.

1.2.2 Definitions

Trees and forests are renewable resources, theoretically at least, so it is appropriate to discuss sustainability---of forestry or forest management. Inasmuch as *"sustainability is simply the ability to maintain something undiminished over some time period"* (Lélé & Norgaard 1996), you might think that the concept of sustainability is simple and straightforward. Think again.

First of all, the simple dictionary definition seems insufficient for those who have dug into the concept of sustainability. They ask questions like:

"What is to be maintained, and at what scale, and in what form?"
"Over what time period and with what level of certainty?"
"Through what social process and with what tradeoffs against other social goals?" (Lélé & Norgaard 1996).

The World Commission on Environment and Development (1987) considers **sustainable forestry** to be the balancing of ecology and economics to meet current human needs while protecting the ability of future generations to meet their needs. This is the goal embodied in the preamble to the Forest Practices Code of British Columbia Act (Bill 40 - 1994).

> *Whereas British Columbians desire sustainable use of the forests they hold in trust for future generations; and whereas sustainable use includes:*
> *(a) managing forests to meet present needs without compromising the needs of future generations,*
> *(b) providing stewardship of forests based on an ethic of respect for the land,*
> *(c) balancing productive, spiritual, ecological and recreational values of forests to meet the economic and cultural needs of peoples and communities, including First Nations,*
> *(d) conserving biological diversity, soil, water, fish, wildlife, scenic diversity and other forest resources, and*
> *(e) restoring damaged ecologies* (sic)*;*

But how can such definitions be measured and evaluated, and at what scale (stand, watershed, landscape)? What is meant by human needs, and are current levels of human wants and needs realistic and sustainable (Amaranthus 1997)?

The concept of **sustained yield** or sustainable harvest can also confuse the discussion. Sustained yield assumes that any species or community of species (like a forest) *"each year produces a harvestable surplus, and if you take that much and no more, you can go on getting it forever and ever"* (Larkin 1977). UBC biologist Peter Larkin concluded over 20 years ago that maximum sustained yield was at best a problematic concept, at least with respect to marine fisheries. It is just as problematic for forestry.

Sustained yield is not the same thing as sustainability. You could produce a sustained yield of timber (for several rotations anyway) without practicing sustainable forestry. But forests provide many goods and services besides wood. Managing for a consistent and sustained supply of one commodity does not ensure that all other commodities and values will be maintained. Nor is the concept of sustained yield particularly appropriate for forests as ecosystems. Even if one includes all known non-timber forest products and all aspects of 'wildcrafting', most components of forest biodiversity are not harvestable resources. Most of the species threatened by genetic impoverishment, loss of local populations, and extinction are at risk because their habitats are being altered, not because they are being over-harvested (Ehrlich 1988; Callicott & Mumford 1997).

Nevertheless, natural resources have continued to be managed (or mismanaged) under the rubric of sustained yield in one form or another, and the histories of forestry, fisheries, and wildlife management show similar patterns (Ludwig and others 1993; Hilborn et al. 1995; Bottom and others 1996; Struhsaker 1998).

We are reasonably confident that some level of forest harvesting, regardless of type of silvicultural system, can be sustained indefinitely in the Central Coast---barring drastic climate change. The important related questions are: what is a sustainable level of forest harvesting?; will that level of harvest translate to effective biological conservation? We don't have the answers to those questions.

Callicott & Mumford (1997) proposed an ecological definition of sustainability: meeting human needs without compromising the health of ecosystems. Sounds good but again, what are human needs and what is ecosystem health? Kolb and others (1994) consider a **healthy forest** to have the following four characteristics:

(1) the physical environment, biotic resources, and trophic networks to support productive forests;

(2) resistance to catastrophic change and the ability to recover on the landscape scale (resilience);

(3) a functional equilibrium between supply and demand of essential resources (water, nutrients, light, growing space) for major portions of the vegetation;

(4) a diversity of seral stages and stand structures that provide habitat for all native species and all essential ecosystem processes.

Another framing of the concept defines a **sustainable ecosystem** as one that, over the normal cycle of disturbance events, maintains its characteristic diversity of major functional groups, productivity, soil fertility, and rates of biogeochemical cycling (Chapin and others 1996). Franklin (1995) understands sustainability as *"the maintenance of the potential for our forest and associated aquatic ecosystems to produce the same quantity and quality of goods and services in perpetuity." Potential* because he wants to imply the option to return to alternative conditions rather than to focus exclusively on current conditions. He declares that *"sustainability absolutely should* not *be viewed exclusively or primarily in terms of the short-term production of specific commodities, such as sawlogs or trophy ungulates, although such concerns are an appropriate component…"* Sustainability thus involves maintaining the physical and biological elements of productivity. In other words, sustainability requires that we prevent:

- *"degradation of the productive capacity of our forest lands and the associated water bodies, that is, net loss of productivity, and*
- *loss of genetic diversity, including extirpation of species, that is, net loss of genetic potential"* (Franklin 1995).

Unfortunately, these definitions lead you down the path to more and more definitions (what is a normal cycle of disturbance?, what are essential ecosystem processes?, which goods and services?) and clarifications. However, it can be done, you can define the processes, structures, and resources required to meet the criteria for a healthy forest or a sustainable ecosystem, at the landscape scale (Franklin 1995; Amaranthus 1997). Then if you do likewise—determine the necessary processes, structures, and resources---for human needs, society's objectives and healthy communities, you could be said to have arrived at a local definition of sustainable forestry.

1.2.3 Scale

Note that we recommend assessing sustainability at the landscape scale, although stand-level tools can help analysis and modelling (Seely and others 1999). You may have encountered the term *"fully functioning forest ecosystem."* This is a legitimate concept, but it makes more sense to apply it at the watershed or landscape scale than at the level of an individual stand of trees. It is not possible to maintain fully functioning forests everywhere at all times, on every hectare of a watershed, even if there was no logging. There will always be some patches of forest in early successional states, some patches even non-forested, some seriously infested with insects or diseases. These patches could very well occur within a fully functioning forested watershed or landscape, which could be a wilderness or a managed forest. Sustainable forestry does not imply ecological stasis. Most forests exhibit a pattern of disturbance-induced change that spans virtually all scales of space and time (Kimmins 1997).

1.2.4 How?

Clearly sustainability, in its ecological, economic, and social dimensions, means different things to different people. *"For the concept of sustainability to be operationally useful…it should be defined so that one could specify a set of measurable criteria such that individuals and groups with widely differing values, political preferences, or assumptions about human nature could agree whether the criteria are being met…"* (Brooks 1992). We are less concerned with how sustainable forestry is variously interpreted, more with how it can be attained.

Franklin (1995) and Bunnell (1997) provide some valuable advice in this regard. Select a set of values (locally determined but internationally credible) to be maintained, and identify or stipulate the appropriate techniques for measurement/assessment or methods for monitoring. Franklin specifies that monitoring should assess:

- *"Forest cover and condition at the landscape level*
- *Flow and quality of water*
- *Structural conditions, including live and dead trees, of the forest stand*
- *Physical, chemical, and biological condition of the soil and*
- *Populations and trends in indicator organisms."*

Table 1 summarizes Bunnell's (1997) suggestions.

Table 1. Values, goals and monitoring for sustainable forestry.

Major value	Goal	Monitoring
BIODIVERSITY	Lose no species from large area	Check lists focused on vulnerable species
PRODUCTIVITY	Keep soil on slopes	Little increase above natural mass wasting
	Maintain fertility	Internodal growth; foliar analysis
FUTURE OPTIONS	Retain some unused forest (protected areas) Some multi-value forestry Contribute to social infrastructure	Some of each approach; balance locally determined
ECONOMIC OPPORTUNITIES	Establish calculable timber supply	Volume schedule
	Long-term employment	Jobs
LOCAL PARTICIPATION	Involvement of local communities in decision-making	Mechanism of involvement

1.2.5 Summary

This has been a rather discursive treatment of a complex topic. It doesn't **have** to be so rambling or complicated. Defining and attaining sustainable forestry should be reasonably simple and straightforward, but in practice it probably won't be---for CCLCRMP or any other such process. In brief:

- Sustainability has ecological, economic, and social dimensions. Ecologists argue that ecological sustainability is fundamental, because it underpins economic and social sustainability.
- Sustainability has several meanings.
- Sustained yield is not the same as sustainability or sustainable forestry.

- Ecological and social considerations must be factored into the determination of sustained yield if we hope to achieve sustainable forest management.
- Ecosystem health and ecological integrity are concepts related to sustainability, but they too have a variety of definitions. Forest health usually means something quite different (typically a utilitarian meaning; a forest is considered healthy if management objectives are satisfied, and unhealthy if they are not).
- We think that the Central Coast can sustain some level of forest harvesting, some level of timber production. We do not know what that level is, nor whether it will translate to effective biological conservation, to ecological sustainability, to healthy and sustainable communities.
- It should be possible to define sustainable forestry operationally, with an attendant set of locally determined and widely acceptable but internationally credible criteria, and a simple but meaningful scheme for monitoring and assessing performance.

1.3 Terminology

SILVICULTURAL SYSTEM

A silvicultural system is a planned program of treatments designed to achieve stand structural objectives throughout the life of a stand. A stand is a *"contiguous group of trees sufficiently uniform in age-class distribution, composition, and structure, and growing on a site of sufficiently uniform quality, to be a distinguishable unit"* (Helms 1998). A silvicultural system includes the harvesting, regeneration, and stand-tending methods employed to meet the stand-level objectives, which in turn can contribute to landscape-level objectives. The names of the traditional systems generally are based on the regeneration method employed or on the number of distinct age classes imposed by the system.

PARTIAL CUTTING

Partial cutting is a generic term covering any prescription where mature trees are deliberately left on a site to meet various stand objectives. Partial cutting would include the harvest methods used for any of the traditional silvicultural systems (see Section 4, Table 6) where original canopy trees are retained. It also can be used to describe commercial thinnings.

HARVESTING SYSTEM

The harvesting system is the procedure by which a stand is logged. The term harvesting **system** refers to the specific phase involved in the log production process. Harvesting **method** refers to the mix of these systems used in a given operation. The emphasis is on meeting logging requirements while concurrently attaining silvicultural objectives. Generally, the harvesting system is described by the primary mode of transporting logs to the roadside.

2.0 STUDY AREA

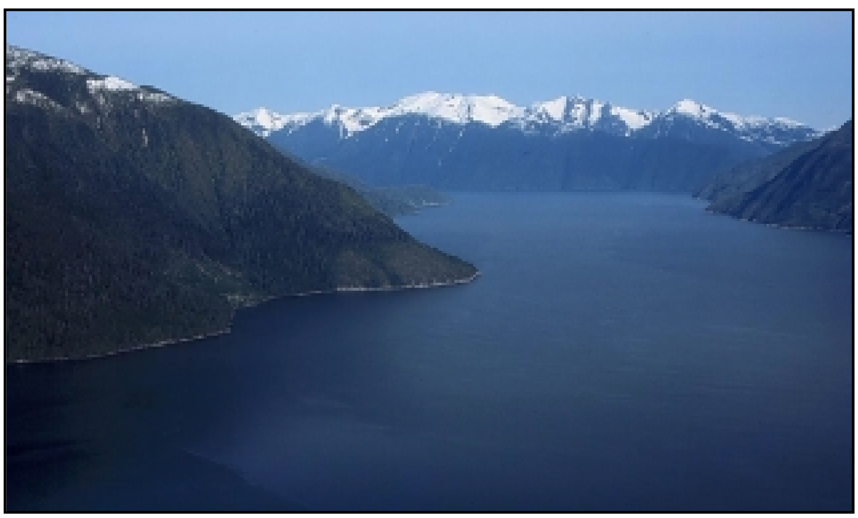
2.1 Physical Environment

2.1.1 Physiography (Holland 1976)

The Central Coast Plan Area includes two major physiographic regions, the Coastal Trough and the Coast Mountains. The Coastal Trough is represented by the Hecate Lowland, a western-most strip of subdued relief mostly less than 450 m elevation. This low-lying terrain has a very intricate coastline, includes both the outer mainland coast and numerous adjacent islands, and typically supports relatively poor-growing forests and extensive peatlands (muskeg). The Coast Mountains in the study area include two subdivisions, the Pacific Ranges and the Kitimat Ranges to the south and north, respectively, of Burke Channel-Bella Coola valley. This mountainous terrain is very rugged, with numerous mountain and valley systems ranging from sea level to 2500-3000 m in the central portions, and deep fiordland (Fig. 2) common along the western sections. Lower and middle elevations typically support productive forests.

2.1.2 Bedrock geology (Baer 1973; Ryder 1978; Farley 1979)

The Hecate Lowland is underlain by flat or gently dipping, granitic, volcanic, and metamorphic rocks. Many of the islands contain a large percentage of gneissic diorite. Foliated metamorphic rocks such as these weather more quickly than massive granitic rocks, and tend to support more productive forests but be more susceptible to slope failures. The Coast Mountains include mainly coarse crystalline, igneous intrusive rocks of the coastal batholith, mostly granitic with minor gneiss and schist. To the east, north, and south of Bella Coola, dominant rock types are andesitic and basaltic volcanics with smaller outcrops of granitic and metasedimentary rocks.



2.1.3 Terrain and surficial materials (Ryder 1978; Yole and others 1982)

The Pleistocene ice-cap covered all of the area except for the highest peaks. Evidence of tremendous ice erosion is everywhere. Extensive icefields remain in the rugged mountains between Bella Coola River and Knight Inlet. Glacial till in the form of morainal deposits was transported and laid down by glaciers. The till is rather spotty in distribution, with fairly regular deposits only towards the interior plateau or eastern sections of the area. Glaciofluvial terraces are prominent in a few major valleys, like the Bella Coola and Kimsquit. In more recent time, there has been significant deposition of colluvial, fluvial, and organic materials.

The Hecate Lowland was heavily scoured by ice and displays extensive areas of bare bedrock as well as large expanses of organic materials that have accumulated in the muskeg and boggy forests. Organic soils over sloping bedrock are common in the western portions, and are notoriously unstable. Colluvial and fluvial deposits, as well as exposed bedrock, dominate the landscape of the Coast Mountains. Colluvial deposits of coarse, angular, fractured bedrock have accumulated on most slopes. These materials are usually well drained but can be unstable. Thin soils over colluvial deposits (e.g., veneers of humus over bouldery colluvial aprons at the base of steep slopes) are very susceptible to logging-related disturbance. Fluvial materials have been deposited along streams and rivers, often in the form of terraces composed of sand, gravel, and silt. Fluvial materials are generally stable but, on active floodplains or fans, are prone to flooding and erosion.

Figure 2. Looking west down Burke Channel.

2.1.4 Soils (Jungen & Lewis 1978; Yole and others 1982)

Forest soils of the Coast Mountains tend to be coarse textured, moderately well drained, and acidic. Typically they are Podzols with fairly thick (frequently 15 cm or more) surface organic layers (humus). Cemented mineral horizons, which restrict root and water penetration, are fairly common in podzolic soils throughout the area, and can increase windthrow hazard.

Brunisols occur on younger landforms such as recent colluvial and fluvial deposits. Regosols are common on active floodplains and recent landslides. Gleysols or gleyed subgroups of other soil types develop in moisture-receiving sites with impeded drainage.

Non-forested organic soils occupy poorly drained, depressional or flat positions throughout the landscape, and are particularly widespread on the Hecate Lowland. Forested, freely drained organic soils (Folisols) occur over mineral soil and bedrock on sloping terrain, more commonly in the western portions of the area. Wet Folisols on steep slopes are prone to landslides (Fig. 3).

> *"Maintaining the organic matter of forest soils is critical, because it contains virtually all of the available nutrients, has high water-absorbing and water-retaining capability, improves soil po* [...] *the mineral soil from surface erosion"* (Clayoquot Sound Scientific Panel [CSSP] 1995).

Figure 3. Recent landslide,Kwatna River

2.1.5 Hydrology (CSSP 1995)

The prevailing wet climate translates to large volumes of water on mountain slopes, due to heavy rainfall or heavy rainfall on melting snow. The forest transmutes some of this water through canopy interception, evaporation, root uptake, and transpiration. But most rainwater moves through the forest soil, with rapid runoff during heavy rains. Rapid drainage through forest soils on steep slopes contributes to slope stability, and landslides often occur where drainage is altered or impeded (CSSP 1995).

Forestry activities, especially roadbuilding, soil disturbance, and rates and patterns of logging, affect the rate and timing of runoff of water. These activities can cause hydrological regimes to deviate beyond the range of natural variation, even though these systems are often "flashy" with highly variable watershed regimes.

Note also that the Central Coast (especially the Outer Coast Mountains) contains quite a few large and medium-sized lakes, like Long, Owikeno, Koeye, Gildersleeve, Link, Ellerslie, Ingram, Mootoo, Whalen, and Kimsquit lakes. Most of these are biologically (beach spawning of salmon, freshwater fish, grizzly habitat), hydrologically (modulation, interception, storage), and culturally very significant. *"Lakes, as a whole, may be less vulnerable than streams to ecological impacts from logging activities"* (CSSP 1995). However, lakes could be negatively affected by sediment from poor roadbuilding or excessive rates of cut, and the shore zone can be regarded as a type of riparian zone---with similar sensitivity to logging.

2.1.6 Hydroriparian ecosystem (CSSP 1995)

One can make a strong case for recognizing and treating waterbodies and the immediately adjacent terrestrial environment as a single system, the "hydroriparian ecosystem", rather than traditionally as two separate systems, aquatic and riparian (CSSP 1995). See the Clayoquot Sound Report 5 Section 2.2.4 for a useful discussion of the nature and functions of this ecosystem. The report's four points bear repeating.

- the hydroriparian ecosystem is a focus of biological activity, and can be likened to the skeleton and circulation system of a watershed.
- these systems are strongly affected by logging and roadbuilding.
- the maintenance of natural subsurface waterflow is important to biological diversity, as well as to slope stability.
- each watershed contains its own hydroriparian ecosystem, largely isolated from the systems in other watersheds. This isolation has important genetic consequences, especially for organisms with poor dispersability.

The report maintains that *"these points emphasize the importance of maintaining vegetation in riparian areas, restricting rates of forest removal (rate-of-cut) within watersheds, constructing and locating roads carefully, and treating watersheds as discrete units."* This seems reasonable. But things get sticky when trying to decide **how** to do it, how to actually designate, protect, and manage the hydroriparian ecosystem.

> *"Unfortunately, foresters, forest planners, and environmentalists seem to be placing more emphasis on …minimum buffer widths than on designing them to match local site and watershed conditions…Designating uniform strips of riparian buffers alone may not, in the long run, protect the integrity of natural processes"* (Burton 1998).

2.1.7 Climate (Cheston and others 1975; Environment Canada 1980; Yole and others 1982)

The study area has a typical coastal climate, with mean annual temperature ranging from 7.5 ^{0} to 8.5^{0} C and mean annual total precipitation ranging from around 1,000 to 4,500 mm or more. The wettest localities are along the westernmost mountains, in the inlet region from Sullivan Bay through Rivers Inlet and Ocean Falls to Butedale, where the complex fiordland causes stormclouds to converge. By the time the moist Pacific air masses have reached the eastern boundaries of the area, passed over several tiers of mountains and been successively lifted and dried, a pronounced rainshadow has been cast. Precipitation at inner coastal sites totals only one-third that along the western mountain front (Table 2), and decreases rapidly inland, as in the Dean, Bella Coola, Talchako, and Klinaklini valleys. Fall is very wet; winter is cool and wet, usually with heavy, wet to moist snowfall, sometimes with cold dry spells and strong outflow winds; summer is relatively warm and wet to moist, sometimes with significant warm dry spells, especially inland.

Table 2. Some climate statistics for selected stations in the Central Coast Plan Area.

Station[1]	Mean Annual Temperature (°C)	Mean Annual Precipitation (mm)	Mean Annual Snowfall (mm)
HYPERMARITIME			
Egg Island	8.2	2484	86
McInnes Island	8.5	2558	98
Bella Bella	---	2672	86
MARITIME			
Wannock River (Rivers Inlet)	7.4	2975	144
Ocean Falls	8.1	4387	155
Swanson's Bay	---	4900	---
SUBMARITIME			
Bella Coola BC Hydro	7.7	2109	139
Bella Coola Village	7.5	1614	191
Stuie (estimated)	---	800	---

[1]Note that all these stations are at low elevations, near sea level. It gets cooler, considerably wetter, and snowier with increasing elevation.

2.2 Biota

2.2.1 Vegetation (McAvoy 1931; Yole and others 1982; Alaback & Pojar 1997)

Upland coniferous forests dominate the vegetation of the area. Western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) are the most common tree species at lower and middle elevations, often joined by amabilis fir (*Abies amabilis*), and sometimes by Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), and yellow-cedar or cypress (*Chamaecyparis nootkatensis*). Amabilis fir, yellow-cedar, and mountain hemlock (*Tsuga mertensiana*) increase in abundance with increasing elevation, and subalpine fir (*Abies lasiocarpa*) occurs in the inland subalpine zone and also at fairly low elevations in cold air drainage sites of glacier-headed valleys. Shore/lodgepole pine (*Pinus contorta*) is very common in the boggy forests and muskeg of the Hecate Lowland, and also occurs inland with Douglas-fir on drier, often recently burned sites.

Red alder (*Alnus rubra*), the most widespread and abundant deciduous tree species in the area, forms dense successional stands on much cut-over bottomland or otherwise heavily disturbed sites such as abandoned logging roads and landings or slide tracks. Black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) dominates successional alluvial forests along the major rivers of primarily the eastern portion of the area. Red alder often joins black cottonwood on alluvial sites, and in the western portion replaces it as the dominant deciduous tree of riparian forests. Paper birch (*Betula papyrifera*) is a species of mixed successional stands on either fairly dry rocky or moist but well-drained sites, and is most abundant in the inland valleys. Trembling aspen (*Populus tremuloides*) is uncommon on drier sites towards the eastern margin of the area.

There is a wide variety of non-forested, shrubby, herb-dominated, or moss- and lichen-dominated vegetation types in the area, especially at high elevations. However, non-forested vegetation is not germane to this report except for two widespread types, slide tracks and peatlands. Active slide tracks (usually snow avalanches but also debris slides) are very common in the Central Coast landscape, and in most mountainous valleys break the forest cover up into irregular blocks. A tall scrub of slide alder (*Alnus crispa* var. *sinuata*) usually dominates the slide tracks. Red alder and Douglas maple (*Acer glabrum*) can be abundant on slide tracks in western and eastern portions, respectively.

Freshwater wetlands also interrupt the forest cover, uncommonly and to a small extent in the valley bottoms of the inner Coast Mountains, frequently but still to a relatively small extent in the outer Coast Mountains, but very frequently and extensively in the Hecate Lowland.

As a consequence, many Central Coast valleys are not continuously forested---not even at lower and middle elevations---unlike many valleys on Vancouver Island and on the Queen Charlotte Islands. Old forests form the matrix in unlogged mountainous watersheds, but the forests naturally occur as patches of various sizes (mostly fairly large) interrupted by shrubby slide tracks, wetlands, cliffs, waterfalls or cascades, and monumental rock walls (Fig. 4). In contrast, much of the Hecate Lowland forest occurs as small and medium-sized patches in a matrix of non-forested peatlands (mostly bogs) and scrub of stunted shore pine, redcedar, yellow-cedar, and both hemlocks (Fig. 5).

Figure 5. Hecate Lowland, Don Peninsula.

Figure 4. Upper Kitlope River.

2.2.2 Fauna (Banner and others 1985; CSSP 1995; Bunnell & Chan-McLeod 1997)

We know of no studies in the area, but it is reasonable to state that invertebrates comprise most of the terrestrial fauna of the Central Coast. No doubt these organisms make critical contributions to ecosystem processes in the area much as they do elsewhere on the northwest coast of North America. Presumably the invertebrate fauna of oldgrowth tree canopies is similarly rich and specialized as in other areas of Pacific Coast temperate rainforest (Schowalter 1995; Winchester 1999), and soil organisms (most of which are invertebrates) are mega-diverse especially in the surface organic layers (Shaw and others 1991; Marshall 1993).

Vertebrates may be better known but are relatively little-studied in the area, except for a few feature species like grizzly bear, Kermode bear, marbled murrelet. The study area is probably representative of the temperate rainforest biome (Alaska to Oregon) in terms of:

- the relative richness of the vertebrate fauna, including marine mammals
- the forest-dwelling nature of the majority of terrestrial vertebrate species
- the disproportionate significance of riparian areas to forest-dwelling vertebrates
- the importance of forest structure to the vertebrate fauna
- the importance of estuaries to fauna and to overall ecosystem functioning.

Grizzly bears are common in the area. Although the bears range widely over a variety of habitats, prime grizzly habitat occurs predominantly below treeline and is largely concentrated in valley-bottom ecosystems associated with important salmon streams. Black bears are common and abundant, and the white or Kermode phase is fairly frequent especially in the Outer Coast Mountains.

Mountain goats are also common. Although they spend much of their lives above timberline, mountain goats migrate down to forested elevations and to valley and inlet lowlands when the snow is too deep at high elevations. During periods of heavy snow, they usually forage in or travel down through mature forest where the snowpack is shallower.

Blacktail deer are common at least where snowfall is not excessive. Typically they winter in valley-bottoms or on slopes with old forests, less snowpack, and abundant browse. Moose range extends toward the coast in the Kimsquit, Dean, and Atnarko valleys, in association with early successional ecosystems in the valley bottoms.

Endangered or threatened vertebrates (red-listed) that occur in the terrestrial environment of the Central Coast include Marbled Murrelet (nesting), Northern

Goshawk, and Keen's Long-eared Myotis. Vulnerable (blue-listed) vertebrates include Grizzly Bear, Fisher, Wolverine (*luscus* subspecies), Tailed Frog (mostly aquatic), Great Blue Heron, Short-eared Owl, Peregrine Falcon (*pealei* subspecies), and Sandhill Crane. See British Columbia Ministry of Forests/B.C. Environment (1997) for more details of these species and their habitat requirements.

2.2.3 Keystone interaction: salmon - bears - trees (Willson & Halupka 1995; Willson and others 1998; Ben-David and others 1998; Reimchen 1999)

Recent research in Alaska and British Columbia has revealed anadromous fish to be "cornerstone" species, in that they provide the resource base to support much of the Pacific coastal ecosystem. The productivity of freshwater and riparian ecosystems is in part fueled by marine-derived nutrient subsidies from anadromous (including eulachon) and inshore-spawning (herring, sand lance) fishes. Most salmon die after spawning, and their carcasses provide substrate and food for a rich community of algae, fungi, and bacteria, which in turn supports increasing populations of invertebrates, which then serve as food for fish in the stream---including juvenile salmon. Furthermore, the predators that feed on living and dead fish can mediate aquatic to terrestrial nutrient fertilization. Animals such as eagles, ravens, crows, river otters, and most significantly bears commonly haul salmon onto stream banks, then several metres back into the forest. Trees and other plants can then take up the nutrients (such as nitrogen and phosphorus), and probably pass them up the food chain to animal consumers. The signature of the fertilizer effect can be detected in isotopic analysis of tree rings (T. Reimchen, personal communication 1999).

Bears and trees are by nature "keystone species", species that make an unusually strong contribution to ecosystem structure or processes, or that determine the abundance of many other species in the ecosystem, and whose removal can make many other species vulnerable to decline or at least local extinction. Salmon appear to link the ocean, fresh water, and the land, supporting a complex food web that crosses the land-water interface (Willson and others 1998). The most important or obvious components of this keystone or cornerstone interaction are salmon, bears, and the trees of the riparian forest. Note that the system is focused on the valley bottoms, which in the Central Coast is also where much of the productive forest occurs. Inappropriate forestry, especially in combination with overfishing and overhunting, can have serious negative effects on such a fundamental interaction. But it is not just fish, bears, and trees that are affected, it is the entire riparian ecosystem and, by extension and interconnection, the coastal environment in general.

2.2.4 Fungi

The fungi of the Central Coast are not well known. No systematic surveys of the area have been conducted, except for the fungi that act as pathogens of commercial tree species (see 3.1.6, Diseases).

We expect that not less than 3000 species of macrofungi (larger fungi) and many more microfungi occur in the Central Coast. Most of the area is forested, so most of these fungi are associated with forests in some way. Several macrofungi known to occur in the

Central Coast are commercially important edible species[1], especially pine mushrooms (*Tricholoma magnivelare*) and chanterelles (*Cantharellus formosus*). Other species form partnerships with tree roots is symbioses known as mycorrhizae. All commercial tree species (and most other plants) in the Central Coast form these mycorrhizae, and without them would grow poorly or not at all. And other fungi form partnerships with green algae and/or cyanobacteria in lichens, many species of which are common and often abundant in the Central Coast. Epiphytic lichens are particularly diverse, with a suite of species more or less restricted to old forests (Goward 1993). Some lichens---those like *Lobaria oregana*, with cyanobacterial partners---are important sources of nitrogen for forest ecosystems.

Many fungi in the Central Coast are microfungi, not visible to the naked eye. These and other non-fungal microbes (such as soil microfauna, algae, bacteria) are so poorly known that we won't consider them further here. But they occur in stupefyingly large numbers and perform many essential functions (Marshall 1993), especially decomposition and nitrogen fixation, in Central Coast ecosystems.

2.2.5 Summary

The biota of the Central Coast is poorly known, but three generalizations seem reasonable:

(1) most organisms are of the forest or associated with forests in some way;

(2) forests of all age classes, including very young and very old, are important for maintaining the diversity of all groups of organisms, from microbes to mammals.

Conventional production forestry impacts the biota in many ways, including:

- causing a decline in structural components typical of old forests;
    - altering microclimatic conditions;
    - interrupting ecological continuity at relatively frequent intervals;
    - truncating natural succession, confining it to a 60- to 100-year long (in coastal B.C.) Procrustean bed (see Fig. 12);
    - causing a decline in the extent of and connectivity among patches of old forest;
    - directly or indirectly affecting aquatic organisms through impacts on hydrologic regulation and water quality.

(3) Some groups of organisms, like canopy insects, epiphytic lichens and epixylic mosses and liverworts, and aquatic invertebrates, are more sensitive to these impacts than are other, less specialized, more vagile groups like vertebrates.

2.3 Biogeoclimatic Units (Klinka and others 1991; Banner and others 1993; Green and Klinka 1994)

The biogeoclimatic units of the Central Coast segregate along longitudinal and altitudinal gradients corresponding to the climates discussed in 2.1.7. From west to east,

[1] See Wills & Lipsey (1999) for a thorough review of commercially important wild mushrooms, among other things.

there are hypermaritime, maritime, and submaritime climates (a narrow band of subcontinental climate occurs along the eastern edge of the area but is inconsequential for our purposes). Low and medium elevations within all three of these climates are represented by the Coastal Western Hemlock zone (CWH), with hypermaritime, maritime, and submaritime subzones. The very wet hypermaritime subzone (CWHvh) corresponds closely to the Hecate Lowland. The very wet maritime subzone (CWHvm) occurs in the outer Coast Mountains. Submaritime subzones occupy the inner Coast Mountains: the moist submaritime subzone (CWHms) occurs at lower elevations primarily along the inner fiords and tributary valleys; the wet submaritime subzone (CWHws) occurs at wetter and snowier elevations above the CWHms; the dry submaritime subzone (CWHds) occurs inland from the CWHms and is restricted in the study area to the Dean, Bella Coola, and Klinaklini rivers. There are biogeoclimatic variants of all these subzones but we don't need to bother with them.

