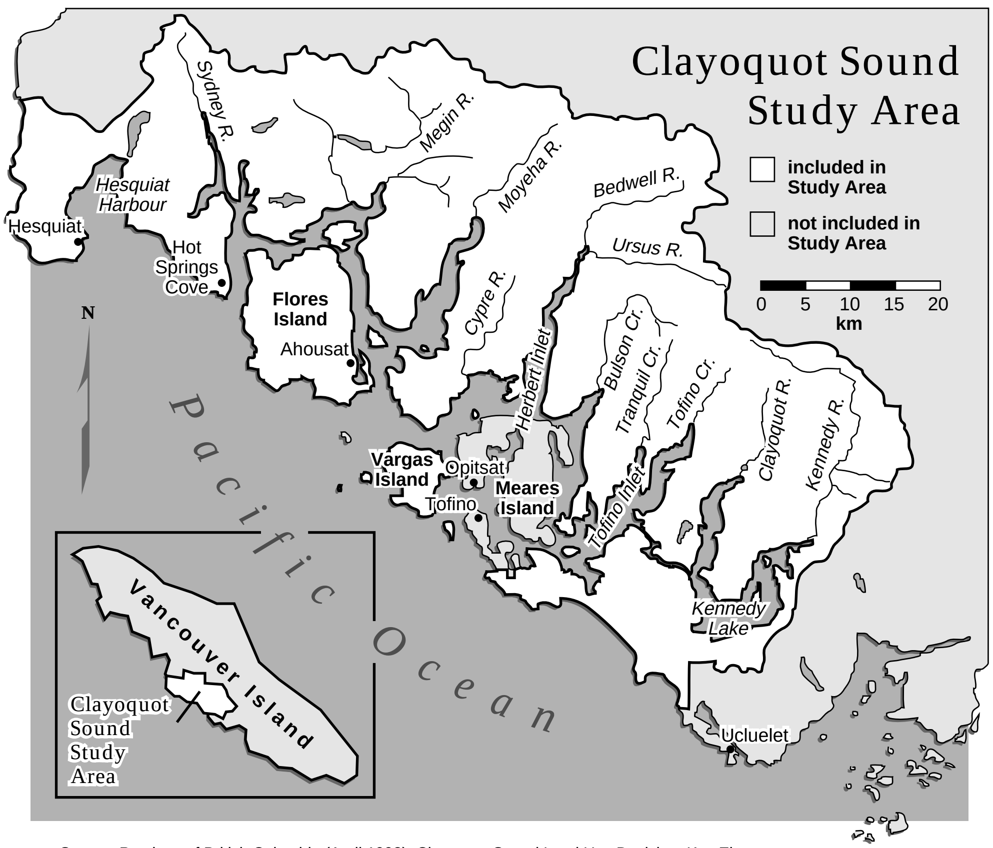
Sustainable Ecosystem Management in Clayoquot Sound

Planning and Practices



Source: Province of British Columbia (April 1993). Clayoquot Sound Land Use Decision: Key Elements.

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Executive Summary

This document presents findings and recommendations of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound based on its review of forest practices standards in effect in Clayoquot Sound as of September 30, 1994.

Panel findings note the extent to which current standards for forest planning and information collection, physical processes of timber extraction, and provisions for incorporating scenic, recreational, and tourism values meet precepts for sustainable ecosystem management.

Ecosystem management must acknowledge the physical structures, processes, and biological constituents of the ecosystem. This document describes those features for the Clayoquot Sound region and makes recommendations appropriate to their nature. Panel recommendations seek to create forest practices standards for Clayoquot Sound that are the best in the world.

Philosophy

Ecosystems, resources, and resource values are interconnected. The Panel asserts that sustainable forest practices in Clayoquot Sound must be judged by the extent to which all resources are respected and sustained. Sustainability depends on maintaining ecosystem productivity and connections.

Two key features have shaped the Panel’s recommendations:

- recognition that ecosystems and the values with which they are imbued are dynamic, and that forest practices and policies must both anticipate and accommodate changing conditions; and

- recognition that forest practices and policies reflect the knowledge, understanding, and values in existence at a point in time.

For such reasons, Panel recommendations invoke the precautionary principle: act cautiously and make subsequent adjustments based on the application of methods tested and found successful in similar environments; support change by diligent monitoring of responses in the Clayoquot environment.

We do not know everything about the ecosystems of Clayoquot Sound, the technology of extraction, or the implications of new management options. The Panel’s mandate is to provide informed advice, supported by science and the experience and knowledge of the Nuu-Chah-Nulth who made this area their home. Policy development and management must proceed adaptively.

Panel recommendations seek to define forest practices that are scientifically sound, operationally achievable, publicly acceptable, and safe. In its deliberations about appropriate forestry practices, the Panel respected the following priorities: safety, ecosystem integrity, operational effectiveness, and visual appearance.

Panel recommendations are intended to provide direction for developing standards that are measurable and enforceable.

Physical Environment

Standards for silvicultural systems, harvesting, and log transport were assessed in light of the physical characteristics and land-shaping processes of the Clayoquot Sound region. Major characteristics of the Clayoquot Sound environment and their implications for management are summarized in the following table.