Subalpine elevations above the various CWH subzones are represented by the Mountain Hemlock zone (MH), with corresponding hypermaritime, maritime, and submaritime subzones. At least some of the MH zone contains productive forests, but very little logging has occurred in the subalpine zone (unlike on the south coast), and more is unlikely under current operability constraints. The Alpine Tundra zone (AT) occurs above the MH, and there is a lot of alpine terrain in the Central Coast, as well as vast amounts of world-class rock and ice.

So for our purposes and to keep it simple, let's say there are three subzones or groups of subzones in the study area, hypermaritime, maritime, and submaritime, and they correspond to three climatic and physiographic regimes. We'll call these three subunits of the study area the Hecate Lowland, the Outer Coast Mountains, and the Inner Coast Mountains (Fig. 6).

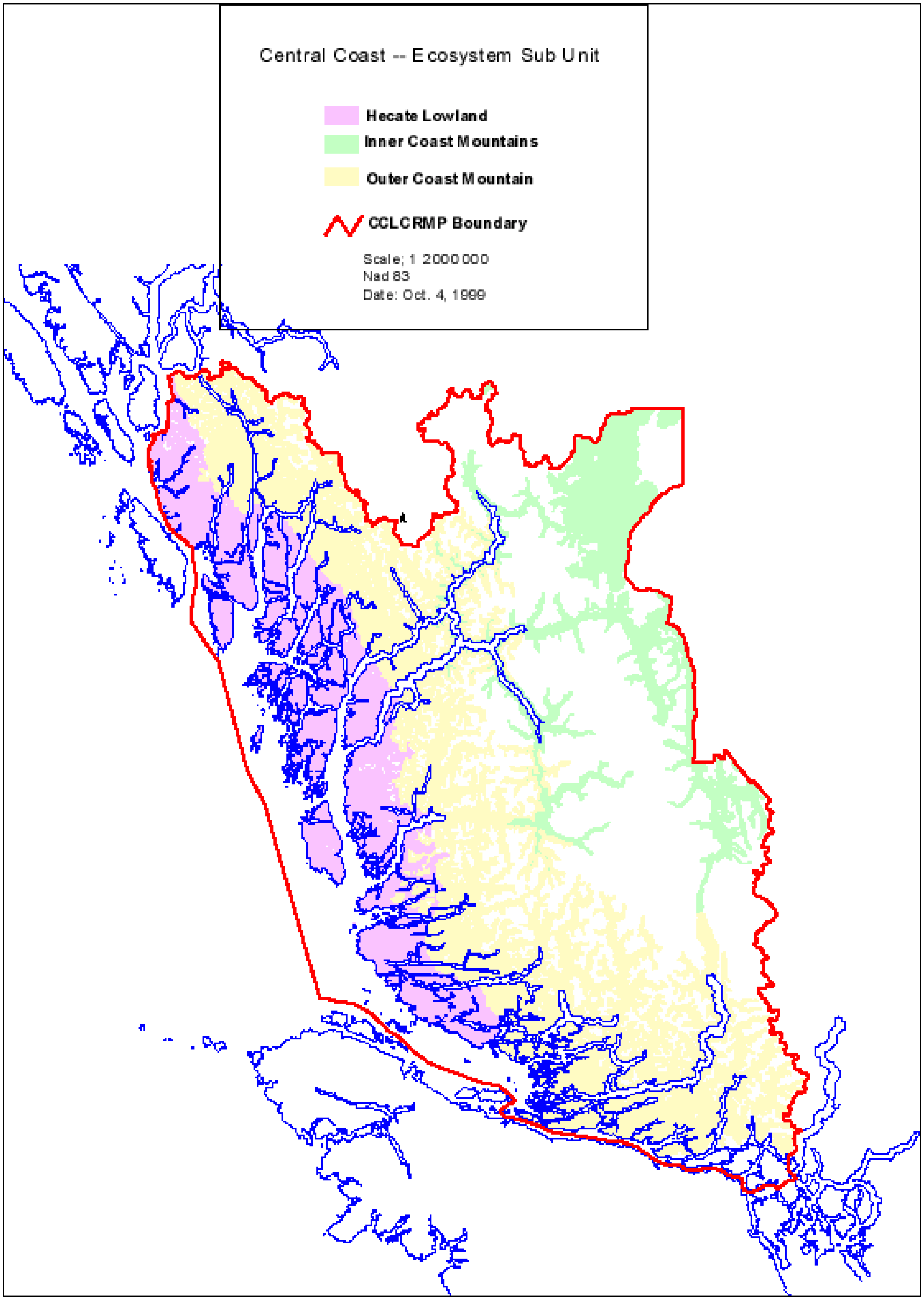


Figure 6. Ecological sub-units of the Central Coast.

2.3.1 Pertinent features of the three ecological subunits

HECATE LOWLAND (Fig. 7)

Figure 7. Hecate Lowland, vicinity of Bella Bella.

- a distinctive and consistent landscape, stretching from Johnstone Strait to Prince Rupert
- really nothing else like it in B.C., but some similarities to northern Vancouver Island (north of Port Hardy) and the western hypermaritime fringe of Vancouver Island, as well as parts of Q.C.I.
- subdued terrain; rough topography but little relief
- wet, cool, very mild climate; lots of cloud cover, fog, drizzle; little or ephemeral snowfall
- extensive areas of lower productivity cedar - hemlock forests, which nevertheless contain large amounts of sound redcedar and yellow-cedar
- productive forests (western hemlock, Sitka spruce, amabilis fir, and the two cedars) restricted to steeper, better drained slopes and to floodplains, or to richer bedrock types (metasedimentary and richer metamorphic and volcanic rocks)
- extensive peatlands (bogs) and boggy forests on subdued, poorly drained terrain

lots of wet greasy organic soils in general, including on forested slopes

- disturbance---in the form of windthrow, landslides, avalanches and floods---typically is small scale (wind damage occasionally extensive) and sometimes intense, but many of the open scrubby forests exhibit more of a tree island than a gap dynamic; the gaps become the matrix
- little large-scale, industrial logging to date; increased harvesting anticipated, especially in the more productive cedar – hemlock types, but unlikely to be on a large scale.

OUTER COAST MOUNTAINS (Fig. 8)

Figure 8. Outer Coast Mountains, upper Kwatna River.

- probably what most people would consider "typical" B.C. coast; mountainous, wet, thickly forested fiordland
- similar forests occur from Vancouver Island and the North Shore Mountains north to the Nass River
- similar environment to much of the wetter portion of Vancouver Island, especially the windward mountains, including Clayoqout Sound
- rugged terrain; many valleys with broad riparian zones, oversteepened sidewalls with frequent slide tracks, and few intermediate hillslopes
- very wet, cool, mild climate; mild winters with heavy rainfall or wet snowfall, which can accumulate and persist for significant periods especially at higher elevations
- forests dominated by western hemlock and amabilis fir (also known as "decadent hembal" if the stands are old and riddled with decay), with variable but often significant amounts of redcedar; Sitka spruce abundant on valleybottoms and yellow-cedar frequent at higher elevations
- dwarf mistletoe common on western hemlock
- advance regeneration of western hemlock and amabilis fir typically abundant
- frequent low intensity, small-scale, gap-forming disturbances are the norm
- moderately cut-over, but in an uneven fashion; some major valleys (e.g., Kwatna, Clyak, Chuckwalla-Kilbella) and islands (especially north of Johnstone Strait) have undergone "first pass"; much more logging anticipated over next 20 years

Inner Coast Mountains (Fig. 9)

Figure 9. Looking up Saloomt River from Bella Coola valley.

- mostly formidable hinterland, probably the most extreme terrain in B.C.
- similar forests occur on southwest mainland (e.g., Squamish-Pemberton area) and some leeward parts of Vancouver Island (because of rainshadow effect, some moisture stress, fire history, and Douglas-fir---at least at lower elevations)
- forests at higher elevations more like those to the north, in Kalum Forest District
- very rugged terrain, but some of the larger valleys with fairly extensive intermediate hillslopes and operable land (e.g., Kimsquit, Machmell)
- transitional between coast and interior, ranging from relatively dry (the inland valleys) to moist (inner fiordland at lower elevations) to wet (middle and upper elevations generally); warm dry spells in summer, historically accompanied by wildfire; moderate to heavy snowfall, which often persists; outflow winds common in winter
- forests dominated by western hemlock and western redcedar, joined by Douglas-fir at low elevations or on warm aspects (fire history), and by amabilis fir at middle and higher elevations
- moisture stress during summer on some sites
- fire history and significant fire hazard, especially at low elevations
- transitional (i.e., between coast and interior), submaritime forests, with a mix of small- and large-scale natural disturbance depending primarily on elevation, terrain, and distance from the ocean.

- relatively heavily logged; most valleys have already undergone “first pass”; large-scale logging not anticipated for another 20 (?) years

2.4 Communities and Resource Development (Kopas 1970; Cheston and others 1975; British Columbia Department of Economic Development 1976; British Columbia Ministry of Forests 1995, 1999)

The Central Coast is one of the more remote and sparsely populated regions of the province, with approximately 3500-4000 permanent residents. Nevertheless, the coastal environment has for centuries supported a well-developed, salmon-based culture of Pacific Coast Indians (Northern Kwakiutl, Bella Coola, Tsimshian groups). Aside from fur trading posts and forts, permanent white settlement first came in the late 1800s as homesteading farmers and fishermen established several distinct communities in the region.

Salmon canning was a basic industry in the early part of the 20th century. The industry peaked around 1917---when for example there were nine canneries at Rivers Inlet---but subsequently relocated (to Prince Rupert and Vancouver) and declined. Commercial fishing in the second half of this century boomed but has seriously declined in the last decade or two, whereas recreational/sport fishing has dramatically increased in the past two decades. Ocean Falls came to be because it was chosen as the site of a pulp mill in 1902. Ocean Falls was the economic centre of the region for most of the 20th century, with a workforce of 1100 and a population of around 3000 during peak production. But the mill was closed down in 1980, and most people left the town.

At present, the main communities are Bella Coola and Waglisla (Bella Bella). About one-half of the region’s population reside in the Bella Coola valley (including Hagensborg and Firvale), and about one-quarter live in Waglisla. Other small communities occur along the outer coast, including Klemtu, Namu, Oweekeeno (Rivers Inlet), Shearwater, Ocean Falls, and in the Johnstone Strait area, including Minstrel Island, Port Neville, and Kingcome Inlet. The remaining population is located in seasonal logging and fishing camps scattered throughout the region. Most of the workers come from the Lower Mainland and Vancouver Island.

In summary, the population is sparse and far-flung, totalling less than 5,000 in an area of 4.8 million hectares. The majority of the permanent residents are First Nations (Lewis and others 1997). The majority of the study area is uninhabited hinterland.

2.5 The Timber Resource

Timber resource information for this report was derived from various B.C. Ministry of Forests’ Timber Supply Reviews. We used Timber Supply Area (TSA) reviews to simplify data compilation and to ensure consistency in comparative analysis. The Central Coast incorporates all of the Mid-Coast TSA, a major portion of the Kingcome TSA, and minor portions of the North Coast and Strathcona TSAs. We combined information from the Mid-Coast and Kingcome TSAs to describe the timber resource of the Central Coast. Note that this information is derived from an operating area similar but not identical to the Central Coast planning area, and it does not include Tree

Farm License areas. For convenience, we compared the Central Coast timber resource with that of a comparable area within the two main Vancouver Island TSAs (Strathcona and Arrowsmith). The Vancouver Island TSAs include landbase beyond what is comparable or similar to that found in the Central Coast. Therefore direct comparisons must be used with caution, however we think that the information fairly accurately reflects comparative conditions between the two operating areas.

2.5.1 Quantity

Forests in the Central Coast are dominated by western hemlock and amabilis fir (collectively, hemlock-"balsam" or "hembal") and western redcedar, with lesser amounts of yellow-cedar, Sitka spruce and Douglas-fir. Table 3 summarizes the TSA inventory of forest type by leading species, as a percentage of the timber harvesting landbase.Table 3 indicates that hemlock/amabilis fir ("hemlock/balsam" or "hembal") stands make up slightly more of the timber harvesting landbase in the Central Coast. The big difference is the higher proportion of redcedar-leading stands and the lower proportion of Douglas-fir-leading stands in the Central Coast.

Table 3. Inventory of commercial forest by leading tree species.

Species	Mid-Coast (%)	Kingcome (%)	Arrowsmith (%)	Strathcona (%)
hemlock/amabilis fir	66	56	33	61
cedar[1]	24	41	29	12
Douglas-fir	5	-	37	26
Sitka spruce	5	3	1	1

	Central Coast (%)	Vancouver Island (%)
hemlock/amabilis fir	61	53
cedar[1]	32	17
Douglas-fir	3	29
Sitka spruce	4	1
Total	100	100

[1]Mostly redcedar, but includes some yellow-cedar-leading stands.

Timber supply analysis projects that the average volume per ha in the Central Coast will gradually decrease over the next 20 decades to roughly 550 m^3/ha Fig. 10). By comparison, volumes in the Vancouver Island TSAs will decline to a low of 500 m^3/ha before rebounding to roughly 660 m^3/ha. Presumably the rebound largely reflects the substantial future contribution by second-growth stands, which are much more extensive on Vancouver Island because of a longer and more intense history of logging.

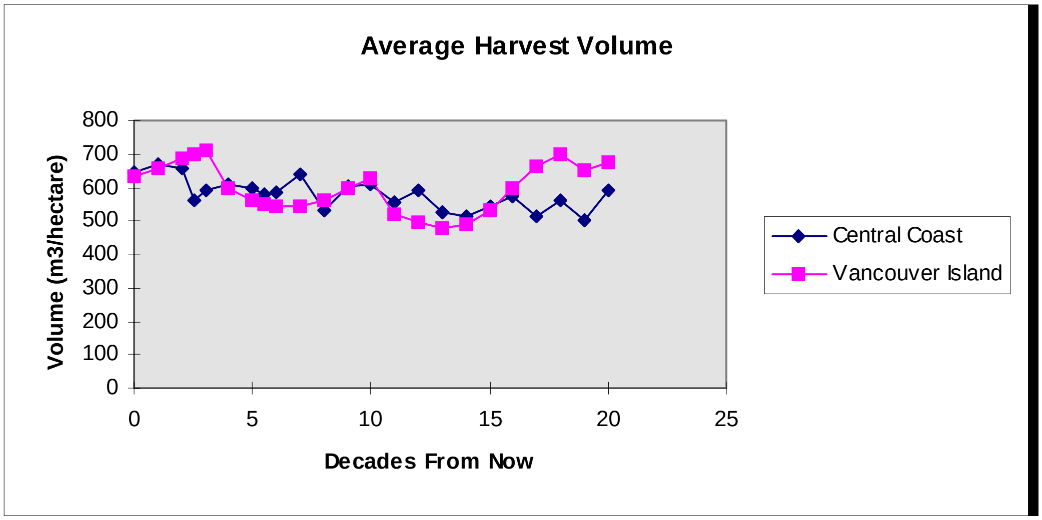


Figure 10. Projected average harvest volume based on timber supply analysis.

2.5.2 Quality

Many of the mature[2] (120+ years old) stands in the Central Coast are on sites with poor and low productivity for growing trees. Some sites, such as well-drained terraces in valley bottoms, are considered very productive. But the majority of mature forests remaining in the timber harvesting landbase have relatively poor site productivity (see Table 5 below)---compared to other coastal forests that is; they are pretty impressive forests nonetheless. Poor drainage on the Hecate Lowland, thin soils at high elevations or on steep terrain in the Inner and Outer Coast Mountains, cold air drainage, frost and occasional summer drought in the Inner Coast Mountains, nutrient-poor bedrock generally---all contribute to the relatively poor productivity. Even though cedar - hemlock stands often have relatively low merchantable volume, the redcedar typically is of sufficiently good quality that these stands can be logged profitably. By contrast, timber quality and logging 'chance' in hemlock/amabilis fir timber types can be very poor in places. Conk and blind conk are major indicators of the stand defect that reduces both recoverable volume and the value (log grades) of that volume. But these indicators are easily missed or difficult to discern; in many cases, level of stand defect is virtually impossible to verify in a field examination. Because old hemlock/amabilis fir-leading stands, particularly in the Inner and Outer Coast Mountains, often have significant decay and poor wood quality (and even sound white-wood has lower value than cedar), they are not as economically valuable as the corresponding cedar-leading stands.

2.5.3 Distribution

In the Central Coast planning area, 12% of the gross land base (excluding water) is currently considered available and deemed feasible for timber harvesting (i.e., makes up the timber harvesting landbase – THLB), according to the draft Socio-Economic and Environmental/Marine Base Case Report provided to the Central Coast planning table.

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[2] To be consistent with common forestry usage in B.C., mature forests include everything 121 years old and older; immature forests are 1-120 years old; oldgrowth forests are 250+ years old; juvenile and young forests are categories of immature (see Fig. 12).

Comparing available THLB only for Crown forest land and after “netting-out” non-productive forests, our TSA analysis indicates that the THLB in the Central Coast is roughly half that available in the Vancouver Island study area.

Age-class distribution (Table 4) over the timber harvesting landbase is not consistent throughout the Central Coast. The majority of all stands within the THLB of the Mid-Coast TSA are currently classed as mature, and most of these are over 250 years old. A small minority of stands are immature and young---less than 40 years old. Because of a more extensive history of harvest, the Kingcome TSA has a large proportion of its THLB in younger age classes. In both TSAs, there is a distinct middle-aged gap in age-class distribution. Little post-logging second growth is old enough yet for harvesting. The gap between young and old stands is an important timber supply issue: allocating the remaining old forests until young stands become old enough to harvest.

In contrast, the age-class distribution in the two Vancouver Island TSAs comprises almost equal areas of forest younger and older than minimum harvestable age (about 80 years). As in the Central Coast TSAs, age-class distribution is dominated by young stands (age 0-80 years) and old stands (>200 years), with a distinct middle-aged gap in between. However, this age-class gap is not nearly as sharp as in the Central Coast, and a large proportion of the young stands on Vancouver Island are expected to be available for harvest over the next 20-30 years.

Table 4. Age-class distribution by TSA and by study area.

Age Class	Mid-Coast (%)	Kingcome (%)	Arrowsmith (%)	Strathcona (%)
Immature	27	53	49	44
Mature	73	47	51	56
	Central Coast (%)		**Vancouver Island (%)**	
Immature	39		45	
Mature	61		55	

Table 5 summarizes the timber harvesting landbase by site productivity. Although some sites at lower elevations in the Inner and Outer Coast Mountains are very productive, site productivity in the remaining Central Coast mature forests (particularly in the Mid-Coast TSA) is significantly lower than in the Vancouver Island TSAs.

Table 5. Distribution of current estimates of site productivity by TSA and by study area.

Productivity Class	Mid-Coast (%)	Kingcome (%)	Arrowsmith (%)	Strathcona (%)
good/medium	45	58	52	71
poor/low	55	42	48	29
	Central Coast (%)		**Vancouver Island (%)**	

good/medium	51	65
poor/low	49	35

2.5.4 Operating environment

Because of differences in historic harvesting and forest management, the future operating environment in the Central Coast will differ depending on which TSA is being discussed. Unlike most coastal TSAs, the Mid-Coast TSA anticipates increasing the current timber harvesting landbase so as to help maintain the current allowable annual cut (AAC). Over the past five years, licensees have demonstrated that harvesting of low quality Hecate Lowland stands and high cost helicopter-operable stands is physically possible and can be economically feasible. Addition of these areas to the timber harvesting landbase could allow the current AAC to be maintained for the next 8 to 12 years, before it declines to the long-term harvest level. The concern is that a corresponding increase in timber supply from better quality and conventionally accessible stands in the Inner Coast Mountains is not anticipated. Therefore, the AAC will probably come from stands with a lower average volume and value and potentially higher average harvesting costs than are currently being experienced. Note that our current information on site productivity, which is based on stems hundreds of years old, probably underestimates the productivity of secondgrowth stands. Some second-growth stands will grow faster and produce more sound wood than indicated by the growth rates and wood quality of the remaining oldgrowth. In contrast, and as is more common on the coast, the AACs in the Arrowsmith, Strathcona, and Kingcome TSAs are expected to decline below the long-term harvest level before rebounding. Factors influencing this decline include:

- a distinct age-class gap; insufficient mature forest to rely on until younger stands become available for harvest
- spatial constraints due to visual quality objectives and to green-up and adjacency restrictions
- lack of the early stand management necessary to bring young stands on line sooner.

3.0 DISTURBANCES/MODIFYING FACTORS

Forests are dynamic systems, with community structure determined by interactions of environment, disturbance and species recruitment (Parminter 1998). Stand-destroying disturbances re-initiate succession, establishing on forested landscapes a successional sequence usually characterized by herb- and shrub-rich early seral ecosystems, followed by the tree-dominated stages *stand initiation, stem exclusion, understory re-initiation*, and *oldgrowth* (Oliver 1992; see Section 4.1). However, most natural disturbances in wet coastal forests affect only a few trees, or do not kill the understory trees, thus the subsequent successional pathways often skip the herb and shrub early stages.

The frequency, size, and magnitude (intensity or severity) of disturbances determine the distribution of seral stages across the landscape, the structure and function of the stands, and (in conjunction with other factors) the species that occur there (e.g., Spies and Franklin 1988; Arsenault and Bradfield 1995; Entry and Emmingham 1995).

Many authors (e.g., Franklin 1992; Hann 1992; Scientific Panel for Sustainable Forest Practices in Clayoquot Sound 1994) have suggested that biodiversity and other important ecosystem attributes will likely be best conserved if disturbances such as logging are kept within the temporal and spatial ranges of variability that characterize natural disturbances. This suggests that we could model forest management practices on natural disturbance patterns, while recognizing the important differences between, for example, wildfire and logging. This makes ecological sense: the resulting landscapes would be composed of patches with sizes, shapes, and age-classes somewhat resembling those which the current biota had experienced in the last 8-10 millennia; and the patches themselves would retain some of the structural elements that provided habitat for those organisms.

To the extent that this is possible, it represents a desirable goal strictly from an ecological perspective. It's important, then, to understand the historic range of variability in natural disturbances in the Central Coast Plan Area.

In B.C., climate is one of the primary factors affecting natural disturbance regimes. The Forest Practices Code's Biodiversity Guidebook (B.C. Ministry of Forests and B.C. Environment 1995) defines five Natural Disturbance Types (NDTs) with different climates and natural disturbance regimes. All five of B.C.'s NDTs (NDTs 1-5) occur in the Central Coast, reflecting a variety of climates from wet west coast to dry interior transition zone (see Section 2.1). Three of these NDTs are relatively unimportant and not considered further here: NDT3, NDT4, and NDT5. NDT3 (ecosystems with frequent stand-initiating events) is represented in the extreme eastern portions of the plan area by small portions of interior zones such as the Sub-Boreal Spruce and the Sub-Boreal Pine - Spruce biogeoclimatic zones. NDT4 (ecosystems with frequent stand-maintaining fires) is represented by the very small portions of the plan area in the Interior Douglas-Fir biogeoclimatic zone, again on the eastern margin of our area. NDT5 (alpine tundra and subalpine parkland) occurs in mountainous parts of the Central Coast, but is largely non-forested.

NDT1 (ecosystems with rare stand-initiating events) in the Central Coast Plan Area includes the following biogeoclimatic subzones: CWHvm and vh; MHmm and wh. NDT1 is described in the Biodiversity Guidebook as follows:

> *Historically, these forest ecosystems were usually uneven-aged or multi-storied even-aged, with regeneration occurring in gaps created by the death of individual trees or small patches of trees...*

NDT1 ecosystems occur throughout the Hecate Lowland and Outer Coast Mountains in the Central Coast Plan Area.

NDT2 (ecosystems with infrequent stand-initiating events) in the Central Coast includes the following biogeoclimatic subzones: CWHds, ms, ws; and small areas in several Engelmann Spruce - Subalpine Fir (ESSF) subzones. NDT2 is described in the Biodiversity Guidebook as follows:

> *Historically, these forest ecosystems were usually even-aged, but extended post-fire regeneration periods produced stands with uneven-aged tendencies, notably in the ESSF and SWB biogeoclimatic zones where multi-storied forest canopies result...*

NDT2 ecosystems occur in the Central Coast in the Inner Coast Mountains.

Disturbances are sometimes classed as 'natural' (e.g., fire, wind, insects) or 'anthropogenic' (human-caused: e.g., logging, roads, settlement). These terms are not always accurate---many wildfires are initiated by humans, for example, and in some parts of our province 'natural' disturbance regimes were influenced by First Nations activities such as burning. However, they provide a useful distinction here between natural disturbances (which we seek to understand and characterize) and the human-caused disturbances (for this report, forest management) which we can try to bring closer to the historical range of variability of natural disturbances.

3.1 Natural Disturbances

3.1.1 Fire

According to the Biodiversity Guidebook, for NDT1: "*fire[s] ...were generally small and resulted in irregular edge configurations and landscape patterns. The mean return interval for these disturbances is generally 250 years for the CWH...and 350 years for the ...MH biogeoclimatic zones*".

Recent research in NDT1 ecosystems in Clayoquot Sound and the lower Fraser Valley (Gavin and others 1996; Gavin and others 1997; Lertzman and others 1998) suggests that these fire return intervals are probably too short. Using radiocarbon (C^{14}) dating of charcoal from forest soil horizons, they estimated fire return intervals of 700-3000 years on sites with southerly aspects, to 3000-6000 years on sites with more northerly aspects. This is consistent with the predominance of old forests on the Central Coast landbase. In similar NDT1 units in Clayoquot Sound, more than 98% of stands in unlogged watersheds were in age classes 8 or 9 (>140 years old)(CSSP 1995); a fire return interval of 250 years would produce landscapes with approximately 57% of the area >140 years old.

While fire is unimportant as a disturbance agent in NDT1, it helps shape the landscape in NDT2. The Biodiversity Guidebook suggests that, for NDT2, "*Wildfires were often of moderate size (20-1000 ha), with unburned areas resulting from sheltering terrain features, higher site moisture, or chance. Many larger fires occurred after periods of extended drought, but the landscape was dominated by extensive areas of mature forest surrounding patches of younger forest. The mean return interval for these disturbances is about 200 years for the ... CWH [and] ESSF biogeoclimatic zones.*" In similar subzones on eastern and central Vancouver Island, Schmidt (1957) documented extensive fires 170, 250, 340, 350, 440, 590, 660, 790, 900, 970, and 1100-1200 years ago, with the most recent very large fire 340 years ago.

3.1.2 Wind

Windthrow in the Inner and Outer Coast Mountains is relatively predictable; i.e., either up or down valley. Down-valley outflow winds seem to be most damaging. In the Hecate Lowland, where there is less topographic influence, windthrow is relatively unpredictable. Most damage comes from low-pressure, fall and winter storm winds from the south and west. Windthrow and windsnap affect areas ranging from individual trees up to large portions of the landscape (Fig. 11). Endemic windthrow events in the Central

Coast create relatively small amounts of damage but this damage is spread over a wide area.

Researchers in the Tongass National Forest in Southeast Alaska found that, in undeveloped landscapes, windthrow typically affects small patches averaging less than 0.05 ha and involving fewer than 10 trees per patch (Julin & Shaw 1999). Incautious logging can of course greatly exacerbate blowdown and contribute to more extensive losses. Damage varies with meteorological conditions (prevailing wind direction, speed, turbulence and gustiness, storm duration, soil moisture, snow and rain loading in tree crowns), topography (wind exposure), tree and stand characteristics (species composition, stand height and density, crown and bole condition, rooting strength), and soil characteristics (depth, drainage, and relationship to root strength [Stathers and others 1994]). Research in Southeast Alaska has demonstrated that the most susceptible stands occur on south-facing slopes directly exposed to prevailing winds, on hilltops and ridge noses and along east- and west-facing slopes where winds accelerate around mountain flanks (Julin & Shaw 1999). Periodically, more severe windthrow events damage significant tracts (100s of hectares) of timber. In exceptional circumstances, hurricane-force winds will blow trees down over large areas (e.g., scattered blowdowns totaling 30,000 hectares on Vancouver Island and the south coast, December 6 1906), and topography, stand and soil conditions become unimportant. The Biodiversity Guidebook states (for NDT1):

> *When disturbances such as wind, fire, and landslides occurred, they were generally small and resulted in irregular edge configurations and landscape patterns. The mean return interval for these disturbances is generally 250 years for the CWH...and 350 years for the ...MH biogeoclimatic zones...Occasionally, major windthrow events have occurred as a result of hurricane-force winds on certain exposed parts of coastal British Columbia. The average return interval for these has been approximately 100 years.*

Windthrow is much less important as a disturbance agent in NDT2.

Fig. 11. Blowdown on south slope, Windsor Cove, southern tip of King Island.

3.1.3 Mass movements and avalanches

Landslide processes can be divided into six groups: falls, creeps, slumps and earthflows, debris avalanches and debris flows, debris torrents, and bedrock failures (Swanston and Howes 1994). Soil mass movements (especially debris slides and debris flows) are the dominant geomorphic processes in some coastal areas in NDT1 (e.g., Howes 1981; Scientific Panel for Sustainable Forest Practices in Clayoquot Sound 1995; Schwab 1998). The same processes operate in the Hecate Lowland and Outer Coast Mountains (Fig. 12) as well: soils are often inherently unstable, being thin, organic, and permanently saturated; heavy rainstorms that might trigger mass movements are seasonally common; and logging often occurs on steep slopes, where much of the productive forest land is located (Haeussler and Yole 1980).

No landslide frequency rates have been provided for areas in the Central Coast, but Gimbarzevsky (1983) reports an average of 2.6 slope failures/km^2 for the Queen Charlotte Islands, with rates much higher in some areas (e.g., 18/km^2 in Rennell Sound). Schwab (1998) reports a 15-times greater rate of mass wasting on human-modified terrain than on forested terrain, with debris avalanches having an areal impact 43-times greater in clearcuts, and 17-times greater on roads, than on unmodified slopes. The length of stream scoured by debris torrents was increased by 7 times in clearcuts and by 21 times by roads.

Clearcut landslide frequencies are higher: on steeper slopes; in areas where natural instability is evident; on gullied or highly dissected terrain; in headwater drainage basins or on steep, imperfectly drained stream escarpments; on concave slopes; in areas with weaker bedrock types (e.g., argillites, siltstones, shales); on more poorly drained sites; and sometimes on particular aspects exposed to seasonal storm paths (Rollerson and Thomson 1998, Rollerson and Millard 1998). Rollerson and Thomson (1998) is a good summary of how hillslope conditions, morphology and surficial materials affect landslide incidence following clearcutting, summarized from work on the Skidegate Plateau (Q.C.I.), west coast of Vancouver Island, and southern Coast Mountains. Note that the Forest Practices Code specifically addresses these terrain and slope stability issues.

The Biodiversity Guidebook notes (for NDT1) that, as with wind and fire, landslides:

> *were generally small and resulted in irregular edge configurations and landscape patterns. The mean return interval for these disturbances is generally 250 years for the CWH...and 350 years for the ...MH biogeoclimatic zones.*

Figure 12. Old landslide track, south King Island.

Landslides are a less important disturbance agent in those parts of the Central Coast in NDT2.