Characteristic	Management Implication
Heavy precipitation delivers large volumes of water onto steep slopes of mountains; strong winds accompany winter storms.	Rates and patterns of forest removal must be prescribed to minimize disturbance to natural runoff mechanisms and to maintain hydrological regimes within the range of natural variation.
Shallow surficial materials are prone to surface erosion and landslides in the prevailing wet climate when protective vegetation is removed. At many sites, the forest floor layer constitutes the entire soil over bedrock.	Forest practices should strive to maintain the organic layer of forest soils because it contains virtually all of the available nutrients, has high water-absorbing and water-retaining capability, improves soil porosity and permeability, and protects the mineral soil from surface erosion.
Steep slopes, climate, and hydrology create conditions of potential instability in surficial materials. Debris slides and debris flows are triggered by heavy rainfall on ground already saturated by rain.	Clearcutting and roadbuilding increase the frequency of these kinds of landslides. Terrain stability assessment should be undertaken to identify sensitive sites.
Debris slides, debris flows, rockfalls, and shifting stream channels contribute to the natural pattern of forest disturbance. Windstorms are the most common natural agent of forest renewal in Clayoquot Sound.	A dramatic change in the rate of disturbance or rates of erosion may change the balance of available habitats and the viability of species. The rate and distribution of harvest must be planned carefully to minimize negative effects.
Vegetation development is affected by the natural disturbance regime.	Forest practices that approximate natural disturbance regimes help to retain ecosystem processes and maintain ecosystem productivity and connections.
Clayoquot Sound's almost continuous old-growth forests are characterized by uneven canopies with gaps where old trees have died and young ones are regenerating.	Retaining some near-continuous, older forest cover, including large live trees, snags, and downed wood, is particularly important to the region's biological diversity.
Much of the richness of resident terrestrial vertebrates is attributable to varied, complex forest cover.	Forest management regimes should maintain variety in forest structure and species in keeping with that found in unmanaged stands.
The forest canopy affects wind, light, diurnal variation in temperature and moisture, and seasonal patterns of snow accumulation and melt both within the stand and in adjacent open areas.	Forests buffer environmental effects; the pattern and timing of their removal or retention should consider effects on other resources.
The native vertebrate fauna of Clayoquot Sound is shaped by and adapted to an environment strongly influenced by water and dominated by near-continuous, long-lived forests.	Forest practices that significantly modify riparian or aquatic ecosystems can adversely affect many species. Reserves help to maintain and protect old-growth, aquatic, and riparian ecosystems.

The hydroriparian ecosystem—comprised of waterbodies and the immediately adjacent terrestrial environment—deserves special consideration in forest planning and management in Clayoquot Sound. It links estuary to alpine environments, is the focus of activity for a large portion of all fauna, and contains the most diverse flora in a watershed. Populations of some species rarely move between watersheds.

Forests in riparian areas play critical roles in shading, food production, and food-gathering processes within streams. These forests affect the rate of water movement through the soil, are the source of whole trees and smaller wood fragments that help to store gravel in the stream channel and provide habitat for a variety of aquatic organisms, regulate stream velocity, and influence stream channel morphology.

The hydroriparian ecosystem is the major travel corridor for many terrestrial and all aquatic organisms—essentially the skeleton and circulation system of the ecological landscape. About 72% of forest-dwelling vertebrates in Clayoquot Sound use riparian areas. Streams, lakes, and estuaries all provide incubation and rearing environments for trout and salmon. Linkages from terrestrial riparian systems to streams continue to the sea.

These land-water systems are strongly affected by logging and roadbuilding activities which can alter channel morphology, hydrology, water quality, and shading or thermal regimes. Events far upstream, well removed from spawning areas, can influence downstream characteristics and organisms. Changes in the riparian environment that modify physical processes or alter food availability influence the invertebrate faunas and thus may alter fish species composition or abundance. These points emphasize the importance of maintaining vegetation in riparian areas, restricting rates of forest removal (rate-of-cut) within watersheds, carefully locating and constructing roads, and treating watersheds as discrete units.

Key recommendations related to the hydroriparian zone include:

- adopting a new classification system based on characteristics of waterbodies and surrounding land;
- designating the entire hydroriparian zone as a special management zone; and
- defining areas entirely reserved from harvest, or where harvest and road construction are constrained, based on the classification system.

Planning

The Scientific Panel recommends an ecosystem-based approach to planning in which the primary planning objective is to sustain the productivity and natural diversity of the Clayoquot Sound region. Planning at a variety of spatial and temporal scales is critical at all stages of forest ecosystem management.

The Panel recommends three levels of planning—subregional, watershed, and site—and a planning process that is informed, iterative, and adaptive. Each level of planning defines the level beneath it, and lower levels provide details for interpretation and analysis at higher levels. The size, planning focus, and time frame of each recommended planning level is summarized in the following table.

Planning area	Map scale	Planning objectives	Time frame	Other comments
Subregional planning level				
Large areas consisting of aggregations of watersheds; generally greater than 50 000 ha.	1:50 000 to 1:250 000	To identify watershed-level planning units and plan linkages among them. To assess and plan for resources (e.g., scenery, recreation, habitats for wide-ranging wildlife populations) that span large areas. To coordinate and plan monitoring activities for subregional, watershed, and site levels.	100 years with major revisions every 10 years or as required.	Maps should be compiled that integrate all resource information, land-use zones, and locate corridors for recreation or animal migration. Extraction activities that cross watershed boundaries, and locations of cultural, scenic, and recreational resource areas should be identified.
Watershed planning level				
A single watershed or a group of contiguous watersheds; 5 000–35 000 ha.	1:10 000 to 1:20 000	To identify and map reserves and harvestable areas within the watershed planning unit.	100 years, showing projected activities in 10-year increments; revisions every five years or as required.	Reserves are intended to maintain long-term ecosystem integrity, protect First Nations' culturally important areas, and protect recreational and scenic values. Each working unit within the harvestable area must be planned in relation to other existing and potential units.
Site planning level				
One or more discrete units ("working units") proposed for a specific management activity; one hectare to several tens of hectares.	1:2000 to 1:5000	To develop management plans within harvestable areas. In areas identified for resource extraction or development, to determine appropriate levels of retention and appropriate harvesting methods.	10 years, starting five or more years ahead of the work, with revisions every year during active operations.	Site-level planning covers many types of sites and working units; e.g., areas proposed for logging (cutting units), recreation (recreation units), or specifically managed habitat for species at risk (wildlife units).

The planning approach recommended by the Panel differs from current planning methods in three major ways:

- planning is area-based, rather than volume-based;

  The planning process identifies the *area* in the watershed available for timber production, specifies a rate (percentage of area per year) at which the watershed can be harvested, and identifies the locations where harvesting may occur.

- forest reserves, based on credible biological and physical criteria, are designated at the watershed level *before* the delineation of harvestable areas and subsequent planning of specific forestry activities; and
- the timber volume available for harvesting each year from a watershed planning unit is determined by the planning process and depends on the characteristics of the area available for harvesting.

  These harvest levels functionally replace the allowable annual cut in defining expectations for harvestable wood volume from planning areas.

The recommended shift to area-based planning is critical to successfully implement other Panel recommendations and to achieve sustainable ecosystem management. Watershed-level planning is key because the cumulative effects of all land-use activities create stress on ecosystems within individual watersheds.

Managing for Timber Production

Most standards regulating forest practices in coastal British Columbia assume that clearcutting is the silvicultural system of choice. In Clayoquot Sound, clearcutting has been the predominant silvicultural system.

While size of cutblocks and means of forest removal have changed over the past few decades, major impacts of clearcutting and associated road construction remain:

- the essentially even-aged stand structures differ significantly from those created by the natural disturbance regime;
- the morphology of stream channels has been substantially disturbed; and
- other forest values, including cultural, scenic, and recreational, have been negatively affected.

In keeping with the goal of sustainable ecosystem management, the Panel recommends a shift in both planning and implementing timber harvesting—from a focus on the trees removed during harvesting to the trees retained. This shift is embodied at the watershed level by delineating reserves to protect ecosystem integrity and forest values, and carried through at the site level by specifying trees to be retained in individual cutting units.

The *variable-retention silvicultural system* recommended by the Panel provides for:

- the permanent retention of forest “structures” or habitat elements (e.g., large decadent trees, or groups of trees, snags, and downed wood) from the original stand that provide habitat for forest biota; and

- a range of retention levels.

The type, amount, and spatial distribution (e.g., aggregated in small intact patches or dispersed as individual trees or snags) of the retained material depend on site characteristics and management objectives.

Specific recommendations under the variable-retention silvicultural system include:

- on cutting units with significant values for resources other than timber or with sensitive areas, implement high levels of retention—at least 70%;
- on cutting units without significant values for resources other than timber or without sensitive areas, implement lower levels of retention;
- retain a minimum of 15% of the original stand on all cutting units with the exception of very small cutting units (less than four tree heights across); and
- retain a representative cross-section of species and structures of the original stand.

Maintaining the natural size- and age-class distributions of trees helps to retain the natural functioning of the forest-dwelling biota and sustain environmental integrity. Retention silvicultural systems meet many ecological objectives, and facilitate protection of culturally important sites, and scenic and recreational values.

Yarding methods, the means of moving logs from where trees are felled to where they are loaded for further transport, are critical to attaining variable-retention silvicultural objectives. The variable-retention silvicultural system requires yarding methods that:

- are efficient and safe;
- can accommodate different levels and distributions of retention;
- are appropriate to steep slopes;
- minimize soil disturbance and damage to retained trees; and
- require low road densities.

Maintaining log control during yarding is critical to minimize site disturbance, and to maximize yarding productivity in variable-retention silvicultural systems. Lateral reach and partial to full suspension capabilities are often required. For these reasons, skyline yarding is the cable-yarding method best suited for retention silvicultural systems. Ground-based systems can also be used where their impact on the soil and damage to the residual stand is not excessive. Most yarding equipment currently used in Clayoquot Sound can be adapted to a variable-retention silvicultural system.

Logs and other partly manufactured forest products are transported by both roads and water in Clayoquot Sound. The road network is used for hauling logs, access by workers, moving equipment (including heavy equipment), and access by recreational users and residents. Water transport is used to move most logs in Clayoquot Sound to processing facilities.

Roads alter slope hydrology and represent a potentially significant source of negative impacts on slope stability, stream morphology, and water quality. Existing road standards are insufficient to ensure that terrestrial and aquatic ecosystems are adequately protected. With respect to roads, Panel recommendations include requirements for:

- road location decisions to reflect the following priorities:
  - protect sensitive terrain (e.g., stability class V), rare habitats, active floodplain areas, and heritage and cultural features;
  - maintain watershed integrity and ecosystem function; and
  - mitigate potential damage to scenic or recreational values;
- the maximum percentage of the *harvestable area* designated for permanent access (roads and landings) to be determined on a watershed-specific basis, and, in general, to represent less than 5% of the harvestable area in a watershed (7% is allowed under current standards);
- full bench cuts and endhaul construction on main or branch roads consistently greater than 55% slopes; and
- revegetating (preferably with indigenous, non-invasive species) all disturbed areas associated with roads.

During the last two decades, major log handling improvements have reduced the impacts of log dumping. Most logs are now sorted and bundled on land, and dumped into the water for storage before transporting to manufacturing centres on log barges. Sheltered waters, however, are still used for dumping, limited sorting, and booming of logs. To protect the important biological and cultural values of estuarine and marine environments, the Panel recommends:

- developing comprehensive standards for log dump development, operation, and maintenance;
- undertaking ecological, physical, and impact assessments on all proposed log dump sites;
- minimizing the time that logs are in water, especially shallow water;
- locating log dumps at sufficient distances from sensitive areas and at sufficient depths to avoid problems; and

- restoring sites damaged by excessive accumulations of bark, woody debris, or fine organic material.

Education and training programs will be required to provide forest engineers, technicians, and forest workers with the knowledge and skills to plan and implement a variable-retention silvicultural system, appropriate harvesting methods, and environmentally sensitive transportation systems. Training must address both silvicultural objectives, such as habitat and biological diversity, and operational constraints, such as harvesting system requirements, road location and construction requirements, windfirmness, and yarding patterns.

Human Values

Clayoquot Sound is important to people for cultural, spiritual, and scenic values, and for recreational and tourism use. Most residents are economically dependent on local forest and marine resources. Landscape appearance is important to residents and visitors alike for aesthetic reasons and as an indicator of forest health. By recommending forest practices that sustain ecosystem integrity the Panel has sought to secure economic benefits and human values for current and future generations. First Nations' values have been addressed specifically in the Panel report *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound.*

New approaches to scenic resource management have been occurring in Clayoquot Sound as part of the Scenic Corridors Planning Process. Many of the Panel's suggestions for improving integration of scenic values into forest planning have already been implemented in this process.