Snow avalanches are an important disturbance agent in the Central Coast. No research has specifically documented avalanche frequency, extent, or severity in the plan area. But the evidence is easy to see. The combination of heavy snow loads and steep terrain, especially in the Inner and Outer Coast Mountains, has created and maintained obvious avalanche chutes or tracks in many areas (Fig. 13). These virtually permanently deforested areas provide seasonally important habitat for many creatures, including grizzly bears, and enhance ecosystem and species diversity in an otherwise predominantly forested landscape. But avalanches are not particularly significant in terms of coastal forest dynamics, because typically the areas they affect aren't forested---nor were they in the past, except perhaps during warmer drier postglacial epochs.

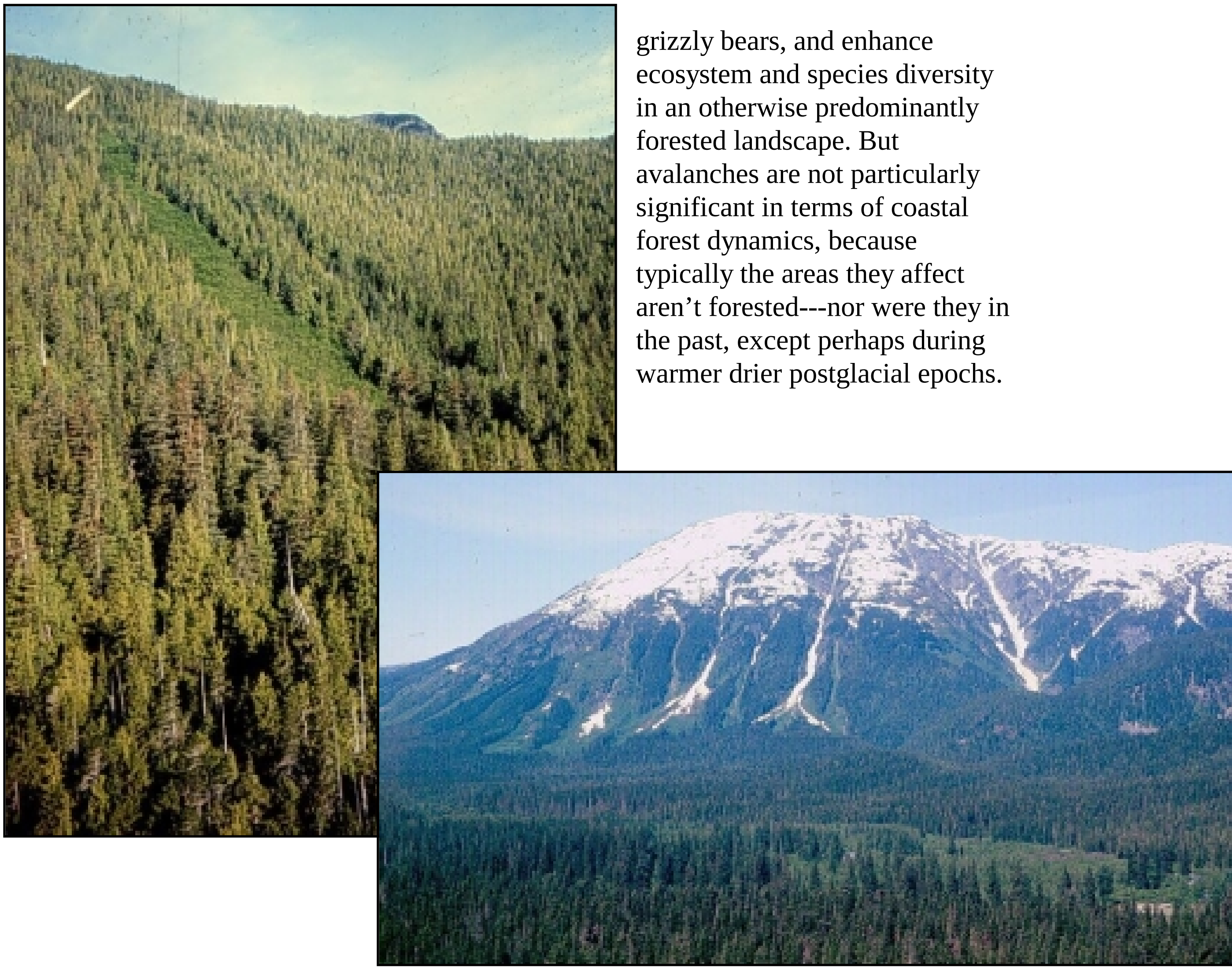

Figure 13. Avalanche tracks, Mount McVicar, Kimsquit River.

3.1.4 Floods

Storms and floods damage property and alter small portions of the landscape in the Central Coast. Septer and Schwab (1995) document rain and flood damage in the northern portion of the Central Coast (north of Bella Coola) from 1891-1991. Though these events damage property and can result in loss of human life, they tend to be small-scale, usually unpredictable events.

Glacial outburst floods, resulting from the breaching of glacier-dammed lakes, are a spectacular type of catastrophic disturbance relatively common in the Coast Mountains of B.C. (Clague & Evans 1994). Although such floods are unusual in the Central Coast, they cannot be ignored. Ape Lake is a notorious ice-dammed, self-dumping lake that has abruptly drained twice in the past 20 years, in the process scouring much of the Noeick valley bottom and obliterating logging roads and young plantations.

3.1.5 Insects

The major insects causing damage to mature forests in the Central Coast are green-striped forest looper (*Melanolophia imitata*), western blackheaded budworm (*Acleris gloverana*), and western hemlock looper (*Lambdina fiscellaria lugubrosa*) (Robinson 1981), all on western hemlock. Saddleback looper (*Ectropis crepuscularia*) is a very minor pest. These defoliators only cause mortality when trees are heavily defoliated for several years in a row. While individual trees have regularly been killed, only a few large outbreaks have been recorded in the Central Coast.

Plantations of Sitka spruce in the Central Coast are often attacked by the spruce leader weevil (*Pissodes strobi*), the Cooley spruce gall adelgid (*Adelges cooleyi*), and the spruce aphid (*Elatobium abietinum*).

3.1.6 Diseases

The major diseases causing damage to mature forests in the Central Coast are hemlock dwarf mistletoe (*Arceuthobium tsugense*), brown stringy trunk rot a.k.a. Indian paint fungus (*Echinodontium tinctorium*), brown crumbly rot (*Fomitopsis pinicola*), red ring rot (*Phellinus pini*), annosus root and butt rot (*Heterobasidion annosum*), and Armillaria root disease (*Armillaria ostoyae* and related species).

Root rots, such as annosus and Armillaria, damage mature and juvenile stands, but they are not very abundant or damaging in older stands on the outer coast. Neither annosus nor Armillaria causes much direct mortality, though annosus in particular can damage the roots of western hemlock and amabilis fir and predispose the trees to blowdown. Root rot is an important disturbance agent and can play a major role in the successional development of a stand.

Other rots, such as brown stringy trunk rot, red ring rot and (to a lesser extent) brown crumbly rot, enter trees through branch stubs, broken tops and scars, and cause heart rot in older trees. These rots directly impact wood quality, but cause only minor amounts of individual tree mortality.

Hemlock dwarf mistletoe is common and sometimes locally abundant on western hemlock in the Central Coast. It rarely kills trees, but can cause significant growth reductions, and can provide heart rots entry into the stem.

Both Armillaria root rot and hemlock dwarf mistletoe are more serious problems for young trees. Armillaria can cause direct mortality and mistletoe can significantly reduce growth rates of young trees. This is primarily a problem where species are used exclusively; e.g., reforesting only with Douglas-fir, or allowing western hemlock regeneration to come up through a mistletoe-infected overstory of western hemlock.

3.2 Human-Caused Disturbances

3.2.1 Logging

Prior to 1900 only limited logging occurred in the Central Coast, mostly in the southernmost part of the plan area (vicinity of Johnstone Strait) and in the Bella Coola valley. A few small sawmills supplied local markets. Subsequently pulp mills at Ocean Falls and on the south coast were developed, and logging expanded to meet the demands of the mills. Peak production years at Ocean Falls were between 1940 and 1960, but since then production declined and eventually ceased in the early 1980s. The only processing facility in the Central Coast is a small sawmill at Hagensborg. The majority of the timber harvested is shipped to Vancouver Island or to the Lower Mainland for processing.

There are several major licensees in the Central Coast; Western Forest Products, Interfor, Timberwest, and MacMillan Bloedel are most active. Most past logging occurred in the southern and eastern portions of the plan area, where timber volume and quality were generally higher than elsewhere. At present, most harvesting takes place in the western and northern portions---the Outer Coast Mountains and the Hecate Lowland---and will probably continue to do so for several decades.

The most recent data indicate that about 49,000 ha in the Mid-Coast TSA (not including TFL land and the rest of the plan area) support forests younger than 60 years. This is about 6% of the total productive forest landbase (i.e., 6% of the forested 37% of the total area), or about 26% of the operable forest landbase. Most of these 49,000 ha of young forest have developed after clearcut logging. The portion of these young stands inititated by fire, blowdown, and pests is insignificant. Almost all the harvesting has been and still is by the clearcutting method (see Section 5.3). Large-scale clearcutting results in large-scale disturbance to forest ecosystems and landscapes. Some of the Central Coast cutblocks are planted, all experience natural regeneration to a greater or lesser degree. Generally speaking, reforestation is not a problem---or can be dealt with if localized problems arise---and the second-growth forests grow rather quickly. Regardless of the mode or rate of recovery, the clearcut forest ecosystems have been radically disturbed, and large-scale clearcutting is unlike virtually all natural coastal disturbances) in the intensity and uniformity of its impacts. Logging is currently by far the major modifying factor or disturbance agent in the Central Coast

3.2.2 Roads

The Central Coast Plan Area includes all of one and parts of three other TSAs. The Mid-Coast TSA has 16,660 ha in “existing forest roads, trails and landings” (B.C. Ministry of Forests 1999); the Kingcome TSA has 3,840 ha in “roads” (B.C. Ministry of Forests 1995), but some of this total is on Vancouver Island and so outside of the Central Coast plan area. We don’t know how many ha of road are in the North Coast portion; most would be in TFL 25. Present and future roads in the Central Coast are predicted to occupy 10% of the long-term timber harvesting landbase. Note that, although overall there are more roads on Vancouver Island, Central Coast operations require significantly more km of road to access an equivalent volume of timber, and the roads go through generally tougher terrain, requiring much more ”hardrock” construction (see Sections 5.2 and 6.2).

Roads have several direct and indirect, negative effects on the environment. Unless “rehabilitated”, roads and landings remove land from tree production. Roads can also cause or contribute to water erosion, slope failures, blowdown, damage to streams and fish habitat, and access to vulnerable populations of wildlife. It should be acknowledged, however, that logging roads can be built and maintained to a standard that greatly reduces negative environmental impacts, and that there have been significant improvements in road building and road maintenance practices in recent years.

3.2.3 Other

- *agriculture*

The only portion of the Central Coast suited for intensive production of a variety of crops is the Bella Coola valley, with total potential farmland of 5000 ha---and probably less than half of that improved for agriculture (Yole and others 1982).

- *hydro*

There is very little hydroelectric development in the Central Coast. The main impoundments are at Ocean Falls and Clayton Falls, and both reservoirs are small (Yole and others 1982).

- *settlement*

Communities in the Central Coast are very small, with a total population of about 3500 (Lewis and others 1997) or 4232 people (B.C. Ministry of Forests 1999; Mid-Coast TSA only). We don't know which figure is more accurate. The total settlement area constitutes a tiny fraction of the Central Coast landbase.

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3.3 Summary

Natural disturbances in the Central Coast differ between the Hecate Lowland and Outer Coast Mountains (largely Natural Disturbance Type 1) and the Inner Coast Mountains (largely Natural Disturbance Type 2).

In the Hecate Lowland and Outer Coast Mountains, fire is rarely an important natural disturbance agent. Forest stands tend to be very old and structurally complex, uneven-aged with significant amounts of dead wood standing (snags) and on the ground (coarse woody debris). Natural disturbances in these older stands are small-scale in nature, primarily involving the creation of canopy 'gaps' by the death of individual (or small groups of) canopy trees. Younger stands occupy a small percentage of most landscapes, and are produced by blowdown, mass movements, and floods. Insects and disease are generally not important disturbance agents in oldgrowth stands, though they do kill individual trees or small clumps of trees, and they become more important in second-growth stands.

In the Inner Coast Mountains, fires have been important as disturbance agents, and large portions of the landscape---at least at lower and middle elevations---probably have regenerated as even-aged stands on a regular (200- to 300-year) basis. Because the stands are younger and burn more regularly than in NDT1, stand structure will be less complex, with smaller volumes of dead wood in the stands. Still, with time between disturbances, these stands will develop some structural complexity as gap processes are initiated. Windthrow and landslides are generally much less important here, whereas snow avalanches become increasingly important from Hecate Lowland through Outer Coast Mountains to Inner Coast Mountains.

4.0 SILVICULTURAL SYSTEMS

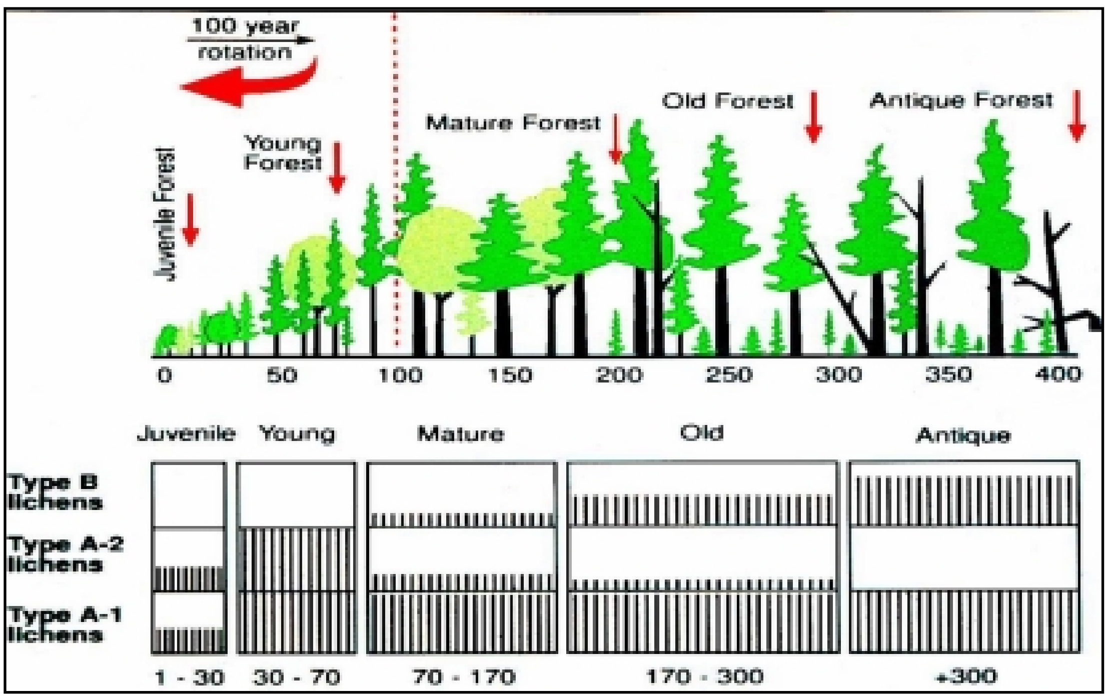
4.1 Succession and Stand Dynamics

As described in Section 3, disturbance is fundamental to the development of the structure, composition, and function of forest ecosystems (Oliver 1981; Attiwill 1994). Disturbance in forested ecosystems varies in both time and space: from frequent low intensity, small-scale, gap-forming disturbances operating at the individual tree scale, to infrequent high intensity, forest- or landscape-scale events that can significantly alter entire stands of trees. The successional development of a stand is closely linked to the nature and intensity of the disturbance(s) affecting it. Forests do not follow some pre-ordained set of laws during development, thus the successional patterns and forest structures that result from disturbance are never entirely predictable. Once started, the development of a forest results from interactions among the different species present and, over time, exhibits some recognizable patterns or stages (after Oliver and Larson 1990) (Fig. 14):

1) STAND INITIATION: After a disturbance, new individuals and species continue to appear for some period of time, usually from a few years to several decades (depending on the type, size and intensity of disturbance).
2) STEM EXCLUSION: After several years, new individuals no longer appear and some of the existing ones die out. The surviving ones grow larger and express differences in height and diameter. In mixed-species stands, dominance can shift from one species to another over many years.
3) UNDERSTORY REINITIATION: After many decades, the process of competition has thinned out the forest canopy to the point where holes or gaps begin to appear. The openings allow light to reach the forest floor so herbs and shrubs can begin to grow again. Advance regeneration present in or near these openings now have the opportunity to release and move up into a higher canopy position.
4) OLDGROWTH: Much later on, overstory trees die in an irregular fashion and understory trees begin to grow up into the overstory. The length of time between stage 3 and 4 depends on the species growing in the forest and the ecosystem association. Oldgrowth forests typically have a very wide range of tree sizes and ages.

Disturbances of any type, size, or intensity can occur during any one of these stages, although some stages are more susceptible to certain kinds (e.g., spruce leader weevils only attack young to immature spruce). Disturbance to a forest stand, however, does not always "reset the clock." If a disturbance is large and intense, say a catastrophic wildfire, forest succession is typically reset to stage one (on burned-over sites only). If the disturbance, however, is smaller and of a lower intensity, forest succession is either held up (i.e., it stays in that stage for longer) or pushed back to an earlier stage.

As a forest ages, disturbances of many different types occur on a continual basis and the forest becomes a diverse mosaic of sizes, ages, structures, and species. Understanding stand dynamics, or the way in which the forest ecosystem moves through these successional stages, can help foresters to develop silvicultural systems that more closely approximate the natural development process. Because most silvicultural operations are tied to different stages of stand development, knowledge of these developmental patterns and their associated structural attributes (vertical as well as horizontal), can help



managers predict how different silvicultural systems will affect future growth and alter the development of a forest stand. Specific treatments can be designed, for example, that open up the canopy of a mature forest, thereby moving the stand more rapidly towards understory reinitiation and the subsequent development of "oldgrowth" characteristics.

Change is a constant in forests; individual forest ecosystems continually change, but some change faster or slower than others. In some old forests, especially in humid forests dominated by gap dynamics, the system can be characterized as a *"shifting mosaic-steady state"* (after Bormann & Likens 1979), with little evidence of change **at the landscape scale** for hundreds or even thousands of years (Lertzman and others 1996). Lertzman and colleagues now have data from coastal B.C., demonstrating that some such forests have gone for several thousand years between stand-destroying disturbances (see Section 3.1.1). Many of the remaining oldgrowth forests of the Central Coast, especially in the wetter parts of the plan area, appear to be in this shifting mosaic-steady state condition.

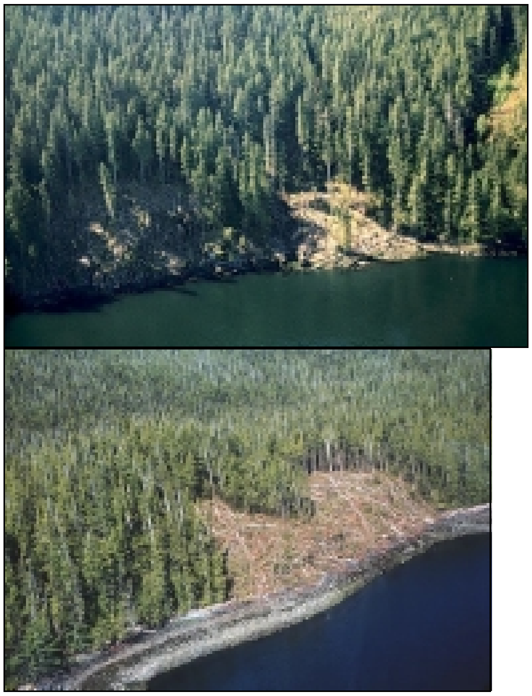
The clearcut silvicultural system has been dominant in B.C for the past 30-50 years, even in coastal landscapes where large-scale disturbances are very rare. As more emphasis is placed on alternative systems in order to meet broader management objectives, foresters need to understand and predict the prevalence and consequences of small-scale disturbance in coastal forest stands and landscapes.

4.2 What Are Silvicultural Systems?

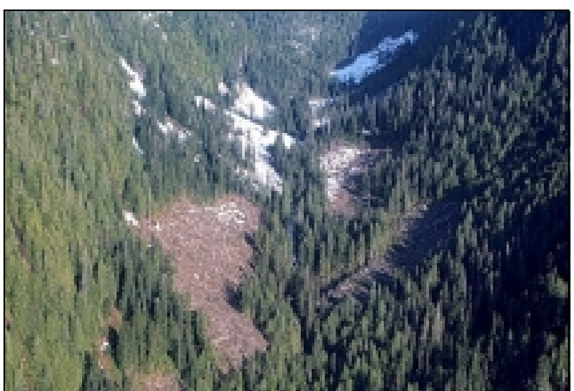
Historically, foresters have manipulated forest stands primarily by implementing one or more of the traditional silvicultural systems (Matthews 1989; Smith and others 1997; Table 6). They are generally viewed as resulting in the development of even-aged (clearcut, strip-cut, seed-tree, shelterwood, or coppice methods) or uneven-aged (group- or single-tree selection methods) forest stands. They were developed and have been applied in western and central Europe for several hundred years, and have been implemented in forested regions throughout the world. A silvicultural system, as opposed to a harvesting system, is considered a cycle of activities by which a forest stand is harvested, regenerated, and tended over time in order to meet stand or landscape management objectives. These traditional systems (Table 6) are thoroughly described in most silviculture texts (e.g., Matthews 1989; Smith and others 1997). Their names generally reflect the type of reproduction method employed and the extent of the original forest canopy structure remaining after the initial harvest. The shelterwood system, for example, leads to reproduction by maintaining partial cover or “shelter” of mature canopy trees after the initial harvest. Once the reproduction is established the shelterwood is generally removed so that the regenerated trees experience full open conditions, resulting in an even-aged stand.

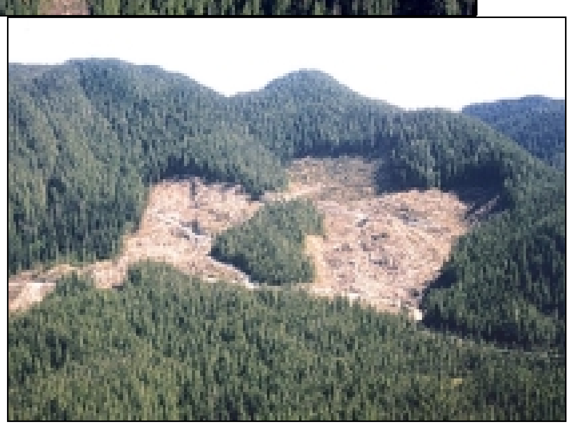
The traditional silvicultural systems were developed in Europe during the 1800s. European forests before that time had been overcut, overgrazed, and high-graded (Weetman 1996). Generally, the traditional systems were designed to meet productive and protective functions in these degraded forests. For example, single-tree selection was commonly used in steep mountainous areas with high avalanche risk. Today, the forests of Europe are largely man-made and are vastly different from the natural forests of the Central Coast. In British Columbia, the growing of timber has been the most common objective of forest management this century, resulting in the dominant use of a system that combined efficient harvesting with promotion of rapid growth rates for regenerating trees; i.e., even-aged management via clearcutting. It is worth mentioning that debate on the virtues of the different silvicultural systems for timber production (especially even-aged versus uneven-aged management), and the conditions under which they can be applied, has been ongoing and without any real resolution for decades (Jones 1945; Bradshaw 1992; Emmingham 1998). Current forest management issues in B.C. frequently centre more on social concerns than on timber production. We can use some of the non-clearcut systems to address such concerns, but our reasons for choosing these systems differ markedly from the rationale and objectives of the foresters who originally developed them. It is unrealistic to expect silvicultural systems designed for the forests of 19th century Europe to be appropriate for addressing the complex issues facing forest management today in British Columbia. As already mentioned, the vast majority of logging in the Central Coast has been via the clearcut (Fig. 15) silvicultural system. All mature trees are removed in one cutting entry, resulting in a single-aged (or single cohort) stand with minimal influence from the original canopy. The only significant exception to the dominance of clearcutting has been active handlogging (Figs. 16, 17) along the coastal fringes. Handlogging can be considered a mixture of single-tree or group selection and high-grading, and rarely extends beyond 100 m from the shoreline (see Section 5.5.2.3 for more on handlogging). Clearcut size and configuration have changed over the years with the most dramatic changes occurring after the Forest Practices Code came into effect (Figs. 18, 19). Since 1970, mean size--and the variance in size--of clearcuts (on **all** Crown-managed lands) declined from about 70 ha to about 40 ha in 1995. A 1998 review of forest development plans in the Chilliwack, South Island, and Campbell River forest districts indicated that average cutblock size in these coastal districts was about 24 ha. In the past few years, clearcutting with reserves (Figs. 20, 21, 22, 23) has become increasingly more common. In addition, a few examples (in oldgrowth) of strip-clearcutting (Fig. 24), group-selection (Fig. 25), and variable retention (not a traditional silvicultural system) have been tested or planned.

Figure 15. Clearcut logging near head of Owikeno Lake, 1978.



Figures 16 & 17. Handlogging, Fisher Channel (l) and east side Hunter Island (r).





Figures 18 & 19. Recent harvesting - clearcuts with reserves, Moses Inlet (l) and Yeo Island (r).

Figures 20 & 21. Recent harvesting in the Central Coast. Clearcut with reserves, north side Noeick River mouth (l); heli-logging, Disco Bluff, South Bentinck Arm (r).

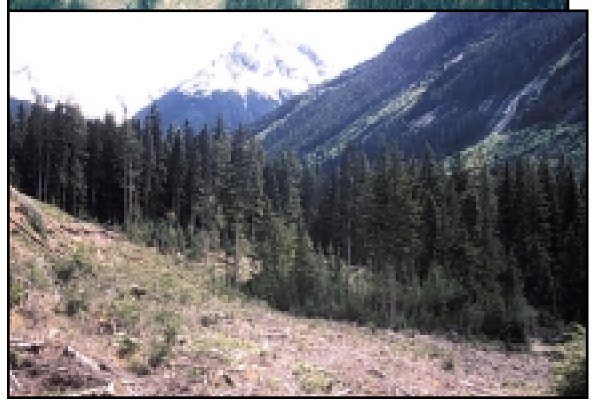


Figure 22 &23 Recent harvesting, clearcut with reserves, near mouth of Kimsquit River.

Figure 24. Strip clearcut, Nusatsum River.

Figure 25. Small-group selection, (0.2 ha opening), Talchako River.

The greatest strength of the traditional silvicultural systems is their immediate recognition by foresters and their long history of use. They served silviculturists well in the past, when the emphasis was on timber production, but lack the needed flexibility, imagination, and innovation that is required to manage forests today (Weetman 1996; Kohm and Franklin 1997). Traditional silviculture systems were also used to develop stand structure where none (as in afforestation) or very little existed. In coastal B.C., we are more typically trying to retain some of the existing stand structure (i.e., legacies), a goal not contemplated by the traditional systems. Traditional practices reflect neither broadened societal objectives for forests nor the scientific findings of the past thirty years (Franklin 1995). It is also our view that, in managing coastal oldgrowth forests (including those of the Central Coast), traditional silvicultural systems are potentially more of a hindrance than a benefit, primarily because their focus is too narrow. Traditional silvicultural systems were not developed to consider non-timber resource values, yet today are being applied for reasons other than timber production. Forest management today must be concerned as much with social issues and with maintenance of critical forest structure for wildlife habitat and ecosystem processes, as with timber production.

In B.C., traditional silvicultural systems have to date largely been applied as a prescribed program of treatments without sufficient thought and attention to stand structural goals. Furthermore, **both even-aged (e.g., clearcut system) and uneven-aged (e.g., single-tree selection system) management will result in structurally simple forests over time unless adjustments are made to meet stand structural goals.** For example, the Clayoquot Sound Scientific Panel Report 5 appears to invoke a rate of cut of 1% per year. Even if all harvesting is single-tree selection, in theory after 100 years you will end up with a forest in which no trees are older than 100 years---unless some trees or groups of trees are deliberately retained. For a discussion of the limitations of traditional silvicultural systems for meeting the diverse demands of current forests management, see Coates and Burton (1997).

More recently, foresters in B.C. are beginning to view silviculture treatments in terms of stand structural goals based on a broader spectrum of forest management objectives. Structural variability (e.g., several tree species, trees of varying size, retention of large trees, snags, and down logs) is desirable within stands after silvicultural manipulation in order to meet a host of forest management objectives. Methods for both describing and prescribing this within-stand variability are required and are often lacking in the application of the traditional silvicultural systems.

We think a better way to classify silvicultural, harvesting, or partial cutting systems is according to the distribution of canopy trees within a prescribed area after logging is completed. Stand structure then usually falls into one of two broad groups: 1) uniform or dispersed applications where inidvidual canopy trees are evenly or irregularly distributed (or absent) after logging; 2) patch or aggregate applications (Coates and Steventon 1994, 1995) where discrete openings are created in the tree canopy, or discrete groups of trees are retained in the opening. Both dispersed and patch applications can be found in the same management unit. Interestingly, when silvicultural systems are viewed this way, the distinction between even-aged and uneven-aged categories (so central to the traditional systems) becomes blurred, because the focus is now on desirable stand structure rather than the type of reproduction method.

Variable retention as articulated by the Clayoquot Sound Scientific Panel (CSSP 1995), and by J. Franklin and others for the coastal forests of Washington and Oregon (see Kohm and Franklin 1997), recommends application of both uniform (dispersed retention) and patch (aggregate retention) (Fig. 26) cutting methods. Recently, MacMillan Bloedel Ltd. has adopted a type of variable retention logging (see the MB web site: www.mbltd.com/enviro; choose Forest Project) that the company intends to employ on its management areas in the Central Coast. The primary intent of variable retention logging is to retain important "biological legacies" within managed stands to greatly improve the management unit's ability to sustain biological diversity and critical ecosystem processes. There is ongoing debate about the spatial and temporal extent of biological legacies, but less debate about the types of biological structures to be retained. The most critical structures or features appear to be large trees (often with a high level of decay), snags of varying size and decay class, downed logs, and multiple tree species. These features are often associated with the oldgrowth stage of forest succession.

Fig. 27 provides a qualitative ranking of the percentage of oldgrowth equivalency of the silvicultural systems, under the assumption that retention of large trees, snags, and down logs is prescribed in the systems that retain some of the original canopy cover. Remember that in traditional single-tree selection all snags, trees of poor form, and large trees would be removed over time to achieve a regulated stand structure of thrifty trees. The variable retention system can range from quite low (similar to the seed tree system) to very high oldgrowth equivalency.