Other Panel recommendations for incorporating non-timber values in forest practices standards include:

- involving provincial, regional, and local governments, First Nations, recreation and tourism groups, industry and other public groups in inventory, analysis, and planning of scenic, recreational, and tourism resources;

- developing an inventory and analysis system for scenic resources and preparing a long-term plan for managing and protecting these resources;

- developing a new scale to describe visual quality objectives that is easier for the public to understand, is unrelated to silvicultural system terminology, and accounts for uses other than forestry;

- developing plans for recreation and tourism at subregional, watershed, and site levels; and

- integrating the planning of visual landscape management, recreation, and tourism with forest planning and management.

Monitoring

Monitoring is an essential part of active adaptive management and improving management practices. Monitoring in the forest ecosystems of Clayoquot Sound will have three goals:

- to ensure that forest activities and practices comply with prescribed standards for ecosystem integrity and cultural integrity;
- to determine whether the forest practices standards adopted for Clayoquot Sound are appropriate for the intended management objectives; and
- to improve the basis for understanding mechanisms, both natural and those induced by human activity, that cause events and create changes in the ecosystem.

Panel recommendations emphasize the second goal—monitoring to evaluate success in attaining objectives. This requires a long-term monitoring program covering areas that are reserved from land-use practices and areas that will experience land-use practices. To this end, the Panel recommends objectives for monitoring:

- watershed and coastal integrity – including hillslopes and forest soils, stream channels, regional streamflow and water quality, and the coastal zone;
- biological diversity – including genetic variation, vulnerable and rare indigenous species, terrestrial environments, old-growth characteristics, and aquatic environments;
- human activities and values – including areas important to First Nations; scenic, recreational, and tourist values; and regional commodity production; and
- implementation of forest management plans.

For each of these areas, the Panel discusses key indicators for evaluating the success of sustainable ecosystem management, as well as specific monitoring activities. In some cases, alternative monitoring procedures are presented.

Local interest and involvement in monitoring are essential to the success of a monitoring program. To assure program efficacy and technical excellence, a professional land manager is also required. Because of labour requirements, the value of cumulated experience in many aspects of monitoring, and the need to secure local commitment to ensure the continuation of the program, many aspects of monitoring should be the responsibility of participants from local communities.

Clayoquot Sound is an excellent place to test the concept of local responsibility for sustainable ecosystem management.

1.0 Introduction

1.1 Panel Mandate

The Panel's goal is to make forest practices in Clayoquot Sound the best in the world.

This is the fifth, and final, report of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound.[1,2] The Scientific Panel was established in response to a recommendation from the Commission on Resources and Environment following the provincial government's April 13, 1993 decision on land use in Clayoquot Sound. The Panel is charged with scientifically reviewing current forest practices standards in Clayoquot Sound and recommending changes to existing standards to ensure that these practices are sustainable. The Panel's goal, as defined by Premier Harcourt, is "to make forest practices in Clayoquot not only the best in the province, but the best in the world."[3]

The Panel's terms of reference focus on defining sustainable forest practices for the General Integrated Management Area as designated in the *Clayoquot Sound Land Use Decision* April 13, 1993. This report, however, considers the Clayoquot Sound region as a whole, particularly when discussing the physical setting and ecological systems (Chapter 2). Some recommendations (e.g., those involving planning) cannot be limited to the General Integrated Management Area.

The Panel's recommendations seek to define forest practices that are scientifically sound, operationally achievable, publicly acceptable, and safe.

Panel recommendations seek to define forest practices that are scientifically sound, operationally achievable, publicly acceptable and safe. In its deliberations about appropriate forestry practices in the General Integrated Management Area in Clayoquot Sound, the Panel invoked constraints in the order: safety, ecosystem integrity, operational effectiveness, and visual appearance. These recommendations are intended to provide direction for the development of subsequent standards that are measurable and enforceable.

The Panel recognizes the important influence of human values and interests (of both indigenous and non-indigenous people) on the management of resources in Clayoquot Sound. The composition and assignment of the Panel, however, allowed it to address only four broad topics:

1 the underlying physical and biological processes sustaining forest growth;

2 the practices of growing and harvesting trees;

3 scenic values, and recreational and tourism opportunities; and

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[1]The Scientific Panel for Sustainable Forest Practices in Clayoquot Sound will be referred to as the Clayoquot Scientific Panel, Scientific Panel, or Panel throughout this document. A list of Panel members is presented in Appendix V. Clayoquot Sound refers to the 350 000 ha area considered by the *Clayoquot Sound Land Use Decision* (British Columbia 1993a) and not the waterbody itself.

[2]The Panel's previous reports include: *Report of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound, Progress Report 2: Review of Current Forest Practice Standards in Clayoquot Sound*, *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound,* and *A Vision and Its Context: Global Context for Forest Practices in Clayoquot Sound.*

[3]Premier Harcourt's announcement of the Clayoquot Scientific Panel, October 22, 1993.

4 Nuu-Chah-Nulth perspectives on forest values and forest practices.

The Panel has not addressed issues beyond these four broad topics of its mandate and its collective expertise.

1.2 Report Context

1.2.1 Previous Panel Reports

The Panel recommends forest practices that maintain the integrity of watersheds and the diversity of natural ecosystems, while providing for the needs of current and future generations.

In its first report, the Panel outlined guiding principles for forest management in Clayoquot Sound (Scientific Panel 1994b). These principles were used to evaluate current forest practices standards in the region. Findings and recommendations arising from this review are documented in the Panel's second and third reports (Scientific Panel 1994a, 1995b), and in this document.[4]

In its second report, the Panel recommended adoption of forest practices that maintain the integrity of watersheds and the diversity of natural ecosystems in Clayoquot Sound, while providing for the long-term spiritual, cultural, social, and economic needs of current and future generations of humans.

This report presents Panel findings and recommendations related to forest planning and information collection; the physical processes of timber extraction; scenic, recreational, and tourism values; and monitoring.