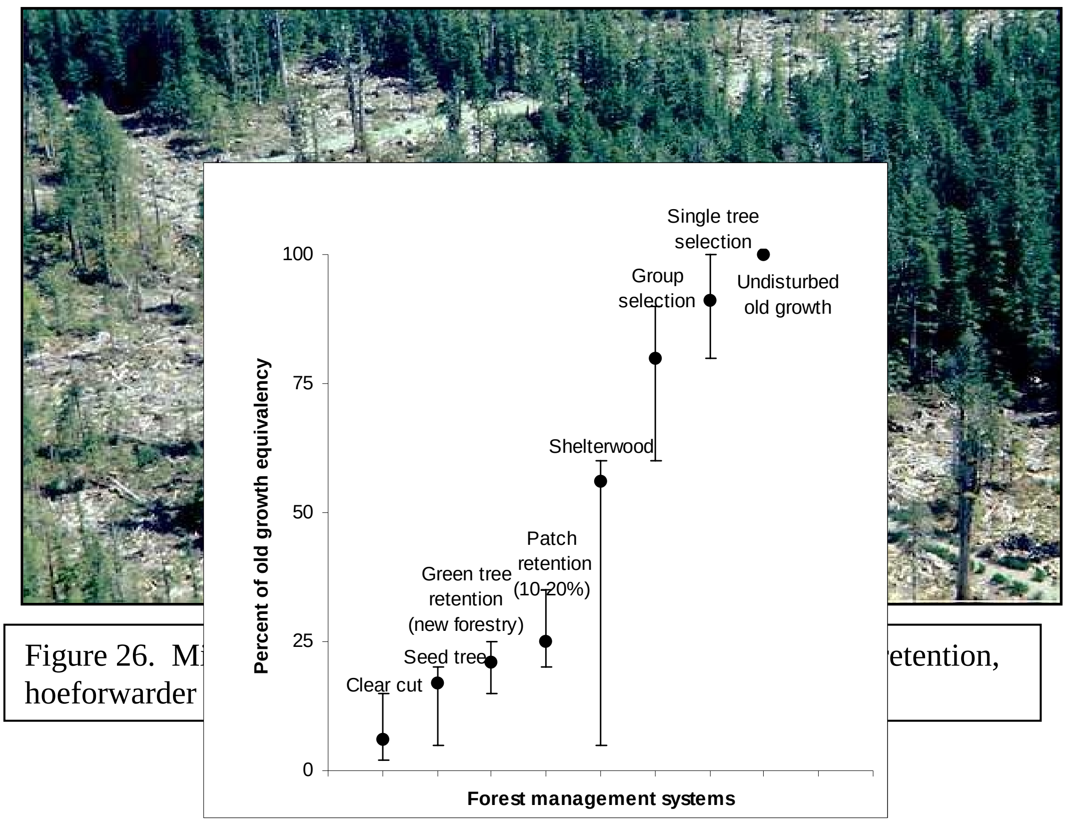


Figure 26. Mi… …etention, hoeforwarder …

Figure 27. Oldgrowth equivalency (%) of silvicultural systems.

4.3 Pros and Cons: Clearcutting vs. Partial Cutting

Clearcutting

1) Advantages:

- Simpler and more economically efficient, particularly for larger units. This includes block design, layout, harvest, site preparation, planting, and stand tending phases.
- Fewer roads and less physical area are required to access similar timber volumes than with partial cuts.
- Provides the most open and uniform light conditions, which is usually preferable for the growth of trees.
- Amount of edge can be reduced (i.e., one large block vs. several small ones).
- Safer operating environment for workers.
- Allows complete removal of diseased / infected trees (e.g., mistletoe, root rot).
- Provides an open environment; good habitat for those species that require or are strongly associated with open, early successional conditions.---which can be maintained for a considerable length of time when combined with cluster planting and density management.

2) Disadvantages:

- Rarely reflects or approximates natural disturbance agents in Hecate Lowland or Outer Coast Mountain forest types. Occasionally approximates natural disturbance in Inner Coast Mountains forest types, especially those at lower elevations.

- Typically retains no “biological legacies” of the original stand (i.e., large trees, snags, sub-canopy residuals, advance regeneration).
- Results in a simplified and more uniform new stand that reduces biological diversity in both the harvested area and across the landscape.
- Provides unsuitable or poor habitat for species that require or are strongly associated with oldgrowth forests.
- Usually requires the use of artificial regeneration for crop re-establishment, although this is less of a problem in the Central Coast than in many other regions of B.C.
- In areas with cold air drainage, frequent frosts, or very exposed to direct sunlight, harsh microclimates can develop within a block after clearcutting, resulting in poor growing conditions for regeneration (planted or natural).
- If extensive, creates large areas of “early seral” structural stages across the landscape. This results in greater risk of or susceptibility to outbreaks of pests and pathogens of regenerating and young forests.
- Potential for troublesome invasion of non-commercial brush species (very high on wet, rich sites of central coast).
- Typically has adverse impacts on non-timber resource values (i.e., water, fish, some wildlife species, aesthetic, recreational, etc.).

Partial Cutting (focus is on variable retention systems, rather than traditional ones)

1) Advantages:

- More closely approximates the natural disturbance patterns that prevail on the Central Coast.
- Less visually intrusive on the landscape and typically more acceptable to the public.
- More likely to maintain biological diversity, because a) retention of some canopy trees in the harvest unit allows maintenance of some remnants of oldgrowth structure (“biological legacies”); and b) there is potential for maintaining some functional aspects of the oldgrowth ecosystem.
- More suited to the use of natural regeneration, although planting can easily be done if desired.
- Allows for the retention of sub-canopy residual trees and/or advance regeneration.
- Can reduce the risk of severe brush competition problems.
- If there is >40% retention and it is uniformly distributed, reduces the need to consider Forest Practices Code adjacency requirements when locating harvest units.
- Reduced light levels and protective canopy cover can improve conditions for the establishment, early growth, and release of shade-tolerant species (e.g., western redcedar, western hemlock, subalpine and amabilis fir in the Central Coast).
- Allows a more flexible harvest pattern.

2) Disadvantages:

- More complex and costly to implement than clearcutting (includes block design, layout, harvest, site preparation, planting, and stand tending phases).
- Can require the purchase of new equipment for harvesting phase.

- Requires that more land be impacted to obtain similar timber volumes.
- Requires that more road be constructed (main and secondary) to obtain an equal volume of timber.
- May not allow for the full growth potential of regenerating trees, especially the more light-demanding species (i.e., Douglas-fir, Sitka spruce, lodgepole/shore pine, and red alder).
- Potentially more hazardous for forest workers.
- Current practical knowledge base and skill level are low for partial cutting systems.
- Potential for residual trees to promote or hasten the spread of diseases and insect pests.
- Potential for abuse of selective harvesting criteria leading to "high-grading" of stands.

4.4 Applicability to Central Coast of Different Silvicultural Systems

Social, economic, and ecological considerations combined with management objectives determine the applicability of a silvicultural system for any given forest stand or group of stands, and also determine the desirable mix of systems within a landscape unit. Where timber production is the primary objective, openings in the original canopy must be large enough to provide good growing conditions for regenerating trees. These openings will likely be at the upper range of natural variability (and larger) than the natural openings found after low intensity, small-scale disturbance that is so common in much of the Central Coast. Research on somewhat similar forests in the Hazelton area suggests that, for regenerating trees to grow at near their full potential growth rates, opening sizes need to be greater than 0.1 ha if the surrounding canopy trees are 30 m tall (Coates & Burton 1999 *in press*). For regenerating trees to grow at near their full potential growth rates in the taller coastal forests, opening sizes would have to be even larger---probably larger than 0.2 to 0.3 ha. This would preclude systems such as single-tree and group selection in timber production areas, because the opening sizes would exceed those typical of the systems (Table 6). It is important that we understand how increasing opening sizes to optimize tree growth or to log most efficiently, affects other organisms and ecosystem processes.

Conversely, where timber extraction is planned but the primary management objective is to retain mature or oldgrowth forest structure and function after tree harvest, a logical first step would be to create opening sizes that fall within the range found in natural, older forests. We would then need to determine what density or frequency of these openings to establish within a harvest unit. The gap processes so common in coastal forests can be retained through single-tree or small-group selection, but the ability to regenerate certain tree species could be compromised along with tree growth rates. Because natural openings do not necessarily allow new seedlings to grow at economically acceptable rates, we must also consider how "open" we can make a stand and still maintain some oldgrowth structure and function. There is no set number for this amount, so a cautious approach is usually recommended, starting with lower levels of removal and moving upwards.

The suitability of a system will vary over different spatial scales and time periods. Prior practices in the management unit (i.e., landscape) also affect choice of a current silvicultural system. This makes it almost impossible to judge that any given system is right or wrong for any given site until the site is placed in the context of a stand, landscape, or multiple landscapes. It is reasonable to expect differences in the extent of the different silvicultural systems among landscape units, for example, based on visual quality objective (VQO) or biodiversity emphasis options. These sorts of zoning decisions are beyond our terms of reference.

Another complicating issue for assessing the applicability of silvicultural systems in the Central Coast, as elsewhere in B.C. and Canada, is our society's ongoing struggle with the strategic direction of forest management. Broadly speaking there are two basic possibilities.

1) A model similar to that in New Zealand - a set of protected areas (some fixed percentage of the land area) and intensive industrial management on the rest of the forested landbase. In the context of the Central Coast, if large areas are protected then emphasis on retaining important forest structure for habitat and/or ecological processes can be lower in harvested stands.

2) The second model attempts to maintain healthy forest function or ecological integrity in the managed landscape. In this model, current ecological thinking would suggest foresters use natural forest dynamics as a guideline for developing silvicultural systems (e.g., Bergeron and Harvey 1997). Some variable retention logging is based, at least in part, on this principle.

Current forest management in the Central Coast (and most of the rest of B.C.) is somewhere in between these two approaches. Opinion varies widely on which of the two models might be the best approach for forest management.

Table 6. Traditional silvicultural systems (modified after Smith 1986; Matthews 1989; Klinka and others 1990)

System	Description	Microclimatic criteria	Typical area of canopy openings (ha)
CLEARCUT	removes part or all of a stand, or several stands in one cut	open conditions dominate over canopy effects	>0.5 or >1.0 (depending on canopy tree height) to >100 ha
SEED-TREE	retains a small number of well spaced seed-producing trees (15-50/ha) on a cleared area for a short time	open conditions dominate over canopy effects	>0.5 to >1.0 after seed-tree removal
SHELTERWOOD	system of successive regeneration fellings that retains a forest cover over all or part of the stand until regeneration phase completed	protective cover during regeneration phase	see below
UNIFORM	opening of canopy even; young trees more or less even-aged	protective cover during a brief regeneration period, then full open conditions	<0.01 to 0.1
GROUP	opening of canopy by scattered gaps; young trees more or less even-aged	gaps expanded successively to full open conditions over 20-40 years	<0.01 to 0.1 initially; enlarged over time
IRREGULAR	opening of canopy irregular and gradual; young trees more or less uneven-aged	canopy openings expanded successively over more than 50 years; some mature trees may be retained at all times	<0.01 to 0.1 initially; enlarged over time
STRIP OR WEDGE	opening of canopy in well-defined strips or wedges; regeneration even-aged in advancing strips or expanding wedges	some canopy shading during regeneration, then full open conditions	depends on length of strip or wedge and canopy tree height; typically <2 times stand height
SELECTION	forest canopy is more or less retained over all of the stand area	canopy effects dominate over open conditions	
SINGLE-TREE	trees removed individually across entire stand	continuous forest cover	<0.01
GROUP	trees periodically removed in small groups	continuous forest cover	0.01 to 0.1
COPPICE	trees originating by vegetative means	open conditions dominate over canopy effects	

Binkley (1997) and Bunnell and others (1998) have articulated option 1, which could also be called the UBC option.

- "…other than abundant arboreal lichens, features of late-succcesional stands can be created at much younger ages through modified silviculture."
- "Zoning helps to maintain all values."
- "We can do better sustaining biological diversity and contributing to social infrastructure by aggregating forest practices into zones of very different intensity."
- "Species are a surrogate for biological diversity. Vertebrates are useful indicators of species diversity. There also are compelling ecological reasons for selecting terrestrial vertebrates as a surrogate for biological diversity."

Carey (1998) has recently outlined the markedly contrasting vision of option 2.

- "Old growth is a unique, irreplaceable, perishable resource."
- "Management of existing landscapes, future landscapes, and second-growth forests offers many opportunities to conserve biodiversity in its broadest sense."
- "Active management holds more promise than apportioning the region into biodiversity reserves, matrix lands managed under new forestry principles, and timber production lands managed by agroforestry."
- "There are too many taxa potentially sensitive to forest management for species-based monitoring."

With respect to oldgrowth, there actually is more concordance of opinion among biologists than indicated by these quotes. Bunnell and others (1998) go on to say that "There have been a variety of attempts to hasten the production of old-growth attributes in managed stands; most of them focused on the requirements of single species. When multiple species are considered it remains untested whether a combination of stand treatments is economically more efficient than simply maintaining old growth." Both views of the forest also recognize the need to maintain areas of oldgrowth. Bunnell and others (1998) recommend "expanding the contiguous extent of late-successional conditions" and restoring late-successional conditions to some areas previously logged.

Furthermore, both camps come to similar conclusions regarding management. "No single approach is sufficient. The worst possible approach to maintain vertebrate diversity would be to manage every hectare the same way" (Bunnell and others (1998). "No single silvicultural system is appropriate for all lands; …there are various pathways to achieving any set of objectives; cultural fit should be used as one criterion for selecting the pathway to be implemented" (Carey 1998).

"All very well", you might say, "but quit beating around the bush. Which silvicultural systems are applicable and appropriate in the Central Coast?" Our response: Virtually any of them (except coppicing) could be applied in these forests. The operational capability exists. For any given stand, there is no compelling ecological reason to forego any system, but in general in wet coastal forests, the smaller the opening (or the greater the retention) the more ecologically appropriate the logging. But not everywhere. Depending on the site and the stand, there can be serious silvicultural and compelling economic constraints. Worker safety will always be an issue. The seed-tree system isn't really appropriate except perhaps in some Douglas-fir stands on drier sites.

As mentioned above, openings should be larger (at least 0.2-0.3 hectares) in areas where the primary objective is production of timber; this would preclude single-tree and small-group selection systems. Conversely if the objective was to largely retain oldgrowth structure and function while still removing some trees, then selection systems would be most appropriate. Variable retention could be applied almost anywhere, and in some forest types (especially “decadent hembal”) probably represents the most appropriate combination of ecological, silvicultural, economic, and safety considerations. And remember that we prefer not to get caught up in the terminology and criteria of traditional silvicultural systems. Let’s just say that some form of partial cutting could be done almost anywhere in the Central Coast. Where and how it is done, the size and shape of openings, the relative proportions of partial cutting and clearcutting, the mix of systems, the distribution of openings on the landscape---all these depend on ecological, economic, and social considerations combined with management objectives.

To summarize, the following points should be kept in mind when defining, evaluating, or selecting a silvicultural system.

- Management objectives and operational constraints, framed within the context of sustainability (in its ecological, economic, and social dimensions), must be identified and clearly articulated prior to deciding on the appropriate system.
- It is not reasonable to expect all forests to persist in late successional or oldgrowth stages, but it is also unwise to convert all forests to early successional (stand initiation and stem exclusion) stages.
- Do not rely **only** on natural disturbance type to determine gap or opening size when logging; conditions specific to the site and stand, landscape context, and management objectives must also be considered.
- Traditional silvicultural systems focus on the regeneration method, but we are more concerned with forest structure, with why, how, where, when, and how much oldgrowth forest or structural features of late-successional forest we need to retain, to address the complex issue of sustainability.
- Broadcast application of the traditional silvicultural systems (any of them) will eventually simplify all managed forests.
- In general, retention (non-traditional) silvicultural systems appear to be more capable of addressing economic and operational issues without “over-simplifying” future forests, thus have a better chance of helping to achieve sustainable forest management.

5.0 HARVESTING SYSTEMS AND METHODS (see also MacDonald 1999 for descriptions with lots of pictures)

Harvesting is a log production process that can be viewed as the manufacture of standing trees into logs and the associated transport of those logs to point of use. The term harvesting system refers to the specific phase involved in the log production process. These systems include falling and bucking, yarding, loading, hauling, dump, sort and boom and final transport to point of use or sale. Harvesting method refers to the mix of these systems used in a given operation; i.e., the combination of harvesting systems employed to transport logs from tree to point of use.

Over the years, there have been many different and often integrated harvest methods used in coastal operations; e.g., multiple yarding swings, skidding swings, railway transport, A-frame and handlog to tidewater, truck logging, helicopter logging, and cut to length. Currently, the most common harvest method in coastal British Columbia is truck logging---a primary transport system that moves logs from stump to roadside, then transports logs to a dump site on log trucks travelling a series of haul roads. While helicopter logging is becoming more popular on the Coast, it is often used as a primary transport system (yarding phase) as part of the truck logging method.

5.1 Harvest Systems Common in Coastal BC

5.1.1 Falling and bucking

Falling-and-bucking refers to the manufacture of a standing tree into merchantable logs. This system is either hand falling or mechanized (e.g., feller-bunchers). Mechanized falling is limited by tree diameter and ground slope and terrain. Because of the wide variation in tree size, and the topography and terrain associated with coastal oldgrowth sites, most mechanized falling on the coast is done in second-growth stands. Only hand falling will be considered in this report.

5.1.2 Yarding

Yarding is the primary transport of logs from the stump to the landing where they can be loaded onto a truck. The yarding system often more closely defines the harvest system. The most common yarding systems used in coastal BC operations are ground based, cable, and aerial.

5.1.2.1 Ground based

Hoeforwarder

Based on hydraulic loader configuration, a machine lifts logs free of the ground and swings them toward the road in successive passes.

- Ability to travel off-road over moderate terrain.
- Moderate sensitivity to terrain and soil conditions and yarding distance.
- High sensitivity to extreme slopes, volume per hectare, and log piece size.
- Virtually insensitive to weather (short of deep snow accumulations) unless soil conditions exceed some threshold level.
- Relatively high capital cost but low operating cost.
- Provides high flexibility; can use as loader, to build backspar trails, to assist directional falling and poor-deflection cable yarding operations, and to carry out site preparation and remedial treatments.
- Can be used in partial cut applications where residual tree density and distribution are low enough (roughly 30-40 stems per hectare) to allow unimpeded swing; otherwise, need to modify method to hoe-slide logs parallel to yarding direction, which reduces productivity.
- Can be used in combination with cable methods to swing logs into yarding corridors, from group selection areas or around retained patches.
- Other than need to establish yarding and swing pattern ahead of time, system is “low tech”, not requiring much yarding experience---but it does require competent operation of equipment.

5.1.2.2 Cable

High lead

Cable yarding uses a fixed tower and manually set chokers to lift one end of a log clear of the ground as it is pulled to the yarder.

- Most efficient yarding uphill.
- Extremely sensitive to available topographic deflection, yarding distance, and landing size and location.
- Moderately sensitive to volume per hectare and piece size.
- Relatively insensitive to weather, short of snow accumulations.
- Because there are many high lead machines available, owning costs are relatively low but operating costs are high, due to large crew complement and low productivity.
- Often difficult to establish landings of sufficient size to accommodate production, so need to "marry" loader to operation to keep landing clear for production and worker safety concerns.
- Because of worker safety issues, not suitable in steep downhill configuration, where there is risk of runaway log striking landing area. Also not suitable in extreme-slope uphill yarding configuration, where rigging crew at risk of being struck by runaway log from yarding or landing operation.
- System is "low tech" not requiring much cable-rigging experience.
- Must string new roads to work around retained trees or patches instead of simply moving among existing yarding roads.

Grapple yarding

The grapple yarder is a carriage-mounted swing yarder that mechanically opens and closes a grapple, used to yard logs to the roadside while rigged in running skyline configuration.

- Ability to swing logs on to road and "walk" along the road eliminates need to construct landing.
- Highly mobile, resulting in high productivity.
- Sensitive to deflection, line of sight, piece size, and yarding distance.
- Operator must be able to see logs to reach maximum productivity.
- Small crew size.
- Doesn't require loader to clear a landing.
- High mobility allows for offset downhill yarding on steep ground.
- Where visibility can be maintained, no restriction on uphill steep-slope yarding.
- Normally requires mobile backspar to maintain sufficient back end lift. Mobile backspar allows seamless yarding road changes.
- Can be double-shifted when fitted with lights.
- Fewer rigging crewmembers required; reduced exposure to yarding cables, which reduces worker safety concerns.
- Flexible system capable of rigging as running skyline with chokers or as slack pulling

carriage.

- Yarding distance constraints increase road density.
- Running skyline configuration of rigging is well suited to yarding corridors and to lateral yarding required in partial cutting operations.
- Mobility while rigged and their ability to utilize chokers or carriage, to yard with 1-2 guylines, to swing and maneuver logs to roadside, make them ideal for the tight spaces and flexibility needed in partial cutting operations.
- Relatively low productivity in partial cutting applications because extra time needed to address worker safety and residual tree damage, and time needed to string new yarding roads.
- High owning cost but relatively low operating cost.
- High availability.

Skyline

A cable method capable of providing vertical lift with a carriage suspended from a skyline cable.

- Provides for greater yarding distance, higher turn speeds, and less soil disturbance and log breakage.
- Multiple configurations, include standing, live (shotgun, slackline), and running (grapple yarder, scab line), capable of providing lift in a variety of topographic and terrain conditions.
- Extremely sensitive to topographic deflection and volume per hectare; i.e., yarding road set-ups and changes time-consuming and costly, therefore volume must be sufficient to offset these costs.
- Requires large landings.
- Requires substantial number of extremely strong anchors.
- Requires high level of skill in rigging, anchoring and splicing.
- Requires large machines and large crews, resulting in high owning and very high operating costs.
- Requires fewer roads.
- Much planning and operating skill required to maintain productivity and ensure worker safety.
- Can be used to reduce road density and cost and can be used to access otherwise inaccessible timber.
- Capable of operating in partial cutting operations, but reduced volume recovery and increase rigging time (to string new yarding roads) will sharply reduce productivity and increase operating costs.

Supersnorkel

The supersnorkel is a cable loader adapted with boom extensions and with a larger drum capacity, brakes and guylines, so that it can cast the loading grapple---allowing for short-distance yarding. This system is normally used as part of an integrated system involving other ground-based or cable systems. It has no practical application in partial cutting operations.

A-frame and handlogging

These are very simple cable yarding systems similar to highlead except that the yarding winch is fixed to a barge or boat. While largely a system of the past, a minor component of A-framing (Fig. 28) and handlogging operations still occurs in the Central Coast.

Figure 28. A-frame logging, Spiller Channel.

5.1.2.3 Aerial

Helicopter

Specialized, large-lift capacity helicopters transport logs either to roadside or tidewater (cutting out loading and truck hauling phases), depending on location. With greater concern for the impact of roads and the need to access trees not accessible by haul roads, helicopter logging has become more popular in recent years.

5.2 Operating Conditions Affecting Choice of Harvest System

The Central Coast has distinctive physical and economic characteristics that exert a major influence on the choice of harvest systems. Influential features include:

- remoteness from major communities and sparse population (55-95% of work force resides outside Central Coast);
- harvesting areas disconnected from camp facilities due to terrain and topography;
- majority of remaining mature forest has relatively low timber volumes; growing sites classified as “poor” and “low” (areas with poor drainage, high elevation forest, or steep terrain with thin soils);
- western hemlock/amabilis fir (“hemlock/balsam”) stands make up a large proportion of that remaining mature forest;
- relatively small operable landbase;

- relatively large inventory of oldgrowth timber (close to $^{2}/_{3}$ of Central Coast covered by forest older than 240 years);
- relatively short season available to complete logging operations (April through October);
- lack of roads and other infrastructure necessary for truck logging operations;
- virtually no fee simple lands available to buffer changing market conditions;
- lack of local processing facilities (roughly 95% of timber harvested in Central Coast is shipped to southwestern B.C.)

5.2.1 Comparison of operating conditions

5.2.1.1 Methods

This report attempts to compare operating conditions prevalent in the Central Coast to those found in similar or comparable ecosystems elsewhere in coastal B.C. Predominant forest ecosystems in the Central Coast are those of the Coastal Western Hemlock (Very Wet Maritime and Very Wet Hypermaritime) and Mountain Hemlock (Moist Maritime) subzones. These subzones are common on northern and western Vancouver Island (represented by the area northwest of Kelsey Bay and northwest of Jordan River). The same subzones also encompass the coastal forests north of the Central Coast planning area. The Coastal Western Hemlock, very wet hypermaritime subzone also occurs on the west coast of the Queen Charlotte Islands. We decided to compare the Central Coast to operating areas on northern and western Vancouver Island for the following reasons:

- forest types, terrain, and topographic conditions are somewhat similar
- operational and economic data are readily available
- Vancouver Island has probably the largest extent and variety of partial cutting applications in coastal oldgrowth
- Vancouver Island has the most, operational and economic information about partial cutting in coastal oldgrowth
- most of the alternative silviculture system applications of interest to the Central Coast planning table, occur on Vancouver Island.

We will refer, in the remainder of this report, to the comparison operating areas on northern and western Vancouver Island as the Vancouver Island operating or study area.

In order to compare both physical and economic operating conditions, representative cutting permits were sampled from both the Central Coast and Vancouver Island study areas. The sample cutting permits were selected from Forest License and Tree Farm License holders in proportion to their respective allowable annual cut allocations. Only major licensee's cutting permits were selected. Information from these cutting permits was collected, compiled, and analyzed. Information from field reviews and interviews with local licensee and Ministry of Forests staff was also used in the comparison.

5.2.1.2 Results

Table 7 compares operating conditions between the Central Coast and Vancouver Island study areas. With the exception of average slope, figures expressed as percents represent the percentage of total cutting authority volume for each study area. As an example, in the Central Coast study area, 86% of total volume sampled in this study requires barging to point of appraisal. We remind the reader that these results are based on a sample of cutting permit data and could deviate somewhat from the results of the broader TSA review (used for the timber resource comparison in section 2.5).

Table 7. Comparison of operating conditions.

Factor	Central Coast	Vancouver Island	Variance
Average cutblock size	18.5 ha/cutblock	22.4 ha/cutblock	17.4%
Average volume of merchantable timber	691 m^3/ha.	848 m^3/ha.	18.5%
Average slope	48%	47%	2.0%
Heli-log volume	19.1%	11.0%	8.1%
Average haul distance	15.2 km	28.4 km	46.5%
Average one-way woods run	15.7 km	27.1 km	42.1%
Isolated cutting authority	100%	20.4%	79.6%
Accommodation provided	96%	8.3%	87.7%
Timber development (m^3/km road constructed)	7,703 m^3/km	12,197 m^3/km	36.8%
Hard rock road construction	91%	19%	72%
Barge to point of appraisal	86%	51%	35%
Tow to point of appraisal	14%	46%	32%
Truck to point of appraisal	0%	3%	3%
Road use charge	0%	3%	3%
Blowdown volume	1.2%	0.6%	0.6%
Partial cut volume	0.1%	1.7%	1.6%
Skyline	2%	2%	0%
Tree crown modification	0%	9%	9%
Lake transportation	29%	0%	29%
Towing to tie-up grounds	47%	1%	46%

Merchantable timber volume

One of the most notable differences is the merchantable timber volume per hectare available for harvest. Merchantable volume per hectare of timber harvested in the Central Coast is 18.5% less than in the Vancouver Island operating area. It appears that recoverable volumes are significantly less in the Central Coast because the predominantly old forests have a high incidence of decay, especially in stands dominated by western hemlock and amabilis fir ("hemlock-balsam" or "hembal" types).

The problem is that there is almost no visible means of detecting these diseased trees without falling and bucking. Pulp content can be up to 60% in badly affected stands. These 'decadent' hemlock-amabilis fir stands have higher logging costs and lower timber values. According to licensee staff interviewed, relative logging costs are high due to reduced wood production (high waste and decay factors) and increased site preparation costs. Correspondingly, log net values are very low in these stands. Local experience indicates that the only economically viable means of harvesting these stands is through use of hoeforwarding technology during periods of high log-market value. But in such terrain and topography there are relatively few sites suitable for this harvest system.

The other issue that will affect merchantable timber volume in the future is the expected shift in timber production from the Inner and Outer Coast Mountains to the Hecate Lowland. Harvest experience over the last five years indicates that a larger portion of this area is economically viable, but in general stand volume and value are lower in the Hecate Lowland than in the Inner and Outer Coast Mountains.

Timber development

In the Inner and Outer Coast Mountains, many drainages are narrow valleys rising within short distances to very steep slopes, and therefore have greater potential for constraints to access development. Most timber values are located in a long linear pattern along either side of a valley bottom river, and only one or two road development headings are available at any given time. As development progresses further up these valleys, timber values decline significantly and become patchy or isolated among old slide and avalanche tracks or bottomland wetlands and glacier forelands. Although the pattern is more random in the Hecate Lowland, merchantable timber is often located in isolated patches among rock outcrops on slopes or between large tracts of peatlands. While topography is not as limiting to number of development headings, the amount of costly “dead” road required to access merchantable timber is significant. These constraints, combined with lower volumes of merchantable timber, result in a Central Coast operating condition whereby significantly more roads than on Vancouver Island must be developed in order to access an equivalent volume of timber.

Helicopter logging

Although gaining wider acceptance throughout coastal B.C., helicopter logging is far more popular in the Central Coast than on Vancouver Island. Higher road costs associated with significantly more "hard" rock construction (see *TRUCK LOGGER* 1999: 22 (2)), smaller cutblock size, lower merchantable timber volume, proximity of timber to tidal waters, and isolated timber patches appear to be favouring use of this harvest system. The 1999 Mid-Coast Timber Supply Review interprets recent harvesting performance as warranting inclusion of some areas with lower timber quality and/or difficult harvest conditions into the timber harvesting landbase. This would substantially increase the proportion of helicopter logging in the Central Coast.

Windthrow

In terms of operating costs or timber revenue, analysis of cutting permit information did not indicate windthrow was a major factor in either study area. Nevertheless, interviews and field review confirmed that windthrow is a significant concern, both on Vancouver Island and on the Central Coast. Windthrow damage can often look much worse than it is in terms of area covered or volume of damaged timber. Nevertheless windthrow can disrupt or thwart management objectives for non-timber resources (riparian reserve zones, viewscapes) and for forest protection (insect pests and occasionally fire). Edge feathering and crown modification of residual trees is being used to reduce windthrow damage around and in cutblocks. But treatments are costly and have not been effective in all cases. For these reasons, windthrow management is a significant issue affecting choice of silvicultural and harvesting systems.

Terrain stability and site productivity

The Inner (especially) and Outer Coast Mountains, compared to the Hecate Lowland, generally have a higher proportion of dry, colluvial sites with thin soils over large boulders or bedrock. Harvesting operations must yard over or around these obstacles and features to protect the productivity of sensitive sites, and this reduces harvesting productivity and increases cost.

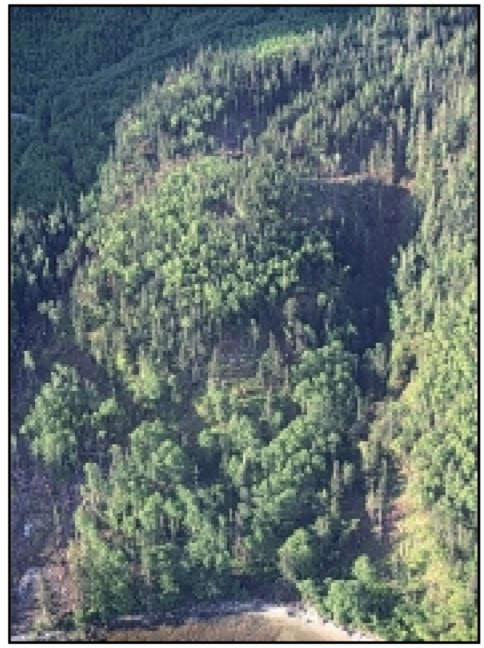
In the Hecate Lowland, a high component of organic soils over bedrock or hardpan creates significantly higher than normal terrain stability hazard, resulting in higher development costs; i.e., costly sub-grade end-hauling, slower development, and higher rate of timber deferral. Organic soils also restrict the use (site degradation could result from unrestricted use) and reduce the productivity of ground-based harvest methods.

Aesthetics

The Central Coast has a spectacular and remarkably extensive coastline, with many fiords, inlets, passes, and protected anchorages. The wealth of shoreline forest creates opportunities for handlogging or A-frame logging. But the high visual resource and recreational values associated with the Inside Passage cruise ship industry and pleasure craft generally, restrict the amount and type of harvesting. According to feedback from Ministry of Forests' staff and Small Business Enterprise Program registrants, it is not economically viable to harvest these shoreline areas using conventionally accepted silvicultural systems. Ministry of Forests' staff indicate that timber sales requiring either selection or clearcut silvicultural systems on such sites have, at times, failed to attract bids. Nevertheless, there continues to be a demand for handlogging sales, and it appears that unconventional silvicultural systems (i.e., some form of partial cutting/patch retention with the flexibility to target higher value trees) could be successful.

5.3 Current Partial Cutting Use - Central Coast

As indicated in Table 7, currently there is very little partial cutting of oldgrowth in the Central Coast study area. The most common alternative silviculture system being used is "clearcut with reserves", meant to address wildlife and biodiversity issues or visual quality objectives. A limited amount of edge feathering within one tree length of a cutblock edge is also being done to reduce windthrow damage. A very limited amount of strip cutting has been used in Inner Coast Mountains transition areas to protect regeneration. Diameter-limit cuttings have been used in shoreline A-frame and handlog operations. Recently there have been several partial cutting operations in second-growth forests in the Inner Coast Mountains (Figs. 29, 30, 31). MacMillan Bloedel plans to implement the variable retention system in the near future, in the Outer Coast Mountains.



Figures 29 & 30. Partial cutting in second-growth forests, Bella Coola valley, near Hagensborg (l); Windy Bay (r).

Figure 31. Diameter limit partial cutting, lower Saloomt River.

5.4 Current Partial Cutting Use - Vancouver Island

In relative terms, there is significantly more partial cutting being done in Vancouver Island operations, but it is not significant in terms of the total volume or area currently being harvested.. The implication is that, in general terms, there is not at present a great deal of documented operational experience in partial cutting of oldgrowth that can be applied to Central Coast operations at this time. Despite this lack of partial cutting experience, the industry trend is to look for economic means of partial cutting to meet silvicultural, biological and market objectives, a trend that has resulted in a number of documented operational trials of partial cutting.

5.4.1 Chamiss Bay

In 1995/96, International Forest Products Limited (Interfor) and the Forest Engineering Research Institute of Canada (FERIC) conducted a study of various intensities of uniform retention, plus two strip cuts and one clearcut on the northwest coast of Vancouver Island. Uniform retention levels ranged from 55% to 70% on steeply sloping ground. The operation was carried out by a grapple yarder and a mini-tower, both rigged with mechanical slack pulling carriages. While the operation successfully achieved management objectives, it has not since been repeated under similar conditions. Licensee staff involved in this project conclude that this type of operation would be better completed using grapple helicopter logging, to address worker safety issues.

5.4.2 Clayoquot Sound

Based on recommendations from the Clayoquot Sound Scientific Panel report, International Forest Products Limited has implemented a series of six cutblocks within Clayoquot Sound. Operational and economic data have been collected and summarized for these blocks. The emphasis was on variable retention silviculture systems, so in most cases these cutblocks have a combination of treatments including clearcut, clearcut with reserves, patch cuts, single tree retention, strip cuts, and group selection (Figs. 32 & 33). Harvest method included hoeforwarding, grapple yarding, tower, and helicopter.

Interfor found that, compared to conventional clearcutting, planning and layout for variable retention were more complex and time consuming, faller productivity was lower (particularly in compartments with >30% retention levels), and yarding productivity was lower. Given the worker safety and operational issues indicated above, staff would prefer to utilize grapple helicopter in place of cable yarding in operations with moderate to heavy retention. *Note: at time of field review, operations remain incomplete in one of these cutblocks due to poor log-market conditions.*

5.4.3 Kennedy Flats (Lost Shoe Creek)

While helicopter and cable yarding systems are highly vulnerable to log market conditions, Interfor successfully implemented variable retention on a flat, low elevation, redcedar-dominated site using the hoeforwarding harvesting system. The treatment consisted of 30% and 40% uniform retention, representative of the original stand but targeting removal of mistletoe-infected hemlock trees (Fig. 33). While hoeforwarding costs were estimated to be 20% higher than normally realized in clearcutting operations, this was not considered significant in terms of total log cost.

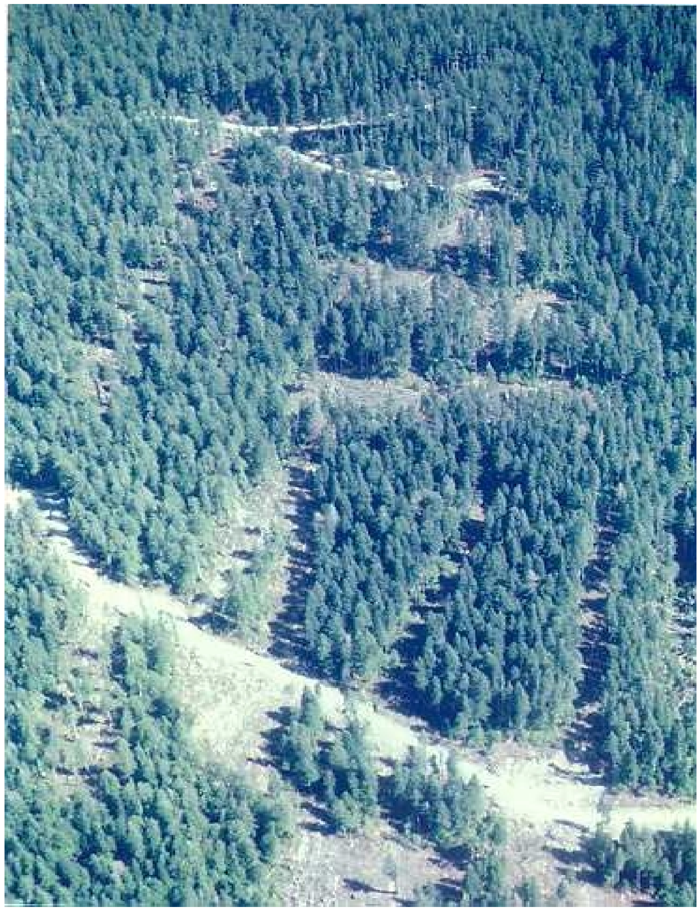


Figure 32. Strip cuts (upslope from road), uniform retention (left-most upslope cut), and 'wiener' patch cuts (across slope). Interfor Block R20, Rolling Stone Creek, Clayoquot Sound.

5.4.4 Retention systems

With the introduction of "retention system" as a defined silvicultural system in the Forest Practices Code Act of B.C., there has been a concerted effort to implement retention since 1998. As defined, a retention system is a silviculture system designed to retain individual trees or groups of trees to maintain structural diversity over the area of the cut block for at least one rotation, and to leave more than half the total area of the cut block within one tree height from the base of a tree or group of trees, whether or not the tree or group of trees is inside the cutblock. MacMillan Bloedel Limited (MB) has committed to phasing out clearcutting largely through the use of this "new" silviculture system. TimberWest Forest Limited and International Forest Products Limited have also committed to eliminate or reduce use of clearcutting largely through use of the retention system. Because MB and Interfor harvest a significant portion of the allowable annual cut in the Central Coast, it is expected that a marked reduction in clearcutting will occur if and when these licensees reach their stated targets.

Figure 33. Uniform 40% retention, hoeforwarder harvesting. Interfor Block LS10, Kennedy Flats, Clayoquot Sound.

In ecosystems somewhat comparable to those of interest in the Central Coast, MB staff are using patch retention or group selection methods. Uniform retention is not being used to any extent because of concerns for worker safety, productivity and residual tree damage (both operational and windthrow). To date, MB has retained 19% of the original stand, on average. Based on field reviews and staff interviews, it appears that MB is, for the most part, using current equipment to achieve the objectives of the retention system. Hoeforwarding has been used to complete logging over a reasonably wide range of retention levels, as well as in strip cuttings. Hoeforwarding is usually restricted to gentle or moderate slopes of $\leq$ 30%. Grapple yarding has been used to implement patch retention at lower retention levels, for strip cuts, and for areas with low levels of dispersed retention. Grapple helicopter systems are increasingly being used to implement patch or dispersed retention at virtually any retention level desired. In addition, special tree preparation and falling techniques and specialized grapple helicopter operations can do single-tree selection for high value timber (e.g., redcedar poles). Because of cost and worker safety issues, large skyline harvest systems have not been used as often.

TimberWest Forest Limited has initially implemented retention systems on low slope, second-growth stands on southeastern Vancouver Island. Operations using hoeforwarding successfully achieved high levels of uniform retention (estimated $\geq$ 40%). TimberWest has also utilized what is referred to as "corridor" logging to grapple-yard around retention patches left to meet visual quality objectives on central Vancouver Island. Access corridors are carefully engineered to allow logging crews to log around or through retention patches with minimal negative effect on productivity or cost.

5.5 Applicability of Partial Cutting in the Central Coast

Compared to clearcutting, partial cutting creates an additional operational dilemma in terms of protecting residual trees. Therefore, conventional clearcut silvicultural systems must be adapted to successfully meet management objectives. Adaptations being used can be grouped into planning, practices, and equipment. Of the partial cutting systems successfully being used elsewhere on the B.C. coast, there is no apparent **operational** (as opposed to economic) reason why they could not be successfully implemented in the Central Coast. With the relatively minor shift to partial cutting operations to date, there has not been a significant need to change the complement of harvesting equipment beyond the re-introduction of slack-pulling carriages and the development of more powerful and efficient helicopter grapples.

5.5.1 Planning

5.5.1.1 Land use planning

Implementation of land use planning can have a significant effect on the operational (timber availability) and economic (net revenue) viability of partial cutting in the Central Coast. Depending on the designation, distribution, and objectives of resource management zones, short- and long-term timber availability and logging costs can be either positively or negatively affected. In 1999, the Ministry of Forests commissioned a report assessing short-term timber supply and economic impacts of applying resource management zone designations, as specified by the Vancouver Island Land Use Plan (VILUP). This plan designated three resource management zones: “general management,” “enhanced forestry,” and “special management.” To guide forest development, each of these zones have specific management objectives; for example, regarding maximum cutblock size, cutblock adjacency, green-up, and retention level requirements. General management zones embody development objectives roughly equivalent to current Forest Practices Code requirements. Enhanced forestry zones have a higher emphasis on timber production and therefore have less constraining objectives, while special management zones have a higher emphasis on other resource values and therefore have more prescriptive objectives. In particular, clearcutting in special management zones is restricted to cutblocks less than 5 ha in size; larger cutblocks require partial cutting.

The report (Olivotto Timber 1999) examined two sample landscape units on the west coast of Vancouver Island. The proposed zoning of the two units (53% general management, 41% enhanced forestry and 7% special management) increased short-term (5-year) timber availability by up to 62% relative to management under the Code (i.e., 100% general management), and decreased operating costs associated with access and development by 16%. Over a medium-term (20-year) period, timber availability increased by a more modest 11% while harvest costs were reduced by only 2%. Volume gains arose because reduced adjacency constraints opened previously deferred areas, a.k.a. leave blocks. Cost reductions resulted where operations were able to harvest from previously built roads associated with many of these deferred areas.

The results of this report indicate that land use planning can have a significant impact on short-term timber availability and harvest costs. In the report’s case studies, short-term gains in timber availability in the enhanced forestry zone more than compensated for losses incurred in the much smaller special management zone. These findings cannot automatically be extrapolated to the Central Coast, but it appears that designation of resource management zones **could** provide an opportunity to improve the economic viability of partial cutting in the Central Coast.

5.5.1.2 Multi-pass silviculture prescription

In order to address the cyclical nature of log markets and provide necessary economies of scale, multi-pass silviculture prescriptions could provide the flexibility to target timber types best suited to the current log market and to allow for larger cutblock size. This would allow an operator to concentrate on the highest value species during weak markets and also reduce development costs and some overhead costs. Given log market conditions like those of 1998-99, this could mean the difference between operating and shutting down. There is potential for this type of operation to degrade or high-grade the stand, so implementation should be carefully considered.

5.5.2 Practice

5.5.2.1 Corridor logging

Depending on terrain and road configuration, there could be instances where patch retention can be achieved simple by co-ordinating the configuration of yarding roads. By “walking” the yarder and the corresponding backspar in opposite directions, logging crews can "pivot" a yarding operation around a small retention patch. Allowing for intermediate "corridors" of 10-15 m width, larger patch retention units can be established. Because this technique requires significant diagonal yarding, it is generally restricted to moderate slopes (≤50%) with moderate yarding distances (≤ 200 m). The technique also must be used with caution, because the overhead hazards associated with oldgrowth timber types raise significant concerns for worker safety.

5.5.2.2 Protection of advanced regeneration

In many ground-based harvest operations, advanced regeneration of suitable tree species can be identified and protected with minimal effect on logging productivity or costs. While mistletoe infestation can make western hemlock unsuitable for retention, patches of advanced amabilis fir, redcedar, and healthy western hemlock stems can be used to meet regeneration or visual quality objectives. Operational techniques similar to those described above for corridor logging could make this a viable aspect of partial cutting.

In transition areas in the Inner Coast Mountains, cold air drainage and ponding can create severe microclimates for regeneration. These conditions can result in plantation failures and longer regeneration delays. Maintaining sufficient forest influence (as in the small-group selection or small patch cuts along Talchako River) appears to help protect regeneration from cold air damage. Retaining standing timber increases logging costs but reduces the costs of stand regeneration and establishment.

5.5.2.3 Handlogging

Handlogging of shoreline stands has a long history on the Central Coast. Most handlogging sales, at least until recently, involved some form of partial cutting. Often the most valuable trees were removed, leaving behind a stand that, from the water, looked little affected by logging. Such operations were economically viable and aesthetically acceptable. Ecologically their most significant feature was that they left a forest behind, a forest that persists although its species composition could have changed. But were the handlogging operations sustainable? There continue to be concerns about the sustainability of future harvests on these handlogged sales. Issues of concern include:

- type of trees removed (usually the best, those with greatest economic value at time of logging)
- type of trees retained (usually the worst, often western hemlock, often infected with mistletoe)
- anticipated growth rates of retained trees, including advance regeneration
- acceptable species (e.g., what to do with mistletoe-infected hemlock?)
- attrition or eventual loss from the stand of tree species (Douglas-fir, redcedar, yellow-cedar) that have high ecological, cultural and economic value, are targeted for removal, and could have problems regenerating on handlogged blocks
- regeneration delay
- will natural regeneration be adequate/acceptable, or will fill-planting be required?
- free-to-grow standards
- expected rotation ages
- suitable silvicultural systems
- is it high-grading??

The shoreline area suitable or available for handlogging is highly significant in terms of aesthetics, quality of recreational opportunities/experiences, public perceptions, and the land-ocean interface component of coastal biodiversity. Retaining some forest cover is important. Logging prescriptions that meet multiple objectives, including timber production, require clear thinking---something often not apparent in partial cutting prescriptions. From a silvicultural perspective, a partial cutting prescription should accomplish at least one of two objectives: 1) significantly improved conditions for the future growth of existing trees, and 2) good conditions for the establishment and growth of new trees. Handlogging prescriptions in particular (and partial cutting prescriptions in general) often fail this simple test. That is, they do not create good growing or regeneration conditions, hence fall into the realm of high-grading. Logging prescriptions that achieve both silvicultural objectives, while also meeting the objectives attached to non-timber resource values, are very good prescriptions. Depending on unique stand conditions, there are many approaches that can be taken. It is not a matter of dogmatically choosing a traditional silvicultural system and applying it in handlogging areas.

We conclude that handlogging should continue on the Central Coast, because it seems socially responsible to provide for some limited amount of logging along the myriad marine waterways, especially if it can be done with acceptable aesthetic and ecological impacts. Partly because of the small scale of the harvesting operations and partly because management objectives for the shoreline zone must address visual and recreational resources as well as timber production and orthodox silviculture, we recommend continuation of handlogging---despite the risks of highgrading, undesirable silvicultural consequences, and potential for long-term decline in stand productivity. Marine biota and resources, especially in the intertidal and near-shore subtidal zones, could also suffer if the logging is not planned and implemented sensitively. Marine surveys and impact assessments should be part of the overall strategy for management of the shoreline landbase. Similarly, visual quality and recreational opportunities should be assessed. In areas with high visual quality objectives, partial cutting with a relatively high level of retention would be suitable, over a small proportion of the shoreline landbase and in combination with longer rotations and enhanced stand tending to ameliorate the visual impact. In areas with low visual quality objectives, lower levels of retention could be combined with more harvesting, and with more emphasis on silviculturally desirable and vigorous regeneration. Several silvicultural systems could accomplish these objectives: small-group selection, diameter-limit with protection of residual trees and in combination with dispersed or patch retention, variable retention in general.

5.5.2.4 Integrating harvest systems

On relatively gentle terrain with slopes <30%, logs can be hoeforwarded into yarding corridors and then grapple-yarded to the roadside. The advantages are that fewer yarding roads are required, there is less residual tree damage, and maximum efficiency of the grapple yarder can be realized. Worker safety issues are minimized because the method utilizes a hoeforwarder and grapple yarder. This combination probably is not as efficient as hoeforwarding directly to the roadside, in short yarding configurations (< 150 meters).

5.5.2.5 Training and communication

While it may not be considered a practice, perhaps the biggest adaptation necessary to successfully implement partial cutting involves people's attitudes. The attitudes of management, planning, and operational staff must be addressed through training and communication. Clearcutting has long been used on the coast as the commonplace system of choice, and its operational requirements have long been taken for granted. It will take a significant shift in attitude or mindset to make partial cutting a success. Key to changing attitudes is communication of management objectives to layout, falling, and rigging crews. Once these crews understand what as well as why partial cutting is required, successful operations will be more likely.

5.5.3 Equipment

5.5.3.1 Grapple yarding with carriage

For partial cutting operations that require lateral yarding capability, there may be some application of various slack pulling carriages for the current complement of grapple yarders common in the coastal industry. There is a wide variety of slack pulling carriages suited for virtually any log size. The biggest disadvantage is lack of flexibility. Oldgrowth forests produce an extremely wide range of log sizes. A carriage must accommodate the largest anticipated log size, thus the carriage will very often be overpriced and underutilized. Lateral yarding can be achieved on moderate slopes, but turn size, cycle time, and road chance time will be negatively affected.

5.5.3.2 Grapple helicopter

Helicopter yarding is likely the most important adaptation in terms of potential use and cost. In recent years, heavy-lift helicopters have been fitted with mechanical grapples. This has allowed licensees to eliminate the overhead worker safety hazard associated with rotor wash capable of dislodging debris from residual trees. Assuming sufficient dead-lift capacity, licensees have complete flexibility in designing retention or selection systems on all but the most extreme terrain. While the grapple eliminates the choker setter, thereby reducing cycle times, turn sizes are somewhat reduced because of the added weight of the grapple. Weather conditions are probably more restrictive in Central Coast operations as well. The biggest disadvantage is cost. Increased use of helicopter logging will increase logging costs, which will restrict application to high value timber types.

5.5.3.3 Single-tree grapple helicopter

Very recently, working with the Worker's Compensation Board, FERIC, and various specialized helicopter and falling contractors, MacMillan Bloedel Limited has developed a single-tree selection system that is proving to be effective in removing high value stems without unnecessarily compromising worker safety. The harvest system involves preparing a selected stem by limbing and topping before placing carefully measured cuts in the base of the tree. The tree is then grabbed at the top by a special grapple attached to a helicopter. The helicopter then exerts force in the direction of the undercut, snaps the tree off the stump, and pulls it straight up before flying it to the associated landing or roadside. This system can extract more value from stands through production of poles and may find application in constrained areas, such as wildlife habitat and oldgrowth management areas. Issues of high-grading again must be carefully considered.

5.6 Implications of Partial Cutting to Timber Yield

The concept of sustainability in forestry is complex, as discussed in Section 1.2. We acknowledge that sustainable forestry cannot be fully assessed or measured by sustained yield or sustained harvest of wood. Nonetheless, one component of sustainability is the continuous yield of a consistent and predictable amount of timber over time. We would be remiss in this report if we did not reflect on the potential effects of partial cutting (compared to traditional clearcutting) on the productive capacity of the landbase to produce commercial timber. Land use planning that contemplates the use of alternative silvicultural systems must consider their effects on timber yield. This is not a simple issue. Here are a few reasons why it is complex:

- there are few long-term studies that document yield from clearcuts, partly because most clearcuts in B.C. have not yet reached an age where they can be logged again, hence their yields are estimates or predictions (although on the south coast much of the post-logging second growth has reached harvestable age).
- long-term studies of partial cutting in B.C. are even rarer.
- timber yields and stand development patterns probably are more predictable after clearcutting than after partial cutting, however, there has been and continues to be considerable debate about the yield of monocultures vs. mixtures in clearcuts (Kelty 1992). Partial cutting adds even greater structural complexity to this debate.

- partially cut stands vary tremendously, both spatially and temporally, in removal rates.
- expected yield after partial cutting will depend on more than just the expected growth rates of newly established regeneration. Equally important will be the abundance, composition, and vigour of residual tree species. Light-demanding species will respond differently than shade-tolerant species and large old trees probably will respond differently than more vigorous young trees.
- the spatial pattern of partial cutting, that is the spatial distribution of retained canopy trees (uniform or patch applications, see section 4.2), can dramatically affect the growth rates of both residual and newly regenerating trees.

The list could go on, but to summarize: "the question of whether the yield from clearcuts is superior to that from partial cuts depends on the circumstances and not on sweeping generalizations" (Smith and others 1997; p. 415).

As discussed earlier (section 2.5), much of the Central Coast is comprised of oldgrowth stands in which many of the mature trees are of poor vigour, with limited capability to respond to improved growing conditions after partial cutting. In these oldgrowth stands, it is probably not realistic to expect canopy trees to significantly improve in growth following partial cutting. Recall the "decadent hembal" stands. With little visible evidence to indicate heart-rot, if implementing partial cutting one would have to be very careful (or lucky) in deciding which canopy trees to remove and which to retain.

In younger, more vigorous stands, there is considerably greater opportunity to enhance growth rates of residual overstory trees following partial cutting. At present, however, such opportunities are limited in the Central Coast. There are relatively few younger, vigorous stands of a commercially viable age available now or in the near future. And windthrow remains a concern. These younger vigorous stands are generally more susceptible to windthrow damage when "thinned" beyond a certain stand density threshold.

Another aspect of this topic is the effect of overstory canopy on advanced understory regeneration. The canopy can protect advance regeneration from extreme weather. But overstory trees can also negatively affect the health of understory trees (mistletoe infestation is probably the best-known example), thereby reducing growth and value. Partial removal of the canopy can "release" advance regeneration (especially of amabilis fir, western hemlock, and redcedar) in some stands, which can jump-start the regeneration process. Presumably this headstart can also shorten the time to free-growing, green-up, and rotation age. The extent to which advance regeneration can contribute to future stand yield is unknown, but advance regeneration has the potential to make significant contributions under certain circumstances.

The issue of how a partially retained canopy affects the growth of newly established regeneration has been the topic of some research in forests similar to those found in the Central Coast (Wright and others 1998; Coates 1999). We know that the ground-level (micro)environment beneath large overstory trees is different from that in a clearcut; the canopy intercepts light and precipitation and modifies temperature. Although regeneration can survive and grow in lower light levels, highest growth rates generally occur under open light conditions. Regeneration growth rates can be expected to progressively decline under increasing amounts of canopy retention.

At a given level of retention, the spatial arrangement of the retained canopy trees can have a profound impact on the growth rates of planted and naturally established regeneration. For example, given the same overall volume removal, growth of regeneration under a partially cut but spatially uniform canopy would be expected to be much lower than growth of regeneration in discrete canopy openings of say 0.2-0.3 hectare. Furthermore, in general most tree species grow their best in full open conditions. Such conditions can be found in relatively small openings (probably greater than 0.2 hectare). From a biological perspective, large clearcuts are not required to achieve high growth rates of newly established Central Coast tree species.

An example of how uniform retention of canopy trees can reduce the growth rates of newly established regeneration is provided by D'Anjou (1999). According to this research, overstory retention has a negative effect on growth rates of conifer plantations; i.e., on height and stem diameter growth as well as on plantation survival. Uniform shelterwood (12% retention) and extended rotation (86% retention) systems applied to lower elevation, even-aged, mature, Douglas-fir-leading stands resulted in a 30-40% reduction in seedling growth in the shelterwood, and even greater reductions in the extended rotation stand. Spatial distribution of retained overstory canopy will be a major factor influencing regeneration development and growth. Patch retention is preferable to uniform retention if regeneration growth is a concern.

While the effect of partial cutting on long-term timber production can not be verified under field conditions, there are several simulation models that indicate trends. Hansen and others (1995) found that retention level and rotation age strongly influence ecological and economic response in Pacific Northwest forests. In simulations of various regimes of tree retention and rotation length, wood production was found to decrease with increasing retention level and rotation age.

In a similar study, Birch and Johnson (1992) modelled growth, yield, and value of coastal Douglas-fir stands with various levels of live-tree retention during regeneration harvests over multiple rotations. Using various combinations of uniform retention levels, tree size, and rotation age, it was found that total net growth declined 6-25%. Scenarios that left mature trees at final harvest reduced harvest volume at each rotation, compared to the base case clearcutting scenario. The reduction depended on the size and number of green trees left standing, growth effects on the understory, and overstory mortality. These studies suggest that timber yields could be overestimated if the effects of partial cutting are not properly integrated into the analysis.

More recently, coastal foresters are beginning to come to grips with the effects of implementing retention silviculture systems, as defined by the Forest Practices Code, in addressing landscape unit objectives. MacMillan Bloedel Limited (MB) has three management goals to guide the design of their version of variable retention: 1) leave a biological legacy of old-forest attributes; 2) maintain forest influence on the majority of the cutblock; and 3) ensure that the cutblock will be perceived by the public as a non-clearcut. In addition, MB has set targets for retention level in various resource management zones. As an example, they target 5% uniform (dispersed) and 10% patch (aggregate) retention in their “timber management zone”.

MB operational staff indicated that, in many cases, attempting to have their cutblocks perceived by the public as non-clearcuts appears to require levels of retention higher than the stated targets. For example, using 10% patch retention could perhaps leave biological legacy and maintain some forest influence on the majority of a cutblock, but it may not be viewed by the public as anything more than small clearcuts among retained timber patches. Lines on a paper plan do not necessarily translate to the real appearance or perceived view of a cutblock; they do not hover in the air a few metres above the canopy. Planning and operational staff also deal with uncertainty when designing these systems. For example, they might use retention levels above targets to cover anticipated harvesting and post-harvesting losses of retained trees. Consequently, the impact on timber yield could be higher than originally anticipated.

In summary, the implications of partial cutting on timber yield are complex. Growth of a multi-species, multi-layered stand under a variety of cutting patterns and site conditions, in the face of unknown natural influences and future changes in management objectives, makes any estimate of timber yield susceptible to criticism. We have a reasonable understanding of stand growth and yield following clearcutting, but we cannot make generalizations regarding growth and yield in partial cutting systems. Based on research results to date, however, partial cutting has some **potential** to reduce timber yields compared to clearcutting.

6.0 ECONOMICS OF TIMBER PRODUCTION

6.1 Methods

In order to determine the economics of timber production, it is useful to compare current economic conditions in the Central Coast to those in areas with similar or comparable ecosystems. We compared logging costs, timber values, and profitability using the representative cutting permit information compiled for Central Coast and Vancouver Island operating areas (see section 5.2.1.1). As previously indicated, there is very little partial cutting represented by these cutting permits. Hence this stage of the analysis was essentially an economic comparison between clearcutting operations. The incremental costs of partial cutting were then estimated based on a review of current literature as well as on field reviews and staff interviews. Finally, the potential profitability of partial cutting was extrapolated from the profitability comparison (assuming clearcutting as the base case) and the estimated incremental cost of partial cutting. Note that this is primarily a stand level comparison. A landscape level analysis could come to different conclusions.

6.2 Economic Comparison

6.2.1 Logging cost comparison

The Ministry of Forests' Coast Appraisal Manual (CAM), effective April 1, 1999 (Cost Base: July 1, 1997), was used to determine operating costs. While there is concern that the CAM cost estimates are too general, we have used them in a comparative, not absolute, analysis that should accurately reflect the cost trends between the Central Coast and Vancouver Island study areas. Table 8 summarizes the comparison of logging cost for the two areas. Costs are averages derived from the total volume of timber contained in the sample cutting permits.

We did not include stumpage costs in the analysis and cost comparison. Stumpage is payment by licensees to the Crown for timber harvested from Crown lands. The amount payable to the Crown is the volume harvested (as measured by scaling) multiplied by a calculated stumpage rate. Because determination of stumpage rate is subject to a base rate additive as well as to a prescribed minimum rate, it was felt that including stumpage costs would skew the analysis.

Table 8. Clearcut log cost by phase.

Phase		Central Coast ($/m^3)	Vancouver Island ($/m^3)
DEVELOPMENT	Roads	14.70	10.27
	Bridges	2.46	1.94
	Major culverts	0.00	0.00
	Reconstruction	0.21	1.03
TREE TO TRUCK	Conventional log	18.00	19.23
	Helicopter log	13.47	8.92
LOG TRANSPORT	Truck hauling	5.06	6.44
	Dumping, sorting, booming, scaling	10.91	9.73
	Barging	6.60	2.68
	Towing	0.58	1.00
	Road maintenance/deactivation	3.63	4.13
ADMINISTRATION	Overhead	22.45	19.63
	Crew transport	2.58	3.14
	Camp overhead	7.56	5.13
	Low volume additive	0.03	0.10
SPECIFIED OPERATIONS	Lake transport	3.54	0.00
	Blowdown	0.18	0.07
	Partial cut	0.00	0.48
	Skyline	0.01	0.12
	Towing to tie-up grounds	0.69	0.02
	Tree crown modification	0.00	0.05
	Basic silviculture	2.36	2.46
TOTAL LOG COST		**115.01**	**96.59**

6.2.1.1 Development costs

Development costs are generally recognized as either new road construction (including bridge and major culvert construction) or reconstruction and replacement of old, existing roads and drainage structures. New road construction consists of right-of-way falling, clearing and grubbing, sub-grade construction, placement of additional stabilizing material, and construction and installation of drainage structures. Development costs also include designated special engineering costs (e.g., end-hauling, construction on really steep slopes or across gullied terrain).

Development costs in the Central Coast are influenced by cutblock size, green-up and adjacency requirements, topographic and terrain conditions, and distribution of merchantable timber types, which can all increase the amount of "dead road" in operating areas. The Central Coast has relatively few opportunities to harvest leave areas previously developed during first-pass logging. This relative lack of development also means that there are more large-capital-cost structures associated with opening up new drainages or watersheds (e.g., major bridges). Road construction in the Central Coast must deal with hard rock (as defined in the CAM) on a continual basis. Because of sensitive soil types and terrain stability issues, end-hauling operations are more common. The result is that development costs in the Central Coast are 41% higher than those incurred in the Vancouver Island study area.