This report presents the Panel's findings and recommendations related to forest planning and information collection; the physical processes of timber extraction—silvicultural systems, harvesting systems, and transportation systems; scenic, recreational, and tourism values; and monitoring. Findings arise from a review of documents, field reconnaissance, and consideration of Nuu-Chah-Nulth and other local ecological knowledge. Panel recommendations are based on the following principles:

- Responsible land stewardship, including forest management, must respect the land and all living things.
- Ecosystems must be recognized as the functional base from which all goods and services are derived, and provisions must exist for determining and setting levels of resource extraction within the limits and capabilities of ecosystems.
- Planning must be long term and inclusive, linking provincial, regional, and local levels. At each of these levels, sustaining ecosystem productivity must take precedence over specific product outputs.
- Social, environmental, and economic dimensions of resource management must be incorporated into the planning process.
- Inventories must be expanded to include the status, abundance, and distribution of resources and values in Clayoquot Sound and the critical

[4] Forest practice standards in documents dated up to September 30, 1994 have been reviewed. Standards under development or in unreleased draft documents on or after this date were not considered.

factors (e.g., slope stability) that affect timber harvesting or other resource-extracting operations. Some undeveloped areas must remain as baseline reference areas against which managed areas can be compared.

- An effective monitoring program must be implemented and adaptive management practised to improve forest practices and procedures as experience and knowledge are gained.
- As part of adaptive management, research must be undertaken to ensure that the standards set are adequate to maintain long-term ecosystem integrity.
- Information and education are essential for successful implementation of new forest practices standards.
- Resource management policies reflect human values, understanding, and knowledge at a particular point and time. They must be reviewed and revised to keep pace with changes in these states.

1.2.2 Complexity of Timber Production Activities

Few people appreciate the complexity of timber production.

Remarkably few people appreciate the complexity of timber production. Focusing on a single facet, such as method of harvesting, is akin to focusing on the surgical procedure while ignoring the patient's state of health and the purpose of the operation. In this report the inherent complexity of forestry manifests itself in three ways.

- First, to offer an integrated, internally consistent approach to timber production, it was necessary for the Panel to address activities from planning through silviculture, harvesting, and log transport. These diverse sets of activities had to be considered in terms of their suitability to the physical setting and ecological systems of Clayoquot Sound.

The report is arranged in a fashion that allows readers to accumulate explanatory background to subsequent sections.

- Second, because these sets of activities are themselves integrated and interdependent, it is potentially misleading to examine any one section of the report in isolation of other sections. The report is arranged in a fashion that allows readers to accumulate explanatory background to subsequent sections.

  A consequence of this organization is that planning—an activity that should embrace and precede all others—is addressed near the end of the report. It has been assigned that position so that readers will appreciate the need for a new planning hierarchy in light of the significant changes that the Panel recommends in silvicultural, harvesting, and transportation systems, and in managing for scenic, cultural, and tourism values.

- Third, complexity almost always is burdened by uncertainty. The approach to forestry recommended by the Panel incorporates a philosophical departure from previous approaches, which itself invokes uncertainty.

Because of this uncertainty and the range and magnitude of forest values involved, the Panel's approach to forest management is "conservative" in the sense of Kaufmann *et al.* (1994):

> "Conservative" management means giving the benefit of doubt to the resource rather than to its extraction or development. (Kaufmann *et al.* 1994:3)

Panel recommendations invoke the precautionary principle: both management and policy development proceed adaptively.

The principle of proceeding cautiously or conservatively in the face of uncertainty has been elaborated formally as the "precautionary principle." The principle applies when there is uncertainty about possible cumulative effects, irreversible changes, adverse interaction, or negative long-term effects (e.g., Bella and Overton 1972; Perrings 1991). The Panel explicitly recognizes the principle in its recommendations that both management and policy development proceed adaptively.

1.3 Terminology

Ecosystem or watershed "health" or "integrity" are bridging concepts.

In this report, frequent reference is made to ecosystem "health" and to ecosystem "integrity." These terms are meant to signify functioning, self-sustaining systems undergoing no systematic changes as the result of unnatural (i.e., human-induced) manipulations. These are not strictly scientific terms. They are what Ehrenfeld (1992) calls "bridging concepts"—concepts which connect a scientific concept about the state or properties of a system with a social value about the normative or desired state. For example, when referring to our bodies, "health" incorporates human values that are not amenable to strictly scientific measurement. "Health" can be used, however, as a useful reference concept for identifying the *stresses* (another bridging concept) to which bodies, watersheds, or ecosystems are subjected. Identifying symptoms of ecosystem stress and response to stress might lead to a set of diagnostic principles for assessing ecosystem state (Schaeffer *et al.* 1988). It is difficult, however, to define a normal state for ecosystems that are also subject to natural disturbances. Scientific methods can describe changes to a system in response to disturbances, and can determine causal mechanisms for most major disturbances (including major human interventions) but the question whether the system is "healthy" (or "unhealthy") remains a question of value and interpretation. This is appropriate. Managing forests (or any other aspect of the natural environment) entails the recognition and incorporation of human objectives for the system, even when a conscious attempt is made to ground management firmly in scientific principles. Used with care, bridging concepts such as "ecosystem health" and "ecosystem integrity" "…can enrich scientific thought with the values and judgements that make science a human endeavour" (Ehrenfeld 1992:142).

1.4 Report Organization

Chapter 1 provides the background and context for the Panel's review of current forest practices standards in Clayoquot Sound and notes how this document relates to previous Panel reports.

Chapter 2 describes the physical characteristics, ecological features, and human values associated with Clayoquot Sound. These characteristics, in combination with the Panel's guiding principles, provide the framework for the review of current forest practices standards.

Chapter 3 describes silvicultural systems historically used in British Columbia, discusses clearcutting as the prevalent system currently used in Clayoquot Sound, and presents the Panel's findings and recommendations relating to silvicultural systems in Clayoquot Sound.

Chapter 4 focuses on yarding methods as a major component of harvesting systems, and presents the Panel's findings and recommendations related to yarding methods in Clayoquot Sound.