6.2.1.2 Tree-to-truck cost

Tree-to-truck costs include all costs to manufacture logs from standing trees, to transport those logs to the roadside or landing, and to load them onto log haul trucks. Tree-to-truck costs include conventional and helicopter logging costs as well as certain specified operation costs.

- *Conventional and helicopter logging*

Logging costs are generally recognized as either conventional (ground or cable yarding) or helicopter. In general, conventional tree-to-truck operations do not vary significantly from those used on Vancouver Island. Conventional yarding costs are 6% lower than those experienced on Vancouver Island. This difference may relate to an advantage associated with first-pass logging; i.e., licensees have more flexibility in designing logging operations based on timber types and ground conditions. Conversely, because of topography, terrain, and administrative restrictions (green up, adjacency and cut-block size restrictions), Central Coast licensees utilize high cost helicopter logging significantly more than Vancouver Island licensees.

- *Specified operations*

Additional tree-to-truck costs are incurred for specified operations such as salvage of blowdown, partial cutting, skyline operations, and tree crown modification. While Vancouver Island operations experience 10% higher costs for such operations, these additional costs are not well represented in either of the study areas, therefore we cannot make definite conclusions about the results.

6.2.1.3 Log transportation costs

Log transportation phase costs cover the movement of logs from the roadside or landing in the woods to the point of appraisal, and include truck hauling, dumping, sorting, booming and scaling, towing to tie-up grounds, lake transportation, barging or towing, and road maintenance and deactivation.

- *Truck hauling*

Truck hauling includes the cost to transport logs from the roadside to the scale site. Cost varies with the haul distance and truck capacity. In general, truck capacity is similar on the Central Coast compared to those used on Vancouver Island. The main difference is in haul distance. Truck hauling distances in the Central Coast are 46.5% less than those on Vancouver Island. Because of longer history of logging, Vancouver Island operations are located further from dump sites. In some cases, Vancouver Island operations have the option of trucking logs longer distances to protected tidal waters, allowing transport by tow rather than by more expensive barge. As a result, truck hauling costs are 21% less in the Central Coast.

- *Dumping, sorting, booming, scaling*

Log handling costs on the Central Coast include the cost of establishing new, but generally smaller, operations under higher environmental standards than originally prevailed on Vancouver Island. These start-ups normally involve very high capital costs that are amortized over the volume of timber they initially develop; i.e., first-pass logging. In small Central Coast drainages with limited volume and duration of operations, the amortization costs can form a significant portion of the total cost of operation. The higher capital cost and operating cost result in a 12% higher cost to Central Coast operators.

- *Towing to tie-up grounds*

Throughout the Coast, logs that have been dumped and boomed are normally towed to tie-up grounds for temporary storage prior to being towed or barged to the point of appraisal. These temporary storage sites must be located in protected areas away from open ocean conditions. Where these temporary storage sites are located more than 10 km away, towing to tie-up becomes a significant expense. Because of unique waterway and landform conditions in the Central Coast, 47% of logs must be towed to a tie-up ground more than 10 km away from the dump site, whereas only 1% of logs on Vancouver Island require such transport. The result is that average cost of towing to tie-up grounds is $\$0.67/m^3$ more in Central Coast operations.

- *Lake transportation*

Twenty-nine percent (29%) of logs transported from the Central Coast must be towed via a lake, de-watered, transported by truck, then dumped and barged or towed to the point of appraisal. This sequence adds, on average, an additional $\$3.54/m^3$ to the cost of log production.

- *Barging and towing*

The transportation of logs to the point of appraisal is done primarily by barge or log tow. In rare cases, proximity of manufacturing facilities allows licensees to transport logs by truck. Towing is significantly cheaper than barging. However, because of potential log loss, towing is not practical outside protected waters. Barging is done where the route from local tie-up grounds to point of appraisal is exposed to open ocean swell; i.e., west coast of Vancouver Island and all points north of Cape Caution on the mainland. Eighty-six (86) % of logs transported out of the Central Coast are transported by barge and 14% are transported by tow. On Vancouver Island, 51% of logs are barged, 47% are towed and 2% are trucked. The result is that net barging and towing costs are 95% higher for Central Coast operations.

- *Routine maintenance and deactivation*

Because most Central Coast operations use recently built roads that are generally built to a higher standard than older roads, routine maintenance and deactivation costs are 12% lower than on Vancouver Island. However, the deactivation component of the cost could be under-represented in this analysis. As Central Coast licensees move to smaller, outer coast drainages, it is expected that deactivation costs will become significantly higher. Given cutblock size, adjacency and green-up requirements, operations in any one drainage or watershed will have a very restricted timeframe between successive logging passes. Under such a scenario, a licensee will be required to deactivate all roads prior to leaving a watershed for an extended timeframe. On Vancouver Island, it is more common for a licensee to remain in the same geographic area using the same log handling facilities. Hence, mainline and main spur roads remain active (deactivation not required) or remain unused for shorter time periods (lower level of deactivation required).

6.2.1.4 Administration

- *Overhead*

General and administrative overhead costs include head office executive and administrative support, operating and support for logging and log supply functions, right-of-way easements, foreshore and other land leases necessary for logging function. Corporate forestry and engineering costs are also included in overhead costs. This includes supervisory, administrative and vehicle support functions, cruising, environmental protection measures, residual and waste surveys, and silviculture overhead costs. Because of the small, isolated nature of Central Coast operations, it is usually difficult to justify retaining staff to provide all of these support functions in every operating area. It is usually more efficient to transport staff, materials, and equipment from a central location or to bring in consulting staff. Consequently, overhead costs average 15% higher for Central Coast operations.

- *Crew transportation (labour)*

Crew transportation includes the labour cost of moving crews to work areas from either isolated locations (camps), or from the nearest community accessible by road. All of the operations in the Central Coast are considered isolated locations, therefore crew transportation is from a camp. On Vancouver Island, 80% of operations are considered accessible, therefore transportation distances are normally greater. The result is that crew transportation costs are 14% less for Central Coast operations.

- *Camp overhead*

Camp overhead varies depending on whether the location is isolated or accessible by ground transport. Costs include camp and marshaling area facilities, shop and office and other pertinent buildings, commuting costs and short camp and equipment moves (<10 km by water). Accommodation costs include crew transport into and out of camp (transport is into and out of camp only, as opposed to every day from camp to work site and home in the evening), freight, cookhouse and bunkhouse. All Central Coast operations are in isolated (inaccessible) areas, whereas only 20% of Vancouver Island operations are considered isolated. Camp overhead costs average 41% higher in Central Coast operations.

- *Basic silviculture*

    Basic silviculture costs are about the same for Central Coast and Vancouver Island operations. While planting costs are expected to be significantly higher in the Central Coast (tougher ground), higher costs for deer browse protection and brushing and weeding are normally incurred on Vancouver Island.

- *Camp move*

    Additional costs result when a logging camp must be moved to a new location more than 10 km away by water. Costs include movement of camp (buildings and facilities) and logging equipment, and deactivation of the old camp site. While this type of cost was not analyzed here, Central Coast moving costs can be expected to be significantly greater than those of Vancouver Island operations.

- *Low volume cost additive*

    Where a cutting authority contains a small volume of timber, it is recognized that due to lack of economies of scale, fixed costs will add significantly to the total operating cost. While low volume cost additive is higher for Vancouver Island operations, influence on total log cost is insignificant.

6.2.1.5 Average total logging cost

Total logging cost is the sum of all phase costs as identified in Table 5 above. Based on this review of appraisal cost data from sample cutting permits, total log costs for Central Coast operations are \$18.42/m^3 higher (almost 20% higher) than those experienced on Vancouver Island.

6.2.2 Comparison of timber value

Timber value is calculated based on log species and grade and average selling price as set by the log market. For purposes of this report, log species and grades were derived from billing records and selling prices were obtained from three-month average domestic log selling prices (August 1999), as prepared by the Ministry of Forests, Economics and Trade Branch.

6.2.2.1 Log species

Table 9. Production by tree species.

SPECIES	CENTRAL COAST (%)	VANCOUVER ISLAND (%)
western hemlock/amabilis fir (“hembal”)	42	62
redcedar	43	29
yellow-cedar	8	5
Douglas-fir	0	3
spruce	7	1
Total	**100**	**100**

Table 9 compares production by species for the two study areas. Note the current production by species (from billing records) compared to the inventory of timber harvesting landbase broken down by leading tree species (compare Tables 3 and 9). Only partial comparison is possible between stand-leading species and species production, but it appears that Vancouver Island operations are producing log species consistent with the inventory profile. In contrast, Central Coast operations appear to be producing a lower proportion of hemlock/amabilis fir ("hembal") logs and a higher proportion of redcedar logs than are present in the inventory. One can conclude that future production will probably have proportionately less redcedar and more "hembal", which could have a negative effect on timber value.

While the coastal log market tends to rise and fall in a fairly regular cycle, traditionally demand for redcedar, yellow-cedar, Douglas-fir, and Sitka spruce has been stronger than demand for hemlock and amabilis fir. Log market value for redcedar, yellow-cedar, Sitka spruce, and Douglas-fir was very high in the early to mid-1990s but prices for all species dropped off sharply between 1995 and 1998. The white-wood species (hemlock, amabilis fir, and spruce) exhibited the biggest declines. The decline in average log price was buffered by rapidly increasing prices for redcedar logs. More recently, higher prices for redcedar, yellow-cedar, Douglas-fir and spruce have increased average log price marginally. However, current prices for hemlock/amabilis fir ("hembal") remain well below 1995 prices.

6.2.2.2 Log grade

While species can be used to make general comparisons of timber value, specific log grades must also be considered. Because log grade has a direct impact on selling prices for a given species, market value by species provides a comparable measure of log quality between the two study areas (Table 10). Based on this summary, average selling price for all tree species produced in the Central Coast is less (6-9%) than that in the Vancouver Island study area. Whereas, average stand selling price in the Central Coast is 3% higher. The apparent contradiction is explained by considering species production of each study area (see Table 9). The Central Coast has been producing proportionately more redcedar logs. Since redcedar commands a higher selling price than other species, increased production of this species increases the stand selling price.

Table 10. Average selling price.

SPECIES	CENTRAL COAST ($/M^3)	VANCOUVER ISLAND ($/M^3)
hemlock/amabilis fir ("hembal")	71.77	76.30
redcedar	138.91	147.24
yellow-cedar	85.58	91.40
Douglas-fir	77.46	177.23
spruce	100.04	118.44
Stand Selling Price	**103.90**	**101.24**

6.2.2.3 Waste and decay billing

We expected that the "decadent hembal" stands associated with the Central Coast could have a larger economic effect, but there was insufficient information available to make any comparison at this time.

6.2.2.4 Average timber value

For purposes of this report, average timber value is represented by average stand selling price as summarized in Table 10. As indicated, selling prices of individual species in the Central Coast are lower in all cases. Even so, the average stand selling price in the Central Coast is slightly higher (3%) than on Vancouver Island because a higher component of redcedar is being produced.

6.2.3 Profitability comparison

For purposes of this report, the profitability of timber production is a very simple comparison of the revenue generated by log production versus the cost of producing those logs; i.e., net revenue before stumpage. Table 11 summarizes the comparison of profitability between the two study areas. Based on current operating and market conditions, the average Central Coast operation is losing $11.11/m^3, a 9.7% loss. The average Vancouver Island operation is realizing a positive return of $4.65/m^3, a 4.8% profit. These figures represent a 'snapshot' of a cyclical system; fluctuations in log markets could change the picture. We cannot say how accurately the net revenue figures reflect actual current operating conditions or longer term average conditions, or foreshadow the future. However, it seems reasonable to conclude that there is a low economic margin for logging in the Central Coast. The implication is that there is less "economic room" to successfully implement higher cost partial cutting in the Central Coast, than on Vancouver Island. Note that the comparison is valid only between the two study areas analyzed in this report.

Table 11. Net revenue by operating area.

OPERATING AREA	SELLING PRICE ($/M^3)	OPERATING COST ($/M^3)	NET REVENUE ($/M^3)
Central Coast	103.90	115.01	<11.11>
Vancouver Island	101.24	96.59	4.65

6.2.4 Sensitivity analysis

The profitability comparison suggests that, under current market conditions, the average operator is losing money logging in the Central Coast. While the best available cost and revenue information was used in this analysis, much of the information depends on fluctuating and uncertain economic factors. In such a context we cannot be certain that the average operator is losing $11.11/m^3 in the Central Coast or making $4.65/m^3 on Vancouver Island. The reality is that licensees have been and will continue to operate in the Central Coast based on site-specific rather than average operating conditions. The question is, under what conditions will these licensees continue to operate?

"Sensitivity analysis" provides a means of dealing with fluctuating and uncertain economic factors, and determining the conditions necessary to successfully operate in the Central Coast. A sensitivity analysis can assess how results would change if certain economic factors were to change. The goal is to determine whether the results of our analysis provide a reasonable basis for report conclusions and recommendations.

We want to determine the sensitivity of net revenue based on log selling price and operating cost. However, the factors affecting both selling price and operating cost are too numerous and too complex to provide meaningful results. In addition, we would have to consider the interaction among these factors. Alternatively, we can use historic market selling price and sample cost information. In doing so, we no longer need to consider individual factors. It is assumed that these factors are already reflected in historic pricing and cost information.

6.2.4.1 Variation in log selling price

Log market price is a function of species composition and log grade. Historically, the market for logs in British Columbia has fluctuated up and down on a fairly regular cycle. Within these cycles, prices for individual species can fluctuate as well. The most marked species variation normally occurs in the "white-wood" species; i.e., hemlock, amabilis fir, and spruce. Fluctuations in market price based on log grade usually relate to variations in lumber markets versus pulp and other wood fibre markets. As prepared by the Ministry of Forests Economics and Trade Branch, Table 12 summarizes the fluctuations in the British Columbia log market since 1993.

Table 12. Vancouver log market price composite.

YEAR	AVERAGE LOG MARKET PRICE ($/M^3)	AVERAGE "WHITE-WOOD" PRICE ($/M^3)
1993	104.07	80.20
1994	109.95	97.38
1995	122.98	123.60
1996	109.16	89.47
1997	115.61	84.10
1998	99.15	66.12
1999	96.45*	68.38*
Range	**26.53**	**57.48**
Percent Fluctuation	**27%**	**87%**

Figure 6. Average based on May-October results.

Using results from Table 11 as the base case, we analyzed net revenue for the two study areas by fluctuating log market price. Figure 34 presents the results of this analysis, which indicate that the average logging operation in the Central Coast will break even if and when the average log market price increases by 11%. On Vancouver Island, if average log market price drops by 5%, the average operation will break even.

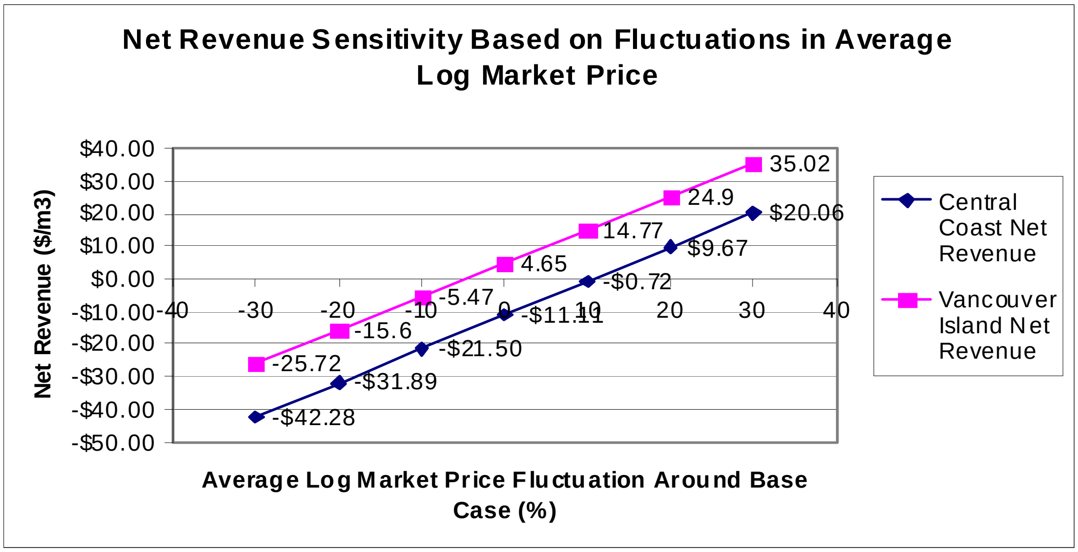


Figure 34. Net revenue sensitivity based on fluctuations in average log market price.

Again using results from Table 11 as the base case, we analyzed net revenue for the two study areas by fluctuating white-wood market. Figure 35 presents the results of this analysis, which indicate that the average logging operation in the Central Coast will break even if and when the average white-wood market price increases by 30%. The average operation on Vancouver Island will break even if and when the average white-wood market price decreases by 10%.

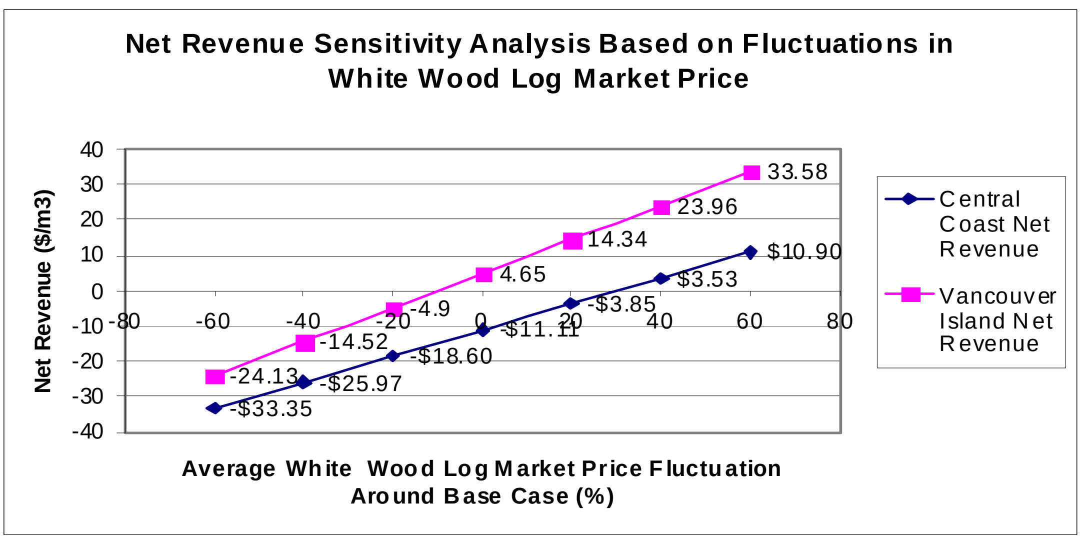


Figure 35. Net revenue sensitivity based on fluctuations in white-wood log market price.

6.2.4.2 Variation in logging cost

Logging cost is a complex function of a wide range of factors. Because there is no composite index of historical logging costs available for this analysis, data from sample cutting authority was used to determine variation in costs. Cost variation here is represented by the minimum and maximum sample costs. Because sample costs included a very wide range due to extraordinary site conditions, 20% of the highest and 20% of the lowest sample results were excluded from the analysis. Once minimum and maximum sample costs were determined, an average variation was then calculated as a percentage of the average log cost shown in Table 8. Table 13 summarizes variation by phase cost. As indicated in this summary, development cost has the largest single variation. Significant variation also occurs in tree-to-truck costs.

Table 13. Log cost by phase.

Phase Cost	**Average Cost Variation (+%)**		
	Central Coast	Vancouver Island	Weighted Average
Development	66	63	64
Tree to truck	47	36	40
Log transportation	25	17	20
Administration	5	8	7
Total log cost	13	17	16

Using results from Table 11 as the base case, we analyzed net revenue for the two study areas by fluctuating phase costs. For both areas, the combined influence of all identified phase cost variations, represented by total log cost, had the greatest influence on net revenue. Figure 36 presents the results of analyzing net revenue sensitivity by varying total log cost. Based on this analysis, the average logging operation in the Central Coast will break even if and when the average total log cost decreases by 9.7%. The average operation on Vancouver Island will break even if and when the average total log cost increases by 4.9%.

Sensitivity analysis appears to corroborate the profitability comparison. In all cases, there is a significantly higher margin (net revenue) available to implement higher-cost alternative silvicultural systems in the Vancouver Island study area than there is in the Central Coast. The sensitivity analysis also shows that relatively small changes in economic factors can make an operation profitable despite evidence indicating the average operation will lose money.

While we cannot be as sure that net revenue results are accurate in absolute terms, we can speculate why we would see these results, at least in the short term. In depressed log market conditions, such as the one indicated in this analysis, licensees will often continue to operate even though revenue does not adequately cover all costs. These costs include the sum of fixed and variable costs. Fixed costs are those not dependent on production output (e.g., capital cost of machinery). Variable costs are those costs dependent on production output (e.g., labour). When log market prices drop, the resultant revenue can drop below total operating costs resulting in a negative net revenue (an operating loss). The decision to operate or shut down will be based on the magnitude of operating loss. If log market price drops to a level that allows the licensee to cover all variable costs and make some return on

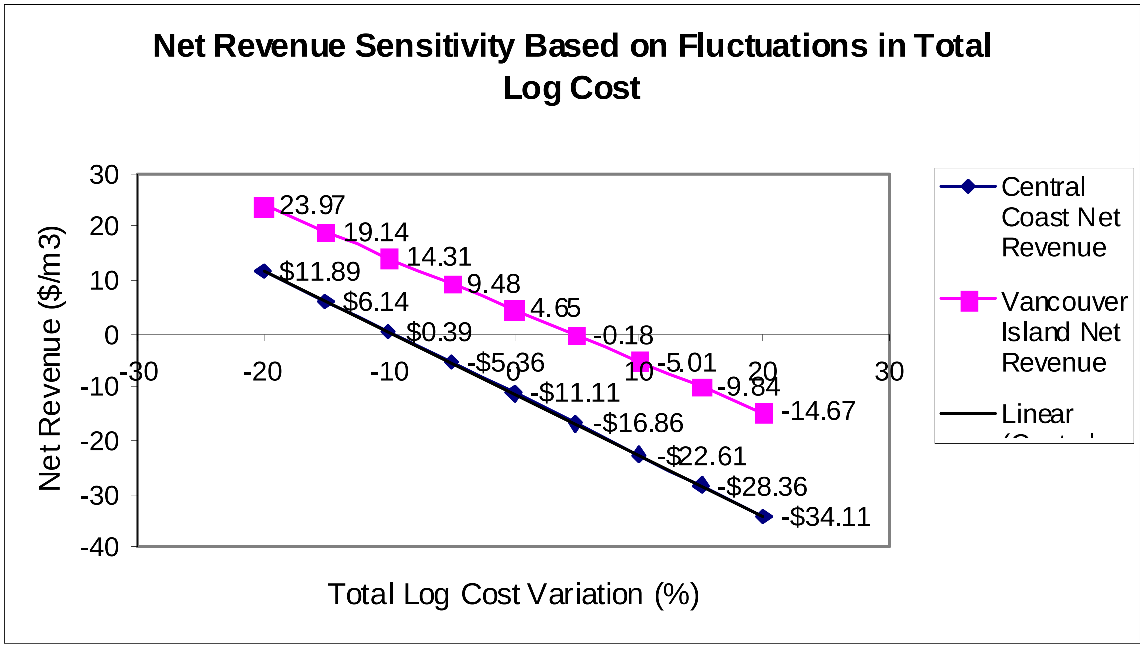


Figure 36. Net revenue sensitivity based on fluctuations in average total log cost.

fixed costs, it is better to keep operating because any return on fixed costs will reduce overall operating loss. If log market price drops to a level below average variable cost, it would be better to shut down production to minimize operating loss at current fixed costs.

In addition to short-term economies, the decision to operate and at what level of production will be influenced by external economic factors. These factors are numerous in the forest products industry and normally outside the direct control of the operator. External economic factors important to an operator's decision include market availability (e.g., Canada/U.S.A. softwood lumber agreement), government land use decisions, tenure agreement cut controls, forest practices legislation, stumpage rates, mill capacity, and desire to maintain labour availability. Another useful way of looking at the profitability comparison results is by interpreting timber supply curves. Williams (1993) used a timber supply curve to look at the opportunity cost of varying the size of the timber harvesting landbase and the order in which forest stands are harvested. In this study, the timber supply curve is a function of average log market price and annual timber production (i.e., supply), assuming harvesting costs remain constant. The annual timber production is calculated as a product of the timber harvesting landbase and the maximum growth rate. The assumption is that as the average log market price increases, more forest land can be added to the timber harvesting land base which, in turn, will increase the annual timber production (supply).

Using an approach similar to the one used by Williams (1993), we can look at the effect variation in log market price has on timber production. Figure 37 shows an example of a timber supply curve for a hypothetical timber supply area. Using this example, we see there is no economically viable timber harvesting landbase if log market price is less than $\$60/m^3$. As log market price increases above $\$60/m^3$, more and more forest land becomes

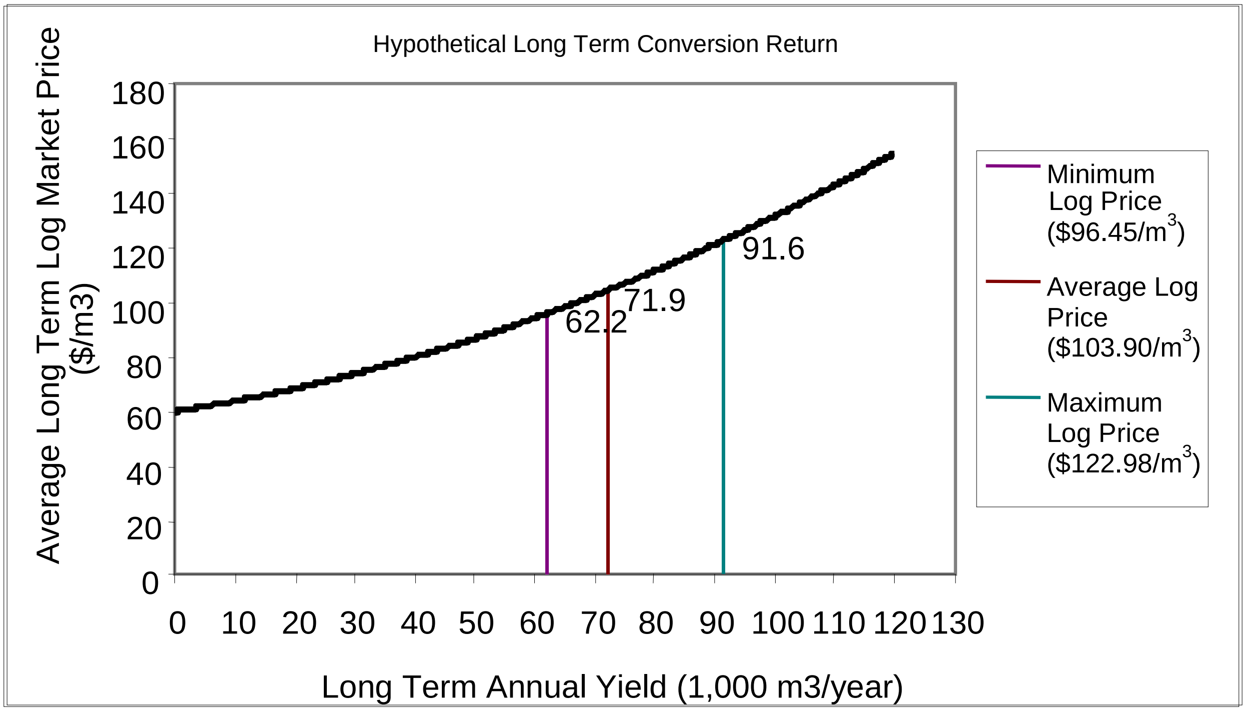


Figure 37. Hypothetical long-term conversion return

economically viable. Should the log market price rise to a sufficiently high level, all available forest land base would become economically viable. In our example, the maximum available forest land base would produce 91,600 m^3/year if the log market price were to reach \$123/m^3. Using this approach, we can then see that despite short-term fluctuations in log market prices, it is still economically viable to be logging in the Central Coast based on sound, long-term projections of log market prices.

6.3 Estimated Incremental Cost of Partial Cutting

Compared to clearcutting operations, the use of partial cutting will involve different costs and will generally be more expensive in a comparison of regeneration cuts. This is because, in a stand-to-stand comparison, partial cutting will always remove less timber per hectare, and fixed costs will have to be amortized over a smaller volume---resulting in higher fixed costs. Assuming volume harvested represents the original stand profile, in theory variable costs should not change. However, depending on intensity and spatial distribution of trees retained, productivity of virtually all phases of harvesting will be lower. Extra time and care must be taken not to damage leave trees, and more area must be covered to harvest an equivalent volume of timber. As well, all aspects of planning are more time-consuming and costly when implementing partial cutting.

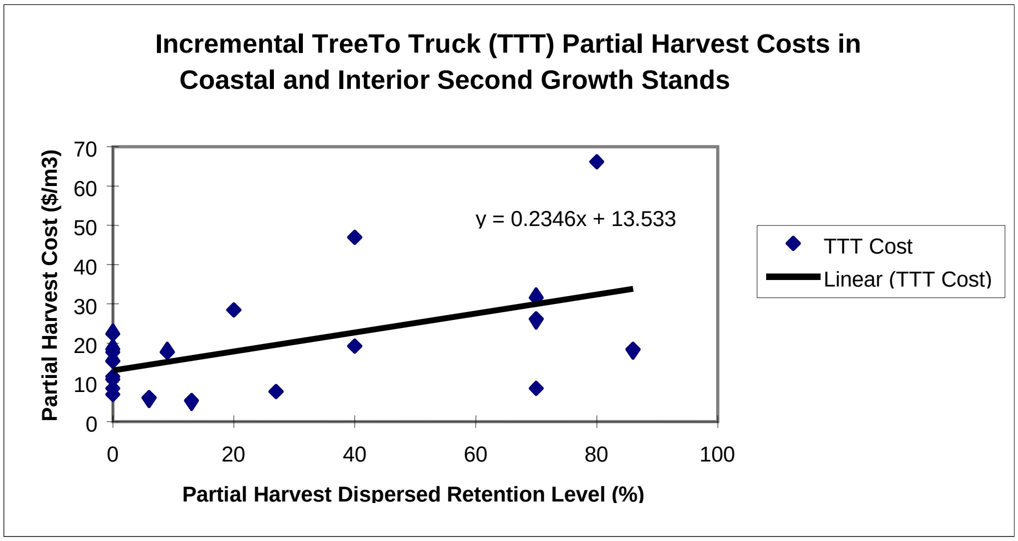
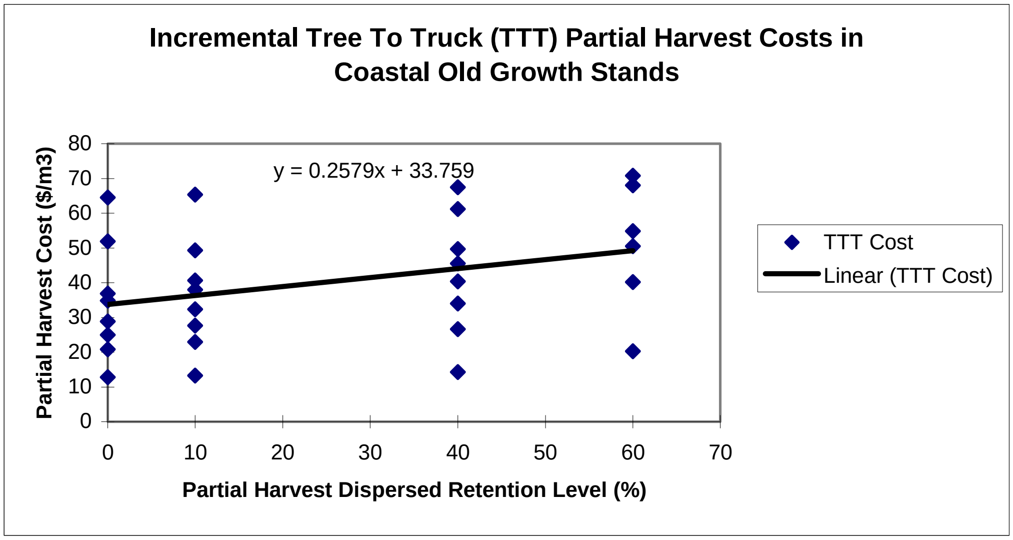


Figure 38. Incremental costs of cutting in coastal second-growth and interior forests.

The magnitude of the incremental cost associated with partial cutting, assuming clearcutting costs are used as a base, depends on many different factors. Partial cutting tree-to-truck costs are influenced by original stand composition and structure, percentage and spatial distribution (patch versus uniform or dispersed) of retained trees, harvest system, log size, slope, terrain, and yarding distance.

The difficulty is in determining how much incremental cost to expect. There is some evidence indicating that harvest costs increase in proportion to level of retention, but most of the information comes from comparative studies of coastal second-growth and interior stands (see Figure 38). As indicated by a linear regression analysis of cost data from these studies, tree-to-truck (TTT) harvest costs increase from a clearcutting base of $13.53/m^3 at an approximated rate of $2.35/m^3 for every 10% increment of uniform retention. This regression analysis represents an approximation of various studies and reports covering different sites, timber types and harvest methods, and the results are **not** statistically significant. Even though these data must be used with extreme caution, there is a consistent trend indicating that, in a stand-to-stand comparison, harvesting costs will increase with an increase in the level of uniform retention.

The same incremental cost increase has been found for coastal oldgrowth timber and terrain. Figure 39 shows harvest costs, based on various retention levels, from data amalgamated by MB and FERIC. The information was derived from a combination of 1997-actual and 1998-extrapolated costs used in development of MB's Forest Project. The data set is merely a best estimate of actual costs and should be used with extreme caution, but it does indicate cost trends similar to those observed in the second-growth studies in Figure 38. Based on these data, conventional tree-to-truck harvest costs in coastal oldgrowth forests will increase from a clearcutting base of $33.76/m^3 at an approximated rate of $2.58/m^3 for every 10% increment of uniform retention. Again, this trend of increasing cost is not statistically significant and must be used with caution.



Interestingly, these data indicate that the cost increase in oldgrowth stands is comparable

Figure 39. Incremental costs of partial cutting in coastal oldgrowth timber types.

to that in second-growth stands.

Based on the FERIC data (Fig. 40), cable yarding systems appear to be the most sensitive to variations in retention level, with grapple yarder operations being the most sensitive. Hoeforwarding and helicopter logging operations are the least sensitive to retention level.

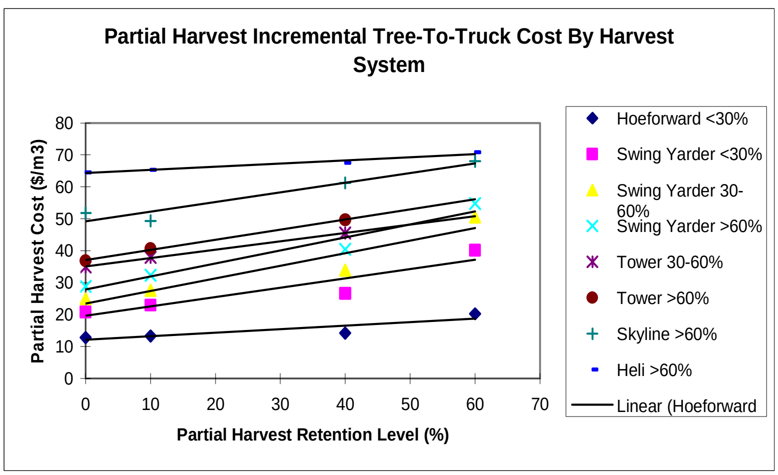


Figure 40. Incremental tree-to-truck cost of partial cutting, by harvest system.

There are few documented partial cutting costs for patch (group) selection systems and virtually none for patch retention systems. Kellogg and others (1991) studied the contrast in planning and logging costs in clearcut, two-story, and group selection cutting units and found that the harvest costs associated with group selection systems using cable yarding were significantly higher than costs for a comparable clearcut setting. However, harvest costs for group selection systems using ground-based methods were virtually the same as for comparable clearcut units. In a similar study, MacDonald and others (1969) found that harvest cost associated with group selection systems using ground-based methods, were the same as for clearcut units.

Results of these studies seem to be consistent with field review and interview responses. In interviews, licensee staff indicated that there is significantly less cost sensitivity when trees are retained in patches. Based on equivalent retention level, in general, patch retention or group selection will be more productive, less costly, and have less residual stem damage (both operational and due to windthrow) than will dispersed retention or individual tree selection. Similarly, ground-based and grapple helicopter harvest methods appear to have less incremental cost when trees are retained or selected in patches. While it is expected that cable harvest costs will increase when logging around patches (as indicated by Kellogg and others 1991), these cost increases are not expected to be significant at lower retention levels (<30%), with use of appropriate cutblock layout and design.

6.4 Potential Profitability of Partial Cutting

As indicated above, compared to the Vancouver Island study area, there is less economic margin available in the average Central Coast operation. The analysis also indicates that implementing partial cutting operations will result in an incrementally higher log cost. The conclusion is that, based on an economic comparison, there are relatively fewer opportunities (less flexibility) to successfully implement partial cutting operations in the Central Coast. Although there is less economic flexibility, our field review and staff interviews did note examples of successful partial cutting in the Central Coast. These examples were implemented based on site-specific, not average, operating and economic conditions. We conclude that, depending on fluctuations in log market selling price, there are economically viable options to do partial cutting in the Central Coast.

While not analyzed in this report, the stumpage rate charged to harvest Crown timber is a very real operational cost affecting the potential profitability of partial cutting. Under the stumpage appraisal process, specified operation costs for partial cutting operations can be recognized as a tree-to-truck cost additive within the Vancouver Forest Region. Recently (effective September 1, 1999), this process was updated to include use of retention silviculture systems. Now the partial cutting cost additive can be recognized for uniform and patch retention silviculture systems. Based on a retention level of 30%, it appears that the process would recognize additive costs of up to $\$6/m^3$ to $\$9/m^3$, depending on retention pattern. While not intended to drive the decision to partial cut, the process is intended to recognize legitimate incremental costs of partial cutting for the purpose of calculating the stumpage rate. Utilizing this cost additive will have a direct, positive effect on the potential profitability of partial cutting.

As indicated above, the economic margin available to implement partial cutting is, on average, less in the Central Coast. However, we may not be able to use this conclusion in absolute terms. If consistent with stand management objectives, partial cutting can be planned and designed to reduce logging cost and increase stand selling price. As an example, operations designed to target individual or patches of cedar trees will produce a higher stand selling price. Alternatively, operations designed to leave low volume or high defect trees (e.g., decadent "hembal") will result in lower logging costs. The key is to determine the economic margin available for a particular stand and partial cutting design.

6.5 Implications of Partial Cutting for Stand Value

To this point, our economic analysis has focused on harvesting cost and revenue in first-pass development; i.e., in regeneration cutting. The analysis indicates that the higher expected harvesting costs associated with partial cutting will result in lower net revenue. However, the analysis does not account for stand response over a full rotation. That is, it has not yet considered stand value, based on different management regimes. One could argue that retaining various amounts of original stand structure, to reduce regeneration costs and increase value through incremental growth, could produce a higher stand value than could be achieved by clearcutting. To see if this could be the case, we looked at several simulation studies that have been done to determine financial impact of various forest management activities over time.

Tesh and Mann (1991) compared cash flow between clearcut and shelterwood silvicultural systems. Using USDA Forest Service rotation prescriptions, three simulation regimes were studied. Study results indicate that net present value from stands for the shelterwood system on gentle terrain can approximate those of clearcuts. However, on steeper slopes where logging costs increase, net present values for clearcuts are generally higher (50-60%) than those for shelterwood systems.

In a similar study, Brodie (1985) used a stand simulator model to compare present net worth for shelterwood and clearcut regimes over one full rotation. The study then compared the stumpage netted by the single-harvest clearcut and the double-harvest shelterwood. Each analysis was replicated on a good site and poor site in Douglas-fir stands of south coastal Oregon. On both the good and the poor site, the net present worth over the full rotation was found to be 10-18% higher for the clearcutting treatment, but planting expenditures for the clearcut wiped out its initial economic advantage. The study also found that, compared to a ten-year shelterwood return period, the net present worth for the clearcutting method was 13% higher than for the shelterwood method. In this case, because the return period was far less than the rotation, the difference in the net present worth more than offset clearcut regeneration costs.

Hansen and others (1995) looked at the effects of canopy retention and rotation length on wood production and value. It was thought that retaining overstory trees for longer rotation lengths would produce larger, higher value logs capable of compensating for stand value lost to reduced wood production. Using simulation models based on stand data from the Willamette National Forest in western Oregon, Hansen and others (1995) found that this was not the case. Calculating cumulative net wood product value, they found that stand value declined with increasing levels of overstory retention. Hansen and others (1995) indicate that this result relates to overstory influence, which creates regeneration conditions favouring normally less valuable, shade-tolerant species. In this study, the high value of large dimension, high quality trees in the retained overstory only partially offset the lower economic value of the understory trees.

As noted earlier in this report, Birch and Johnson (1992) modeled growth, yield, and value of coastal Douglas-fir stands with various levels of live-tree retention during regeneration harvests over multiple rotations. Using various combinations of uniform retention levels, tree size, and rotation age, they found that the present net value of harvest declined under all leave-tree scenarios, depending on the number of leave trees left, their size, and the rotation length.

7.0 CONCLUSIONS AND RECOMMENDATIONS *(recommendations are in italics)*

The Natural Environment

The Central Coast is most like the North Coast and the southern portion of the Kalum Forest District. In terms of climate, physiography and terrain, the Central Coast has less similarity to Vancouver Island and the southwest mainland coast. The forests and the distribution of timber types (mostly hemlock-amabilis fir and redcedar-leading) are most like those of the North Coast, but are also reasonably similar to those of northern Vancouver Island and Clayoquot Sound. But the plan area is too large and variable for such generalizations to have much meaning.

Recognize the three ecological subunits, Hecate Lowland, Outer Coast Mountains, Inner Coast Mountains; acknowledge their environmental differences; use them in strategic planning.

Most Central Coast forests are very old and structurally complex. Natural disturbances in these older stands are usually small-scale, primarily involving the creation of canopy gaps through the death of individual or small groups of trees. Fire is rarely an important agent of natural disturbance in the Hecate Lowland and Outer Coast Mountains. Fire return intervals could be much longer than previously thought, **perhaps** 3 to 10 times longer than the original estimates of 250-350 years. Fire has been more important in the Inner Coast Mountains, where large portions of the landscape (at least at lower and middle elevations) probably have regenerated as more or less even-aged stands on a regular (200- to 300-year) basis.

The biota of the Central Coast is poorly known, but three generalizations seem reasonable:

(1) most organisms are of the forest or associated with forests in some way;
(2) forests of all age classes, including very young and very old, are important for maintaining the diversity of all groups of organisms, from microbes to mammals;
(3) some groups of organisms, like canopy insects, epiphytic lichens and epixylic mosses and liverworts, and aquatic invertebrates, are more sensitive to the negative impacts of conventional forest management than are other, less specialized, more mobile groups like vertebrates.

The “hydroriparian” ecosystem is a focus of biological activity, is the arena for the keystone interaction among salmon, bears and riparian forests, and is disproportionately important to biological diversity and ecological function in coastal watersheds.

We recommend that riparian forests get special attention and treatment.

The Operating Environment

The Central Coast has distinctive operating conditions, both physical and economic, including very small population, remoteness, isolation (communities and work sites), lack of infrastructure, distant processing facilities, relatively small operable forest landbase, large oldgrowth inventory, and patchiness of good productive forest. Compared to a reasonably similar portion of Vancouver Island, the Central Coast has less merchantable volume/ha, lower quality timber, shorter operating season, more road construction/m^3 of wood, more costly roads (tougher terrain), and proportionately more helicopter logging. These distinctive features influence the choice of harvest system, which in turn will affect an operation's ability to implement alternative silvicultural systems.

We conclude that successful operations in the Central Coast must have harvesting equipment and supporting operations that are mobile and provide broad flexibility. Individual operations are relatively small and short in duration. Operators can not afford to retain or import equipment purpose-built for individual situations. They require equipment flexible enough in application to cover virtually all situations. From an operational perspective, patch retention or variable retention silvicultural systems appear to provide the best opportunity to implement partial cutting operations that will be economically viable in oldgrowth forests of the Central Coast. These systems provide more of the required flexibility in planning, layout, harvest/retention, suitable equipment, and worker safety. The hoeforwarding and helicopter grapple yarding systems appear to provide the greatest economic flexibility. Both of these systems will probably be used more in future, in subdued and difficult terrain, respectively. Conventional cable systems (grapple yarders and highlead towers) are capable of partial cutting, but these methods are much more sensitive to incremental costs and therefore provide less economic flexibility. Operational difficulties distinctive to the Central Coast will limit application of long distance skyline yarding. A-framing and handlogging can also be used to implement partial cutting but provide little economic flexibility, given the low site productivity and stand value normally associated with these methods

The distinctive operating environment of the Central Coast also translates to higher logging costs and lower net revenue than in comparable areas of Vancouver Island. Despite lower log value for individual species, current stand selling price in the Central Coast is slightly higher (because of proportionately more redcedar harvested) than on Vancouver Island. But based on current operating and market conditions, our analysis shows that average operating costs in the Central Coast are almost 20% higher than those experienced by the average comparable Vancouver Island operation. Moreover, wood for the next 10-20 years is projected to come primarily from the Outer Coast Mountains and the Hecate Lowland, and increasingly from low productivity redcedar-hemlock stands and from stands accessible only by helicopter. Licensees will therefore probably be harvesting stands less valuable and more costly than at present. Economic comparisons indicate that there is less flexibility in the Central Coast to implement alternative silviculture systems that will increase harvesting costs. Sensitivity analysis indicates that this economic relationship will continue into the foreseeable future.

Partial cutting will result in higher incremental costs than clearcutting, and generally the greater the level of uniform retention the higher the costs. Higher cost sensitivity is expected for cable harvesting methods than for ground-based methods.

Patch retention on steeper ground requiring cable yarding methods will also have higher incremental harvesting costs. Patch retention (on suitable ground) using ground-based methods (hoeforwarding) will have less significant incremental costs of harvesting. Opportunities to implement patch retention and group selection systems do exist in the Central Coast. Opportunities to retain advanced regeneration could lower harvesting costs. Alternatively, efforts to target higher value species or grades could increase log value. *Economic margin has to be considered before implementing partial cutting.*

Most Central Coast forests are very old, the rest are juvenile or young. There are few middle-aged (40-120 years old) stands, so at present there is little opportunity for commercial thinning. When the younger stands reach a suitable age and condition, there will be good opportunities for commercial thinning (a form of partial cutting) in many valleys of the Inner Coast Mountains.

Disturbance

The bulk of logging in the next 10-20 years will be in forests with natural disturbance type 1 (NDT1: ecosystems with rare stand-initiating events; gap dynamics prevail; opening sizes typically 1 to a few tree heights in width, or 0.001 to 3-4 ha in size; larger openings occasional). Forest management that approximated such a disturbance regime would call for lots of small openings, a few larger cutblocks, and for more "biological legacies" to be left behind in the openings.

At the current rate of cut, we don't recommend that sort of forest management, at least not spatially and over large areas.

Taking smaller volumes from each stand, while cutting the same volume overall, would simply spread the cut over more land. More roads per m^3 of cut would be required, unless all operations were by helicopter. Most openings would be too small to take much advantage of the extra light. Initial growth of many seedlings would be limited by available light. Forest diseases such as dwarf mistletoe and root rots would be more easily spread from old forests to regenerating ones. The landscape would become much more fragmented, with a higher percentage of 'edge'. There would be additional safety concerns, and operations would be more expensive. Economic, operational, social, and even ecological factors make it difficult to follow natural disturbance patterns while maintaining the present volume of timber production. But an understanding of natural disturbance patterns and of forest structure (its ecology, importance, and management) will certainly help improve forest management.

Nor do we recommend clearcutting everywhere, especially at the current rate of cut.

Extensive clearcutting would result in a very different distribution of age classes and stand structures than does natural disturbance in these coastal forests. This would have important consequences for biological diversity, because complex, multi-storied, multi-aged stands with lots of dead wood (standing and on the ground) would be converted to young, single-storied, single-aged (or single cohort) stands with greatly reduced amounts of dead wood. And many people don't like the way clearcuts look. This can be important for aesthetic as well as for economic (tourism/ecotourism, market defense) reasons.

One could conclude that, if trying to approximate the natural disturbance regime, clearcutting (with openings greater than some size, say 5 hectares) should be done rarely in NDT1. At least, if one agrees that biodiversity and other important ecosystem attributes are more likely to be conserved if disturbances such as logging are kept within the temporal and spatial ranges of variability that characterize natural disturbances (see Section 3.0). There are some practical problems with this view, although in principle it makes ecological sense. Regardless of rate of cut, it would be difficult in the Central Coast to closely approximate natural disturbance regimes with road-based forest harvesting. Single-tree and small-group selection using only helicopter yarding would probably come closest. In many old forests of the Central Coast, it appears to be "clearcut or not at all", given wood quality and the tight economic margin. Merely spreading the existing cut over more land via partial cutting everywhere would end clearcutting, but would also result in a host of other problems (as already mentioned). Rate of cut becomes an issue whether we want it to or not.

We do recommend leaving more biological legacies, trying to maintain key elements of forest structure (live trees of varying species, size and condition--including some large stems, multiple canopy layers, canopy gaps, understory patches, snags of varying size and decay class, downed logs [see Section 4.2]). We also recommend that as much attention be paid to what to leave *as to what to take.*

Succession and Stand Dynamics

Forests in the Central Coast develop much as they do elsewhere in coastal B.C. Successional pathways depend on the nature and intensity of the associated disturbance and on the regeneration cohort; the scenarios play out in reasonably well-understood ways. Traditional or conventional forest management 1) manipulates stands to bring them to a harvestable stage sooner by trying to reduce or eliminate shrub-herb early successional stages, by juvenile spacing and pre-commercial thinning, and sometimes by fertilizing; and 2) harvests the stands as soon as commercially possible; i.e., before the understory reinitiation stage of stand development. In other words, foresters try to shorten the stand initiation and stem exclusion stages, they try to remove unwanted competing plants like deciduous shrubs and trees, and they nullify the understory reinitiation and oldgrowth stages by cycling the forest land on short rotations. To a greater or lesser degree (see Fig. 25), all silvicultural systems also have such consequences for ecological succession. These forest management practices have a negative impact on those organisms associated with shrub-herb early successional ecosystems or with late-successional old forests.

We know the scope of this problem and the seriousness of the negative impact only in general terms, but no doubt the impact deepens and widens as the area brought under forest management increases. The consequences are also a function of the rate of cut and the intensity of stand manipulation. And remember that the forest landscape provides the meaningful context. It is not possible to maintain all elements of biodiversity on every hectare or all stages of forest succession in every stand.

We recommend that the ecological consequences of compressing and truncating natural succession in managed forests (and especially on lands designated for an emphasis on timber production), are evaluated, especially at the landscape scale. Address the problem through: landscape unit planning; successional stage distribution; deployment of a variety of silvicultural systems according to desired similarity to early and late successional stages, including non-traditional retention systems to help retain desired levels of stand structure and biological legacies; longer rotations for some stands.

Silvicultural Systems

Except for very large clearcuts and coppicing, there are no compelling, *a priori*, biological or ecological constraints to any silvicultural system **on an individual stand basis.** But the landscape consequences depend on the rate and extent of harvest, and all sorts of factors enter the picture at that scale---like number of roads required, levels of canopy retention, fragmentation, age-class structure. In other words, in some important ways it doesn't matter as much **how** you log as **how much** you log. Even so, one can generalize that silvicultural systems that retain a certain level or amount of critical stand structures (see Section 4.2) make more biological, ecological, and also silvicultural sense than those that don't.

Except for coppicing, all silvicultural systems, traditional and non-traditional, could be implemented on the Central Coast. There are no compelling operational (equipment, skilled labour) constraints. The most serious silvicultural constraints centre on windthrow (always a concern), high-grading, and forest pests. Although it can be done, in general partial cutting is difficult to implement in oldgrowth western hemlock - amabilis fir ("decadent hembal") forests, which are still widespread. It is unwise to impose the same system everywhere; a mix of systems makes more sense.

Implement a variety of silvicultural systems, operationally not merely for demonstration purposes. Monitor any associated blowdown and its consequences, not just in or near the treated stands but also in nearby untreated, natural stands.

Based on research results to date, however, partial cutting has some **potential** to reduce timber yields compared to clearcutting. The planning table must recognize this potential before making large-scale commitments to partial cutting. Given the lack of long-term studies on growth and yield of partial cuts, we must operate under uncertainty.

But different silvicultural systems have different economic consequences, some cost more than others; partial cutting costs more than clearcutting. When markets are unfavourable, it's tough to make a profit logging in the Central Coast, regardless of silvicultural system. Innovations in harvesting technology are unlikely to significantly reduce harvesting costs. Even though clearcutting remains a viable silvicultural system, international economic and market realities are driving an increasing use of partial cutting, and partial cutting makes more ecological sense in these forests. Site conditions and management objectives should determine use of silvicultural system. The following is repetitious but it bears repeating:

At the current rate of cut: *We don't recommend doing partial cutting everywhere, over the entire plan area, because we don't think that would be ecologically sensible, silviculturally desirable, or economically viable. We also don't recommend clearcutting everywhere, because it doesn't make ecological sense, and because it could have some undesirable silvicultural and economic consequences.*

That's the gist of it, but to summarize, the issues/constraints/concerns affecting the broadcast application of partial cutting include (see also Section 4.3):

- worker safety; partial cutting is more dangerous than clearcutting
- undesirable landscape-level consequences; partial cutting requires that more land be impacted to harvest the same volume of timber as clearcutting, and (except for helicopter logging) requires more roads; depending on level of retention, partial cutting can also result in greater forest fragmentation
- potential for high-grading; criteria for partial cutting, especially of the more selective systems, can be abused
- cost; partial cutting will result in higher incremental costs than clearcutting
- forest protection - in particular, windthrow, mistletoe and root rots, and damage to residual stems; partial cutting exacerbates these problems
- implications for long-term yield of timber; partial cutting **could** reduce timber yields compared to clearcutting, depending on level of retention and on rotation length
- the effect on stand value; net present value of partially cut stands could decline over a full rotation or multiple rotations, compared to clearcut stands.

Issues/constraints/concerns bearing on extensive clearcutting include:

- disturbance; clearcutting doesn't usually reflect or approximate natural disturbance regimes in the Central Coast and, if extensive, results in a major shift in age-class structure over the forest landscape, with major consequences for biological diversity
- forest ecology; clearcutting typically retains few or no "biological legacies", hence provides poor or unsuitable habitat for species that require or are strongly associated with oldgrowth forests.
- silviculture; clearcutting often requires planting for successful regeneration; can result in harsh microclimates and poor growing conditions for regeneration.
- forest protection; clearcutting also exacerbates windthrow (in adjacent stands), and can increase the risk of outbreaks of pests and pathogens of young stands.
- non-timber forest values; clearcutting typically has adverse or undesirable impacts on non-timber resources (water, fish, aesthetics, some forms of recreation).
- public opinion; many people don't like clearcutting; the negative opinions can be expressed in the marketplace.

There are, however, economically viable opportunities, on the right sites or in specific drainages with certain operational flexibilities. At the site level, *we* *recommend using partial cutting in the following applications:*

- *In general and where circumstances warrant, as variable retention systems.*

  Management objectives and site-specific operational and economic conditions will determine where exactly it can be done, but it appears that variable retention is feasible in most forests of the Central Coast. It will be most difficult to implement retention systems in the "decadent hembal" forests, but then one could say that about all of the silvicultural systems.

- *To address regeneration delay where it is a problem, either by retaining advance regeneration of preferred species in a variable retention scenario, or by using small patch or strip cuts to protect artificial regeneration.*

  The latter concern appears to be an issue mainly in the Inner Coast Mountains, where plantations can suffer from regeneration delay or failure due to cold air ponding.

- *As commercial thinning, where and when stand conditions are appropriate.*

  The Central Coast does not yet have many suitable stands, but commercial thinning has great potential as an ecologically and economically appropriate form of partial cutting in second-growth forests.

- *To extract some wood from some (not all) riparian forests while maintaining essential forest structure and ecosystem function.*

  Single-tree and small-group selection and perhaps irregular shelterwood would be appropriate here, implemented in such a way that opening size and density would fall within the range found in natural oldgrowth riparian forests. One would have to set some upper limit on amount of original canopy removed, say 30% or so. Note that clearcuts, though largely inappropriate in riparian ecosystems, should not always be excluded from consideration. For example, there could be good reasons for generating stands of deciduous trees (red alder and black cottonwood) here and there in the riparian zone. If natural disturbances don't do it, clearcuts could.

- *In Douglas-fir-leading forest types in the Inner Coast Mountains, in particular by using helicopter logging on steep rocky slopes.*

  Such forests are usually well-suited for partial cutting in terms of stand structure, and typically have site conditions (rocky soil, moisture stress) and landscape considerations (aesthetics; often in areas of high visual quality objectives) amenable to some level of retention. Note that if the intent is to regenerate Douglas-fir, the opening must be large enough to provide full light in some parts of the block.

- *In redcedar/yellow-cedar-leading types in the Hecate Lowland, where several systems (group selection, strip, group and irregular shelterwood, variable retention) could be implemented, most efficiently through hoeforwarding.*

  Given the short history of operational experience in these forests, we encourage a cautious approach. Some issues in the lower productivity cedar-hemlock and bog forests of the Hecate Lowland (adequate regeneration and growth, paludification) are still large unknowns, presently the subject of research (see Banner 1999; also Prescott & Weetman 1994). These forests also often have high aesthetic values, if they occur (and are visible) along the Inside Passage and other recreational waterways.

  In both of the latter forest types, measures would have to be put in place to avoid both high-grading and stand conversion (attrition of the desirable species---Douglas-fir and the cedars---and eventual replacement by less desirable, more shade-tolerant western hemlock and amabilis fir).

For landscape-level examples of viable opportunities, see **Strategic Planning** below.

We recommend that a process be established to monitor the effectiveness of different silvicultural systems in meeting social, economic, and ecological goals, and that adaptive management be considered as a model for this process.

Few studies have specifically investigated the effects of silvicultural systems on social, economic, and ecological values in the Central Coast. Our recommendations are based on available information, but in many cases the information is insufficient to predict the effect of various practices on species and ecosystem diversity, operational costs, or community benefits. It is important to develop a plan for monitoring the effects of different silvicultural systems in the Central Coast. The specifics of such a monitoring system are beyond the scope of this report. Many recent literature references (e.g., Walters 1986; Walters & Holling 1990; Bormann and others 1994) have suggested that adaptive management is a cost- and time-effective method for learning from our management practices and experiences. More information about adaptive management can be found at the Ministry of Forests' Adaptive Management Website at: http://www.for.gov.bc.ca/hfp/amhome/AMHOME.HTM

Strategic Planning

Establishment of land use zones with development of flexible management objectives could have a positive effect on timber yield and logging revenue. In some (not all) drainages, the potential advantages could help offset the expected incremental cost of doing partial cutting. Alternatively, management objectives for certain zones could expressly invoke or promote partial cutting. *Explore these possibilities.*

For a landscape-level example, consider that most remaining undeveloped drainages in the Central Coast are relatively small and have patchy timber. Typically they are developed with a full-scale operation, including a camp and roads, that stays for 5-10

(?) years, then pulls out and goes somewhere else, to return 10-15 years later for a second pass, and perhaps again for a third pass. This is not particularly efficient, and the dispersed activities can have negative ecological consequences at the landscape scale.

In groups of individual, often parallel, small drainages (most apparent in Outer Coast Mountains), consider compressed harvesting schedules in some drainages and reduced or no activity in neighbouring ones (in other words, a staggered development schedule).

- in this fashion, a single small watershed could be a management unit under a single prescription
- an equivalent timber yield could be realized while reducing some environmental impacts (e.g., road development) and operational costs.
- the prescription should include a variety of silvicultural systems (with an emphasis on retention systems, to soften the ecological impacts) over space and maybe time (the "operable" lifetime of the watershed; 15-25 years?)
- no traditional 2- or 3-pass system; go in once, with attendant infrastructure; remove xx% of volume; pull out, don't return for at least 100 years
- remove a much smaller % of volume or abstain from adjacent equivalent watershed(s).

As another approach, consider trial use of multi-pass silvicultural prescriptions, to target species and log grades that would allow operations to work within market cycles 'normally' experienced in the lumber and pulp industry.

- beware the obvious dangers of high-grading and "cut the best/leave the rest"; trials must be monitored to specifically address issue of high-grading
- ideally this would be tried in some of the same drainages in which the 1-pass system was being implemented
- higher incremental harvesting costs of partial cutting could be offset.

Address silvicultural systems in strategic planning at the level of land use zoning.

Management objectives developed under zoning provisions could help determine the success of implementing alternative silviculture systems. Zoning can be used to address landscape level issues (e.g., visual quality objectives of Inside Passage). Once management objectives have been developed, it becomes easier to determine the appropriate silviculture system. Suppose **for the sake of argument** (we're not endorsing or rejecting this zoning approach), CCLCRMP called for three zones on productive forest land. One could develop an outline for each zone. For example,

1) Timber Production Emphasis ("Enhanced Forestry", "General Management")

- goals of this zone
- appropriate silvicultural systems to achieve goals, with brief explanation why appropriate
- size (range) and shape of openings; levels of retention
- appropriate harvesting systems

- concerns or constraints

2) Functional Forest Emphasis (“Special Management”)

- likewise

3) Value Emphasis

- likewise

One could also construct a table, stratified by the 3 ecological subunits and generalized forest types within them. We are not going to do that here, but such a table could look something like this:

HECATE LOWLAND

forest type	appropriate silv. system[1]	suitable harvesting system	constraints or concerns
CwHw average forests; medium and some poor sites	group selection, variable retention, small clearcuts	hoeforwarder, grapple yarder, high lead, helicopter	adequate regeneration of Cw
CwHw low productivity and bog forests; poor and low	logging inappropriate; group selection maybe	helicopter, small machines with high-flotation tires or treads, corduroy roads (?)	paludification (bog-ification), site degradation (organic soils), high-grading of Cw
productive upland forests (Hw, Ba, Cw, Ss); medium and good sites	variable retention, small clearcuts, strip shelterwood, group selection	---	slope stability
riparian forests (floodplain Ss, Hw, Cw, Ba)	group selection, irregular shelterwood	---	erosion, brush hazard, bears

[1]Depends on zoning emphasis (timber production, forest function, value).