Chapter 5 describes road and water transportation systems for wood and wood products in Clayoquot Sound, and presents the Panel's findings and recommendations related to roads and water transportation in Clayoquot Sound.

Chapter 6 describes scenic, recreational, and tourism values and resources in Clayoquot Sound, and presents the Panel's related findings and recommendations.

Chapter 7 summarizes the planning hierarchy and process that the Panel asserts to be critical to the successful implementation of its recommendations. In particular, it describes the system of reserves the Panel considers essential to maintain ecosystem integrity.

Chapter 8 describes the role of monitoring in forest ecosystem management in Clayoquot Sound, and recommends monitoring procedures to assess the success of new forest practices (that follow Panel recommendations) in achieving their intended objectives.

Chapter 9 lists sources cited in the report.

The recommended approach to sustainable ecosystem management is intact and complete only when all chapters are considered.

The necessarily linear nature of a document hinders communication of wholly integrated concepts. It is ineffective and potentially dangerous, for example, to consider silvicultural systems separately from harvesting and transportation systems. Similarly, the silvicultural system recommended by the Panel cannot be separated from the recommended approach to planning. Chapter boundaries are necessarily arbitrary. Although each chapter provides information critical to understanding subsequent chapters, the recommended approach to sustainable ecosystem management is intact and complete only when all chapters are considered.

Appendices to the report include a list of all Panel recommendations in this report (Appendix I), a classification system for the hydroriparian zone (Appendix II), a discussion of inventory requirements to support planning (Appendix III), a glossary (Appendix IV), and a list of Scientific Panel Members (Appendix V).

2.0 The Clayoquot Sound Environment: *hishuk ish ts'awalk*

Sustainability depends on maintaining ecosystem productivity and connections.

From establishing general and guiding principles to making recommendations for sustainable forest practices, the Clayoquot Scientific Panel has followed the premise that sustainability depends on maintaining ecosystem productivity and connections. The Nuu-Chah-Nulth people, original stewards of the resources of Clayoquot Sound, embrace this concept in the term "***hishuk ish ts'awalk***," or "everything is one." Ecosystems, resources, and resource values are interconnected. The Panel asserts that sustainable forest practices in Clayoquot Sound must be judged by the extent to which *all* resources are respected and sustained.

The Panel believes that selecting and implementing the most appropriate and practical methods for growing and extracting wood from Clayoquot Sound must proceed from understanding the physical, biological, and cultural aspects of the environment and the ways in which they are interrelated. These aspects are reviewed in the following sections.

Photo 2.1

Clayoquot Sound is a region with steep mountains, heavy precipitation, and temperate rainforests. Long inlets extend deep into the coastal mountain ranges.

2.1 The Physical Landscape

Understanding the physical characteristics of the landscape is prerequisite to assessing the adequacy of forest practices standards.

Within Clayoquot Sound, more than 80% of the remaining older forests in the General Integrated Management Area are located on slopes steeper than 30° (about 60%) (Sondheim 1994).[5] In a region of heavy precipitation, this combination of large trees and steep terrain poses significant challenges to many forestry activities. Understanding the physical characteristics of the landscape and the forces shaping them is prerequisite to assessing the adequacy of current forest practices standards and recommending their improvements.

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[5]For operational expediency, the slope characteristics were based on average values for each of the BTM (baseline thematic mapping) polygons. An alternative and more accurate method would have been to base the slope analysis directly on specific locations as derived from digital terrain mapping.

2.1.1 Climate and Hydrology

The weather and climate of Clayoquot Sound are strongly influenced by the region's proximity to the Pacific Ocean and by its mountainous topography. In winter, a succession of frontal storms moves onto the west coast of Vancouver Island, resulting in prolonged and heavy precipitation. Cells of particularly heavy rainfall embedded in storm systems, and topographic steering of winds create considerable local variation in rainfall intensity. Both abundance and intensity of rainfall probably increase with increasing elevation. Precipitation records for weather stations in the vicinity of Clayoquot Sound show that during winter, daily rainfalls of 10–15 mm are not uncommon and extreme values reach 180–220 mm (Table 2.1). Strong winds commonly accompany winter storms. Heavy rainfall (90–140 mm) also occurs occasionally during summer storms. In general, total precipitation decreases inland.

Table 2.1 Extreme daily precipitation
for selected locations on the west coast of Vancouver Island: maximum values for winter (November–February) and summer (June–August).

Weather station	Winter		Summer		Period of record
	Intensity (mm/24 hr)	Date	Intensity (mm/24 hr)	Date	(years)
Tofino	184.2	Feb. 1982	131.3	Aug. 1975	48
Ucluelet (Kennedy Camp)	185.1	Nov. 1978	135.4	July 1972	26
Estevan Point	218.9	Jan. 1944	95.3	Aug. 1909	83
Carnation Creek	222.8	Feb. 1986	97.8	July 1972	20
Port Alberni	127.5	Jan. 1968	52.2	June 1980	30

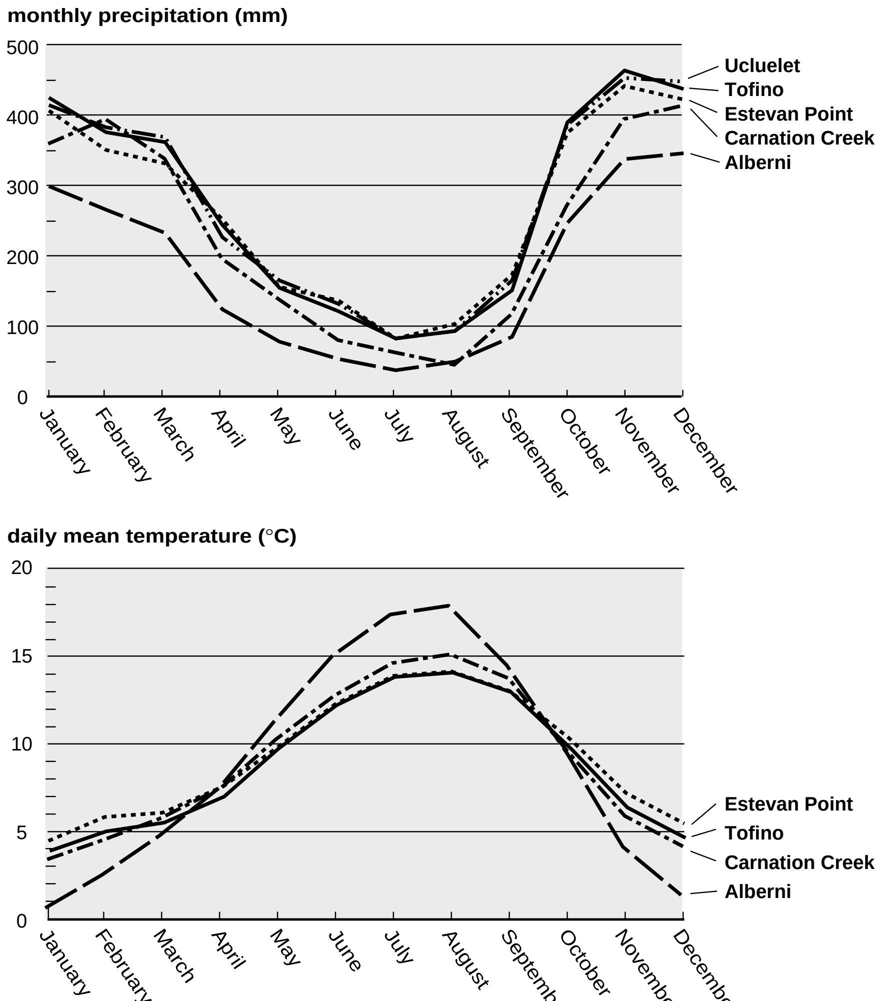
Throughout the year, temperatures are moderated by the ocean, so that winters are relatively mild and summers are relatively cool (Figure 2.1). The elevation at which winter freezing occurs fluctuates widely: rain often falls at high elevations and snow sometimes falls at sea level. Prolonged periods of subzero weather are unusual. Intense winter rain generates the highest stream discharges, particularly when it falls onto melting snow ("rain-on-snow events"). While there is no markedly dry season, the summer months are relatively dry due to prevailing high pressure systems and decreased frequency of storms.

Heavy rainfall delivers large volumes of water onto steep slopes in the mountains of Clayoquot Sound.

Heavy rainfall delivers large volumes of water onto steep slopes in the mountains of Clayoquot Sound. Considerable water is intercepted by the forest canopy, including arboreal mosses and lichens, from where it evaporates. The trees take up more water from the soil through transpiration. Nevertheless, most rainwater is absorbed into the forest soil through which it moves in a network of pores and channels formed by old root channels, animal burrows, and zones of highly permeable soil (Chamberlin 1972). During prolonged or intense rainstorms, most water runs off rapidly through the soil. Unimpeded, rapid drainage through forest soils on steep slopes is a significant factor promoting slope stability (Tsukamoto *et al.* 1982; Sidle *et al.* 1985). Landslides often occur in places where drainage is altered (see Section 2.1.4, Slope Processes).

The extent of forest cover influences the total annual runoff of water, and, in many instances, the timing and peak rate of storm runoff (Hetherington 1987). Construction and maintenance of roads and ditches, and compaction and disturbance of soil alters drainage pathways and hydrological regimes. Standards for location, construction, and maintenance must avoid negative impacts. Rates and patterns of forest removal (rate-of-cut) must be prescribed to minimize disturbance to natural runoff mechanisms and to maintain hydrological regimes within the range of natural variation in a watershed.[6]

Figure 2.1 Mean monthly temperature and precipitation.



[6]In North America, the terms “drainage basin” and “watershed” are used interchangeably to refer to the land surface area drained by a stream system; in Europe, the term watershed refers to the drainage divide between two adjacent drainage basins. In this report, either term refers to drainage basins.

2.1.2 Terrain and Surficial Material[7]

The Clayoquot Sound area encompasses parts of two contrasting physiographic regions: the Estevan Coastal Plain and the Vancouver Island Mountains (Holland 1964). The Estevan Coastal Plain consists of gently undulating or almost flat land that is subdivided into numerous islands and peninsulas by inlets, channels, and Kennedy Lake. The continuity of the plain is further broken by steep, rocky hills, some of which—such as Meares Island—are outliers of the mountains.

The Vancouver Island Mountains are steep and highly dissected.

The Vancouver Island Mountains are steep and highly dissected, with sharp ridgetops and only very small remnants of the gently sloping uplands that are widespread on other parts of Vancouver Island. Valleys are deep glacially eroded troughs, with gentle slopes restricted to valley floors. In the inland parts of the main drainage basins, ridgetops commonly rise to over 1000 m, peaks attain heights of more than 1300 m, and valley sides are commonly steeper than 30° (about 60%). Toward the coast, summit elevations become lower, with ridgetops descending to about 500 m. The coastal inlets extend across this transition zone and well into the mountains.

Both mountains and plain are underlain by a variety of rock types (Jeletzky 1954; Muller and Carson 1969). Most widespread are coarse crystalline metamorphic and intrusive rocks. Older volcanic rocks and sedimentary rocks, including limestone, occupy relatively small areas. All these rocks are cut by numerous steeply dipping faults, most of which run from northwest to southeast, parallel to the general trend of the coast. Erosion of the fault zones has created many tributary valleys and deep gullies. Bedrock outcrops are common on steep slopes and at high elevations. On gentle slopes and in the coastal lowlands, bedrock is generally buried by glacial and post-glacial deposits.

Landforms and land surface characteristics, such as slope stability, are closely related to the distribution and characteristics of surficial materials.

In most parts of Clayoquot Sound, landforms and land surface characteristics, such as slope stability, are closely related to the distribution and characteristics of surficial materials, such as glacial deposits, stream and marine sediments, and colluvium (slope deposits). The physical properties of these materials were determined by their processes of deposition. Deposition took place during the last glaciation, about 12 000 years ago, and continues today (Howes 1981).