...and so forth for Outer and Inner Coast Mountains.

Other Recommendations

Develop ecosystem restoration projects for some valleys of the Inner Coast Mountains---something considerably beyond the rather limited scope of “watershed restoration”.

It would be desirable to restore the riparian ecosystem and some of the splendid old Douglas-fir and redcedar forests in the lower valleys. What does this have to do with our terms of reference? Recall that forests have productive, protective, and social functions. All three functions could be addressed in valley-bottom forests by restoration projects that included a mix of silvicultural systems, with a predominance of partial cutting and a focus on commercial thinning. Commercial thinning and other systems could produce wood, which could allow some areas to be managed under extended rotations for late-successional or oldgrowth features (see Curtis & Carey 1996). And the forestry activities could provide meaningful work, especially perhaps for some of the permanent residents.

Continue to allow partial-cut handlogging along parts of the shoreline, with due regard to aesthetics, recreational opportunities, marine resources, and highgrading.

As discussed in Section 5.5.2.3, handlogging can have some undesirable consequences silviculturally and with respect to long-term stand productivity. But if done properly it makes sense socially, aesthetically, and ecologically. Furthermore, it involves a tiny fraction of the total annual cut yet can be crucial to the economics of the small operations involved. In areas with high visual quality objectives, partial cutting with a relatively high level of retention (of overstory and understory) would be suitable, over a small proportion of the shoreline landbase and in combination with longer rotations and enhanced stand tending. In areas with low visual quality objectives, lower levels of retention could be combined with more harvesting, and with more emphasis on silviculturally desirable and vigorous regeneration. Several silvicultural systems could accomplish these objectives: small-group selection, diameter-limit with protection of residual trees and in combination with dispersed or patch retention, variable retention in general.

We recommend that the CCLCRMP table also read a recent note (Duncan 1999) summarizing a pertinent study in Southeast Alaska.

Researchers examined a broad array of silvicultural options for the forests of Southeast Alaska, a region with natural and operating environments reasonably similar to those of the Central Coast. The U.S. researchers came to several of the same conclusions that we did. For example, they found that *"timber harvesting by using alternatives to clearcutting is viable in the current marketplace and technically feasible across a wide range of cutting intensity."* They maintain that *"'ecologically informed' partial cutting can produce high-quality timber and retain the forest structure essential for wildlife and fish."* A summary of the research is also available at:

http://www.fs.fed.us/pnw/sciencef/scifind 19.html

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9.0 REFERENCES

9.1 Literature Cited

Alaback, P., and J. Pojar. 1997. Vegetation from ridgetop to seashore. Pages 69-87 *in* Schoonmaker, P.K., B. von Hagen, and E.C. Wolf, editors. The rain forests of home: Profile of a North American bioregion. Island Press, Washington, D.C.

Amaranthus, M.P. 1997. Forest sustainability: An approach to definition and assessment at the landscape level. General Technical Report PNW-GTR-416. US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon. 14 p.

Arsenault, A., and G.E. Bradfield. 1995. Structural-compositional variation in three age-classes of temperate rainforests in southern coastal British Columbia. Canadian Journal of Botany 75: 54-64.

Attiwill, P.M. 1994. The disturbance of forest ecosystems: the ecological basis for conservative management. For. Ecol. Manage. 63:247-300.

Baer, A.J. 1973. Bella Coola - Laredo Sound map areas, British Columbia. Memoir 372. Geological Survey of Canada, Ottawa, Ontario. 122 p.

Banner, A. 1999. Pattern, process, and productivity in hypermaritime forests: the HyP^3 project. Extension Note #38, Forest Sciences, Prince Rupert Forest Region, Smithers, B.C. 6 p.

Banner, A., J. Pojar, R. Trowbridge, and A. Hamilton. 1985. Grizzly bear habitat in the Kimsquit River valley, coastal British Columbia: classification, description, and mapping. Pages 36-49 *in* G.P. Contreras and K. E. Evans, compilers. Proceedings grizzly bear habitat symposium, April 30-May 2, 1985, Missoula, Montana. U.S.D.A. Forest Service General Technical Report INT-207, Ogden, Utah.

Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R. Trowbridge. 1993. A field guide to site identification and interpretation for the Prince Rupert Forest Region. Land Management Handbook Number 26, British Columbia Ministry of Forests, Research Branch, Victoria, B.C. 503 p.

Ben-David, M., T.A. Hanley, and D.M. Schell. 1998. Fertilization of terrestrial vegetation by spawning Pacific salmon: the role of flooding and predator activity. Oikos 83: 47-55.

Binkley, C. 1997. Preserving nature through intensive plantation forestry: the case for forestland allocation with illustrations from British Columbia. Forestry Chronicle 73: 553-559.

Bormann, F.H., and G.E. Likens. 1979. Catastrophic disturbance and the steady state in northern hardwood forests. American Scientist 67: 660-669.

Bottom, D.L., G.H. Reeves, and M.H. Brookes, technical coordinators. 1996. Sustainability issues for resource managers. General Technical Report PNW-GTR-370. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon. 54 p.

Bradshaw, F.J. 1992. Quantifying edge effect and patch size for multiple-use silviculture - a discussion paper. For. Ecol. Manage. 48:249-264.

British Columbia Department of Economic Development. 1976. The Mid Coast report. A summary report of development possibilities in the Mid-Coast, northern Vancouver Island and Queen Charlotte Islands region of British Columbia. Victoria, B.C. 175 p.

British Columbia Ministry of Forests and B.C. Environment. 1995. Biodiversity guidebook. Province of British Columbia, Victoria, B.C. 99 p.

British Columbia Ministry of Forests and B.C. Environment. 1997. Species and plant community accounts for identified wildlife. Volume 1. Province of British Columbia, Victoria, B.C. 171 p.

British Columbia Ministry of Forests. 1995. Kingcome Timber Supply Area analysis report. Victoria, B.C.

British Columbia Ministry of Forests. 1999. Mid Coast Timber Supply Area analysis report. Victoria, B.C. 114 p.

Brooks, H. 1992. Sustainability and technology. Pages 29-60 *in* Science and sustainability: Selected papers on IIASA's 20th anniversary. International Institute for Applied Systems Analysis, Laxzenburg, Austria.

Bunnell, F.L. 1997. Operational criteria for sustainable forestry: focusing on the essence. Forestry Chronicle 73: 679-684.

Bunnell, F.L., and A.C. Chan-McLeod. 1997. Terrestrial vertebrates. Pages 103- 130 *in* Schoonmaker, P.K., B. von Hagen, and E.C. Wolf, editors. The rain forests of home: Profile of a North American bioregion. Island Press, Washington, D.C.

Bunnell, F.L., L.L. Kremsater, and M. Boyland. 1998. An ecological rationale for changing forest management on MacMillan Bloedel's forest tenure. The Forest Project. http:\\www.mbltd.com\

Burton, P.J. 1998. Designing riparian buffers. Ecoforestry 13: 12-22.

Callicott, J.B. and K. Mumford. 1997. Ecological sustainability as a conservation concept. Conservation Biology 11: 32-40.

Carey, A.B. 1998. Ecological foundations of biodiversity; lessons from natural and managed forests of the Pacific Northwest. Northwest Science 72: 127-133.

Chapin, F.S., III, M.S. Torn, and M. Tateno. 1996. Principles of ecosystem sustainability. American Naturalist 148; 1016-1037.

Cheston, W.C., R.B. Addison, V.A. Holm, and W.G. Swanson. 1975. Bella Coola regional study. Volume 1. British Columbia Forest Service, Special Studies Branch, Victoria, B.C. 197 p.

Clague, J.J., and S.G. Evans. 1994. Formation and failure of natural dams in the Canadian Cordillera. Bulletin 464, Geological Survey of Canada, Ottawa, Ontario.

Clayoquot Sound Scientific Panel. 1995. Sustainable ecosystem management in Clayoquot Sound: Planning and practices. Report 5. Victoria, B.C. 296 p.

Coates, K.D. 1999. Conifer seedling response to northern temperate forest gaps. Forest Ecology and Management *(in press).*

Coates, D. and D. Steventon. 1994. Principles of patch retention harvesting. Extension Note #2, Forests Sciences, Ministry of Forests, Smithers, B.C. 5 p.

Coates, K.D. and D. Steventon. 1995. Patch retention harvesting as a technique for maintaining stand level biodiversity in forests of north central British Columbia. Pages 102-106 *in* C.R. Bamset, ed. Innovative silviculture systems in boreal forests, symposium proceedings. Clear Lake Ltd., Edmonton, AB.

Coates, K.D. and Burton, P. J. 1997. A gap-based approach for development of silvicultural systems to address ecosystem management objectives. For. Ecol. Manage. 99:337-354.

Dale, V.H., J. Agee, J. Long, and B. Noon. 1999. Ecological sustainability is fundamental to managing the national forests and grasslands. Bulletin of the Ecological Society of America 80: 207-209.

Ehrlich, P.R. 1988. The loss of diversity: causes and consequences. Pages 21-27 *in* E.O. Wilson, editor. Biodiversity. National Academy Press, Washington, D.C.

Emmingham, B. 1998. Uneven-aged management in the Pacific Northwest. Journal of Forestry 96: 37-39.

Entry, J.A., and W.H. Emmingham. 1995. Influence of forest age on nutrient availability and storage in coniferous soils of the Oregon Coast Range. Canadian Journal of Forest Research 25: 114-120.

Environment Canada. 1980. Canadian climate normals, 1951-1980. Temperature and precipitation, British Columbia. Atmosperic Environment Service, Downsview, Ontario, 268 p.

Farley, A.L. 1979. Atlas of British Columbia. University of British Columbia Press, Vancouver, B.C.

Franklin, J.F. 1992. Forest stewardship in an ecological age. The ninth annual C.E. Farnsworth Memorial Lecture, Faculty of Forestry, State University of New York College of Environmental Science and Forestry, Syracuse, New York.

Franklin, J.F. 1995. Sustainability of managed temperate forest ecosystems. Pages 355-385 *in* M. Munasinghe and W. Shearer, editors. Defining and measuring sustainability: the biogeophysical foundations. The World Bank, Washington, D.C.

Gavin, D., K.P. Lertzman, L. Brubaker and E. Nelsen. 1996. Long-term fire histories in a coastal temperate rainforest. Bulletin of the Ecological Society of America 77(3): 157.

Gavin, D., K.P. Lertzman, L. Brubaker and E. Nelsen. 1997. Holocene fire size and frequency in a coastal temperate rainforest. Bulletin of the Ecological Society of America 78 (4): 93.

Gimbarzevsky, P. 1988. Mass wasting on the Queen Charlotte Islands: a regional overview. Land Management Report Number 29, B.C. Ministry of Forests, Research Branch, Victoria, B.C.

Goward, T. 1993. Epiphytic lichens: going down with the trees. Pages 153-158 *in* S. Rautio, editor. Community action for endangered species; a public symposium on B.C.'s threatened and endangered species and their habitats. Federation of B.C. Naturalists/Northwest Wildlife Preservation Society, Vancouver, B.C.

Green, R.N., and K. Klinka. 1994. A field guide to site identification and interpretation for the Vancouver Forest Region. Land Management Handbook Number 28, British Columbia Ministry of Forests, Research Branch, Victoria, B.C. 285 p.

Haeussler, S., and D. Yole. 1980. Forest soils and slope stability conditions in the proposed Ocean Falls operating area. Unpublished report, B.C. Ministry of Forests, Research Section, Smithers, B.C.

Hann, W.J. 1992. Management for landscape and ecosystem biodiversity. Pp. 63-71 in Evenden, A.G. (compiler). Proceedings - Northern Region Biodiversity Workshop. 11-13 September 1990, Missoula, Montana. Northern Region, USDA Forest Service, Missoula, Montana.

Hilborn, R., C.J. Walters, and D. Ludwig. 1995. Sustainable exploitation of renewable resources. Annual Review of Ecology and Systematics 26: 45-67.

Holland, S.S. 1976. Landforms of British Columbia. A physiographic outline. Bulletin Number 48 (2d edition). British Columbia Department of Mines and Mineral Resources, Victoria, B.C. 138 p.

Howes, D.E. 1981. Terrain inventory and geological hazards: northern Vancouver Island. Bulletin 5, B.C. Ministry of Environment, Assessment and Planning Division, Victoria, B.C.

Howes, D.E. 1987. A terrain evaluation method for predicting terrain susceptible to post-logging landslide activity: a case study from the southern coast mountains of British Columbia. Technical Report Number 28, B.C. Ministry of Environment and Parks, Recreational Fisheries Branch, Victoria, B.C.

Jones, E.W. 1945. The structure and reproduction of the virgin forest of the north temperate zone. New Phytologist 44:130-148.

Julin, K.R., and C.G. Shaw III. 1999. Science matters: Information for managing the Tongass National Forest. Miscellaneous Publication, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. 28 p.

Jungen, J.R., and T. Lewis. 1978. The coast mountains and islands. Pages 101-120 *in* K.W.G. Valentine, P.N. Sprout, T.E. Baker, and L.M. Lavkulich, editors. The soil landscapes of British Columbia. British Columbia Ministry of Environment, Resource Analysis Branch, Victoria, B.C.

Kelty, M.J. 1992. Comparative productivity of monocultures and mixed-species stands. Pages 125-141 *in* M.J. Kelty, B.C. Larson, and C.D. Oliver, editors. The ecology and silviculture of mixed-species forests. Kluwer Academic Publishers, Dordrecht, Netherlands.

Kiekens, J-P. and R. Clark. 1999. Certification schemes will affect BC's timber harvest. Forum (publication of Association of B.C. Professional Foresters) 6: 9-10.

Kimmins, J.P. 1997. Forest ecology: a foundation for sustainable development. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Klinka, K. and others. 1990.

Klinka, K., J. Pojar, and D.V. Meidinger. 1991. Revision of biogeoclimatic units of coastal British Columbia. Northwest Science 65: 32-47.

Kohm, K.A. and Franklin, J.F. (Eds.) 1997. Creating a Forestry for the 21st Century. Island Press, Washington, D.C.

Kolb, T.E., M.R. Wagner, and W.W. Covington. 1994. Concepts of forest health. Journal of Forestry 92: 10-15.

Kopas, C. l970. Bella Coola. Mitchell Press Limited, Vancouver, B.C.

Larkin, P.A. 1977. An epitaph for the concept of maximum sustained yield. Transactions of the American Fisheries Society 106: 1-11

Lélé, S. and R.B. Norgaard. 1996. Sustainability and the scientist's burden. Conservation Biology 10: 354-365.

Lertzman, K.P., Sutherland, G.D., Inselberg, A. and Saunders, S.C. 1996. Canopy gaps and the landscape mosaic in a coastal temperate rainforest. Ecology 77:1254-1270.

Lertzman, K., Gavin., D., Hallett, D., Brubaker, L., Lepofsky, D., and Mathewes, R. 1998. Long-term fire histories and the dynamics of wet coastal forests. Northwest Science **XXX**.

Lewis, K., J. Crinklaw, and A. Murphy. 1997. Revised study areas for the Central Coast LRMP area. Province of British Columbia, Land Use Coordination Office, Victoria, B.C. 225 p.

Lubchenco, J., and many others. 1991. The sustainable biosphere initiative: an ecological research agenda. Ecology 72: 371-412.

Levin, S.A. 1993. Science and sustainability. Ecological Applications 3: 545-546.

Ludwig, D., R. Hilborn, and C. Walters. 1993. Uncertainty, resource exploitation, and conservation: lessons from history. Science 260: 17, 36.

Mann, C.C. and M. Plummer. 1999. Call for ‘sustainability’ in forests sparks a fire. Science 283: 1996-1998.

Marshall, V.G. 1993. Sustainable forestry and soil fauna diversity. Pages 239-248 *in* M.A. Fenger, E.H. Hamilton, J.A. Johnson, and E.J.R. Williams, editors. Our living legacy. Royal British Columbia Museum, Victoria, B.C.

Matthews, J.D. 1989. Silvicultural Systems. Oxford Scientific Publications, Oxford, UK.

McAvoy, B. Ecological survey of the Bella Coola region. Botanical Gazette 92: 141-171.

Meffe, G.K., P.D. Boersma, D.D. Murphy, B.R. Noon, H.R. Pulliam, M.E. Soulé, and D.M. Waller. 1998. Independent scientific review in natural resource management. Conservation Biology 12: 268-270.

Oliver, C.D. 1981. Forest development in North America following major disturbances. For. Ecol. Manage. 3:153-168.

Oliver, C.D. 1992. A landscape approach - achieving and maintaining biodiversity and economic productivity. Journal of Forestry 90: 20-25.

Parminter, J. 1998. Natural Disturbance Ecology. Pages 3-41 *In*: Voller, J., and S. Harrison (editors). Conservation Biology Principles for Forested Landscapes. U.B.C. Press, Vancouver, B.C.

Prescott, C.E. and G.F. Weetman, editors. 1994 Salal cedar hemlock integrated research program: A synthesis. Faculty of Forestry, University of British Columbia, Vancouver, B.C. 85 p.

Reimchen, T. 1999. Bears, gardeners of the forests. Vancouver Sun, page A17, Sept. 30, 1999.

Robinson, B. 1981. Silviculture activities in the Mid Coast Timber Supply Area. An Interim Report. Unpublished report, B.C. Ministry of Forests, Research, Smithers, B.C.

Ryder, J. 1978. Geology, landforms and surficial materials. Pages 11-33 *in* K.W.G. Valentine, P.N. Sprout, T.E. Baker, and L.M. Lavkulich, editors. The soil landscapes of British Columbia. British Columbia Ministry of Environment, Resource Analysis Branch, Victoria, B.C.

Schmidt, R.L. 1957. The Silvics and Plant Geography of the Genus Abies in the Coastal Forests of British Columbia. Technical Publication T46, Department of Lands and Forests, British Columbia Forest Service, Victoria, B.C.

Schowalter, T.D. 1995. Canopy arthropod communities in relation to forest age and alternative harvest practices in western Oregon. Forest Ecology and Management 78: 115-125.

Schwab, J.W. 1998. Landslides on the Queen Charlotte Islands: processes, rates, and climatic events. Pp. 41-47 In: Hogan, D.L., P.J. Tschaplinski, and S. Chatwin (editors). Carnation Creek and Queen Charlotte Islands Fish/Forestry Workshop: Applying 20 Years of Coast Research to Management Solutions. Land Management Handbook 41, B.C. Ministry of Forests, Research Program, Victoria, B.C.

Scientific Panel for Sustainable Forest Practices in Clayoquot Sound. 1994. Review of current forest practice standards in Clayoquot Sound. Progress Report 2. Cortex Consultants, Halfmoon Bay, B.C.

Scientific Panel for Sustainable Forest Practices in Clayoquot Sound. 1995. Report 5. Sustainable Ecosystem Management in Clayoquot Sound. Planning and Practices. Victoria, B.C.

Sedjo, R.A. 1999. Mission impossible. Journal of Forestry. 97: 13-14.

Septer, D., and J.W. Schwab. 1995. Rainstorm and Flood Damage: Northwest British Columbia 1891-1991. Land Management Handbook 31, B.C. Ministry of Forests, Research Program, Victoria, B.C.

Seely, B., J.P. Kimmins, C. Welham, and K. Scoullar. 1999. Management models: defining stand-level sustainability, exploring stand-level stewardship. Journal of Forestry 97: 4-11.

Shaw, C.H., H. Lundkvist, A. Moldenke, and J.R. Boyle. 1991. The relationships of soil fauna to long-term forest productivity in temperate and boreal ecosystems: processes and research strategies. Pages 39-77 *in* W.J. Dyck and C.A. Mees, editors. Field Trials to Assess Environmental Impacts of Harvesting, Proceedings, IEA/BE T6/A6 Workshop, Florida, USA, February 1990. Report Number 5, FRI Bulletin Number 161. Forest Research Institute, Rotorua, New Zealand.

Smith, D.M., B.C. Larson, M.J. Kelty, and P.M.S. Ashton. 1997. The practice of silviculture. Applied forest ecology, 9th edition. John Wiley & Sons, New York.

Spies, T.A., and J.F. Franklin. 1991. The structure of natural young, mature and old-growth Douglas-fir forests in Oregon and Washington. Pp. 91-109 In: Ruggiero, L.F., K.B. Aubry, A.B. Carey, and M.H. Huff (editors). Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285, USDA Forest Service, Portland, Oregon.

Stathers, R.J., T.P. Rollerson, and S.J. Mitchell. 1994. Windthrow handbook for British Columbia. Working Paper 9401, B.C. Ministry of Forests, Research Branch, Victoria, B.C.

Struhsaker, T.T. 1998. A biologist's perspective on the role of sustainable harvest in conservation. Conservation Biology 12: 930-932.

Swanston, D.N., and D.E. Howes. 1994. Slope movement processes and characteristics. Pp. 1-17 In: Chatwin, S.C., D.E. Howes, J.W. Schwab, and D.N. Swanston (editors). A Guide for Management of Landslide-Prone Terrain in the Pacific Northwest. Land Management Handbook Number 18, B.C. Ministry of Forests, Research Branch, Victoria, B.C.

Weetman, G.F. 1996. Are European silvicultural systems and precedents useful for British Columbia silviculture prescriptions? FRDA Rep. 239, Canadian Forest Service and B.C. Ministry of Forests, Victoria, B.C.

Wills, R.M., and R.G. Lipsey. 1999. An economic strategy to develop non-timber forest products and services in British Columbia. Final Report, Forest Renewal BC Project No. PA97538-ORE.

Willson, M.F., and K.C. Halupka. 1995. Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9: 489-497.

Willson, M.F., S.M. Gende, and B.H. Marston. 1998. Fishes and the forest. BioScience 48: 455-462.

Winchester, N. 1999. Severing the web: changing biodiversity in converted northern temperate ancient coastal rainforests. Northwest Science 72: 124-126.

World Commission on Environment and Development. 1987. Our common future. Oxford University Press, Oxford, UK.

Wright, E.F., K.D Coates, C.D. Canham, and P. Bartemucci. 1998. Species variability in growth response to light across climatic regions in northwestern British Columbia. Canadian Journal of Forest Research 28: 871-886.

Yole, D., J. Pojar, and B. Robinson. 1982. Ecosystem classification of the Coastal Western Hemlock Zone within the Mid-Coast Timber Supply Area, Prince Rupert Forest Region, British Columbia. Unpublished report. B.C. Ministry of Forests, Research Section, Smithers, B.C. 190 p

9.2 References for Sections 5 & 6

_________. 1997. Uneven-aged Silviculture Field Tour. International Forest Products Limited. Unpublished IUFRO tour handout. Tofino, B.C. 28 p.

Andersson, Bjorn; Warren, Francois. 1996. Harvesting Coastal Second-Growth Forests: Hand Falling and Skyline Yarding. Forest Engineering Research Institute Of Canada. Technical Note TN-239. Vancouver, B.C. 14 p.

Andersson, Bjorn; Young, Glen. 1998. Harvesting Coastal Second-Growth Forests: Summary of Harvesting System Performance. Forest Engineering Research Institute Of Canada. Technical Report TR-120. Vancouver, B.C. 37 p.

Beese, Bill. 1999. *Personal Communication*. MacMillan Bloedel Limited. Nanaimo, B.C.

Bennett, D.M. 1997. Partial Cutting in Mountainous Old-Growth Forests in Coastal British Columbia: Harvesting Productivity and Cost, and Residual Stand Impacts. Forest Engineering Research Institute Of Canada. Technical Report TR-119. Vancouver, B.C. 20 p.

Bennett, D.M. 1993. Partial Cutting in a Second-Growth Douglas-Fir Stand in Coastal British Columbia: Productivity, Costs and Soil Impacts. Forest Engineering Research Institute Of Canada. Technical Note TN-199. Vancouver, B.C. 12 p.

Birch, Kevin R.; Johnson, K. Norman. 1992. Stand-Level Wood-Production Costs of Leaving Live, Mature Trees at Regeneration Harvest in Coastal Douglas-fir Stands. Paper 2720 of the Forest Research Laboratory. Oregon State University. Corvallis, Oregon. 4 p.

Boswell, Brian. 1998. Vancouver Island Mechanized Thinning Trials. Technical Note TN-271. Forest Engineering Research Institute of Canada. Vancouver, B.C. 15 p.

British Columbia Institute of Technology. 1996. Introduction to Forest Harvesting Methods. Burnaby, B.C. Course Manual. Modules 1-5. 169 p.

British Columbia Ministry of Forests. 1999. Coast Appraisal Manual. Revenue Branch, Victoria, B.C. 114 p.

British Columbia Ministry of Forests. 1999. Timber Availability and Cost Estimates for the Eliza and Kashutl Landscape Units. Unpublished report prepared by Olivotto Timber for the Vancouver Forest Region. Nanaimo, B.C. 24 p.

Brodie, J.D. 1985. Economic analysis of shelterwood versus clearcut decisions. *In*Proc. Conf. On Shelterwood Management System. J.W. Mann and S.D. Tesch (editors). Oregon State University, For. Res. Lab., Corvallis, Oregon. Pp. 29-32.

Colpitts, Bruce. 1999. Personal Communication. International Forest Products Limited. Hagensborg, B.C.

D'Anjou, Brian. 1999. Roberts Creek Study Forest: Demonstration Shelterwood Block Stand Structure and Regeneration: Five-year Results. Unpublished report. Research Section, Vancouver Forest Region, Ministry of Forests. Nanaimo, B.C. 7 p.

D'Anjou, Brian. 1999. Roberts Creek Study Forest: Phase 1 Douglas-fir and Western Red Cedar Survival and Growth under Three Silviculture System; Second-year Results. Unpublished report. Research Section, Vancouver Forest Region, Ministry of Forests. Nanaimo, B.C. 5 p.

Hansen, Andrew J.; Garman, Steven L.; Weigand, James F.; Urban, Dean C.; McComb, William C.; Raphael, Martin G. 1995. Alternative Silvicultural Regimes in the Pacific Northwest: Simulations of Ecological and Economic Effects. Abstract from the Ecological Society of America. 1 p.

Hedin, I.B. 1996. Shelterwood Harvesting with a Skyline System in a Coastal Second-Growth Forest. Technical Note TN-243. Forest Engineering Research Institute of Canada. Vancouver, B.C. 8 p.

Hedin, I.B. 1994. Shelterwood Harvesting in Coastal Second-Growth Douglas Fir. Technical Note TN-216. Forest Engineering Research Institute of Canada. Vancouver, B.C. 10 p.

Hedin, I.B.; De Long, Deborah L. 1993. Comparison of Harvesting Phases in a Case Study of Partial-Cutting Systems in South Western British Columbia. Special Report SR-85. Forest Engineering Research Institute of Canada. Vancouver, B.C. 16 p.

Howard, Andrew F.; Coultish, Lesley E. 199 . Production Equations for Tower Yarding in Coastal British Columbia. Journal of Forest Engineering. Faculty of Forestry. University of British Columbia. 7 p.

Howard, Andrew F.; Young, G. Glen; Rutherford, Dag. 1993. Alternative Silvicultural And Harvesting Systems For Second-Growth Forests in British Columbia. Working Paper WP-6-003. Faculty of Forestry. University of British Columbia. Vancouver, B.C. 94 p.

Jaccard, Rick. 1999. *Personal Communications*. TimberWest Forest Limited. Mesachie Lake, B.C.

Kellogg, L.D., Pilkerton, S.J., Edwards, R.M. 1991. Logging requirements to meet New Forestry prescriptions. *In* Proc. Conf. On Forestry Operations in the 1990's: Challenges and Solutions. J.F. McNeel and B. Andersson (editors). Council on Forest Engineering, Nanaimo, B.C., pp. 43-49.

LaLari, Indra. 1997. Productivity Analysis of Alternative Harvesting Practices in Clayoquot Sound Under the Clayoquot Sound Scientific Panel Report Recommendations. Unpublished report prepared for International Forest Products Limited. Tofino, B.C. 103 p.

Lawson, Gary. 1999. *Personal Communication*. TimberWest Forest Limited. Campbell River, B.C.

MacDonald, A.J. 1999. Harvesting Systems and Equipment in British Columbia. FERIC Handbook No. HB-12. Forest Engineering Research Institute of Canada, Vancouver/B.C. Ministry of Forests, Forests Practices Branch, Victoria. 197 p.

McDonald, P.M., Atkinson, W.A., Hall, D.O. 1969. Logging costs and cutting methods in young-growth ponderosa pine in California. Journal of Forestry 67(2):109-112.

MacMillan Bloedel Limited. 1999. MacMillan Bloedel Forest Project. First Year Progress Report. Unpublished Ministry of Forests Field Trip Notes. Nanaimo, B.C.

McMillan, Donald. 1999. *Personal Communication*. International Forest Products Limited. Ucluelet, B.C.

Moore, Keith. 1994. The Use of Alternate Silviculture Systems and Alternate Harvesting Practices in the Vancouver Forest Region. Unpublished report prepared for the Ministry of Forests, Vancouver Forest Region. Queen Charlotte City, B.C. 44 p.

Pavel, Mihai. 1998. Harvesting Second Growth Western Hemlock on Vancouver Island: Productivity, Cost and Predicted Log Value. Technical Note TN-278. Forest Engineering Research Institute of Canada. Vancouver, B.C. 7 p.

Phillips, Eric J. 1996. Comparing Silviculture Systems in a Coastal Montane Forest: Productivity and Cost of Harvesting Operations. Forest Engineering Research Institute Of Canada. Special Report SR-109. Vancouver, B.C. 42 p.

Price, Stanley. 1999. *Personal Communication*. MacMillan Bloedel Limited. Hagensborg, B.C.

Seppanen, Tim. 1999. *Personal Communication.* Riparian Environmental Management. Campbell River, B.C.

Skabaikis, Gary. 1999. *Personal Communication.* Western Forest Products Limited. Campbell River, B.C.

Stathers, R.J.; Rollerson, T.P.; Mitchell, S.J. 1994. Windthrow Handbook for British Columbia. Ministry of Forests. Research Program Working Paper 9401. Victoria, B.C. 31 p.

Studier, Donald. 1993. Carriages For Skylines, Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 3. 14 p.

Suther, Graham; Balke, Jennifer. 1997. Alternative Silviculture Systems Data Base: Vancouver Forest Region. Opportunities for Wildlife Research. Unpublished report prepared for the Ministry of Environment, Lands and Parks. Nanaimo, B.C. 75 p.

Tesch, S.D.; Mann, J.W. 1991. Clearcut and shelterwood reproduction methods for regenerating southwest Oregon forests. Oregon State University, For. Res. Lab., Corvallis, Oregon, Res. Bull. 72. 43 p.

Thibodeau, E.D.; Krag, R.K.; Hedin, I.B. 1996. The Date Creek Study: Productivity of Ground-Based Harvesting Methods in the Interior Cedar-Hemlock Zone of British Columbia. Forest Engineering Research Institute Of Canada. Special Report SR-114. Vancouver, B.C. 38 p.

Williams, D.H. 1993. Opportunity Costs of Rules Defining the Timber Harvesting Land Base and Harvesting Order. Consultant's Report prepared for MacMillan Bloedel Limited. Halfmoon Bay, B.C. 13 p.