Till, the most common glacial material, was deposited directly by melting ice. Basal till, a compact mixture of sand, silt, clay, and stones, accumulated under the ice. Ablation till is the loose debris that melted out on top of the ice. Till covers most gentle to moderately steep slopes in Clayoquot Sound. On steeper slopes, weathered till is naturally susceptible to debris slides and debris flows. Both basal and ablation tills have been modified by gully erosion, most of which probably occurred in early post-glacial time prior to the establishment of a protective cover of vegetation.

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[7]The term “surficial materials” refers to relatively young geological materials, such as glacial till and stream deposits, whereas “soil” refers to the uppermost 1–2 m of these materials that has been modified by physical, chemical, and biological processes.

Glaciofluvial materials, consisting of sand and gravel deposited by glacial meltwater streams, comprise the raised deltas (now prominent terraces) near the heads of most inlets in Clayoquot Sound. These deltas were formed at the end of the last glaciation (about 12 000 years ago), when sea level was as much as 50 m higher than at present (Friele and Hutchinson 1992). Glaciomarine sediments (chiefly silt and sand), which accumulated in shallow marine waters when sea level was higher (Clague *et al.* 1982), now blanket gentle slopes close to sea level. These sediments are most extensive on the coastal plain, but are also present along inlets within the mountains. They are prone to surface erosion and landslides where protective vegetation is removed.

Photo 2.2

Rivers and streams form the core of the hydroriparian system that links uplands with the ocean. Rivers, streams, deltas, and estuaries are sensitive sites which contribute to the biological diversity of Clayoquot Sound.

Shallow surficial materials are prone to mass wasting in the prevailing wet climate.

Since the glaciers receded, weathering, slope processes, streams, and coastal processes (waves and currents) have modified the landscape, resulting in erosional landforms (such as canyons, gullies, and sea cliffs), and the accumulation of colluvium, fluvial (stream) sediments, and marine deposits, including beaches. Downslope movement of weathered glacial materials and bedrock, by processes ranging from rockfall to debris flow, has formed distinctive colluvial landforms such as debris-flow fans and talus cones, as well as a thin covering of rubble on steeper rocky slopes. Fluvial sands and gravels deposited by streams constitute floodplains, river terraces, alluvial fans, and deltas. Post-glacial marine sediments include beach deposits up to 6 m above present sea level that date from a short period of higher sea level 6000 to 5000 years ago (Hebda and Rouse 1979; Clague 1989), and modern beaches.

On the steep terrain of much of Clayoquot Sound, the shallow surficial materials overlying compact glacial till or bedrock are prone to mass wasting in the prevailing wet climate.

2.1.3 Soils

Most of the forest soils in Clayoquot Sound are podzols; folisols and gleysols also occur.

Since the last glaciation, the upper part (about 1–2 m) of surficial materials has been modified by soil-forming processes. Much of the soil-forming activity proceeds invisibly within the forest floor and soil, mediated by microbes, fungi, insects, and other invertebrates.[8] The combination of physical and chemical weathering (breakdown) of mineral material in the moderate perhumid environment produces soils with a higher silt and clay content than the original parent materials. This renders soils more prone to erosion than the surficial materials, particularly if surface organic soil horizons are removed. Most forest soils in Clayoquot Sound are podzols; folisols and gleysols also occur (Jungen and Lewis 1978; Jungen 1985).

Nitrogen and phosphorus commonly limit plant growth.

Podzol soils have developed in till and other surficial materials on well-drained to imperfectly drained slopes which have not been greatly affected by land-shaping processes during the past 12 000 years. Podzols are acidic soils and low in nutrient cations, such as calcium, due to leaching[9] from the year-round heavy rainfall (Lewis 1976). Accumulation of oxides in the lower part of a podzol soil often forms cemented layers of low permeability (“hardpan”), hindering drainage even in gravelly materials with initially high permeability.

The content of plant-available nitrogen and phosphorus, which are both stored largely in soil organic matter, is low in podzols, and nitrogen or both nitrogen and phosphorus commonly limit plant growth. Phosphorus is retained tightly in podzols, either in organic forms or as very slowly soluble mineral forms because of low soil pH. As a result, its release to groundwater and then to streams is minimal. The resulting shortage of phosphorus in west coast streams is the limiting factor for primary production in streams (Stockner and Shortreed 1976, 1978; Mundie *et al.* 1991).

Podzols exert a significant influence on both physical and biological processes. The organic layer (i.e., the forest floor of accumulated forest litter) is usually only 10–30 cm thick, yet it protects against soil erosion, supplies most available nutrients, and supports diverse life in the soil.

At many sites, the forest floor layer constitutes the entire soil over bedrock. Such soils, consisting entirely of forest litter in various stages of decomposition, are termed folisols. These folisols typically occupy 20–40% of the landscape in Clayoquot Sound, being most extensive in rocky terrain, such as in the Bulson watershed. Gleysols are poorly drained mineral soils that occur in flat to depressional areas, commonly on glaciomarine materials and floodplains. The wettest sites have organic soils, ranging from the mucks of western redcedar swamps to the thicker, peaty organics of shore pine bogs and open bogs.

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[8] Invertebrates are creatures without a backbone (vertebrae) (e.g., insects, worms, slugs, spiders, crustaceans).

[9] Leaching is the washing out of nutrients released during weathering and organic matter decay.

It is critical to maintain the organic matter of forest soils.

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 porosity and permeability, and protects the mineral soil from surface erosion.

2.1.4 Land-Shaping Processes

Slope processes, stream erosion and deposition, and coastal processes are continually shaping the land.

Although the present-day landscape of Clayoquot Sound may appear static to the casual observer, slope processes, stream erosion and deposition, and coastal processes, all of which are natural agents of forest disturbance, are continually shaping the land. Slope processes and stream processes are strongly influenced by the passage of water through the landscape, and thus are driven by the intense winter rains and snowmelt.

Slope Processes

Debris slides and debris flows are the most common types of slope movement in Clayoquot Sound.

Debris slides and debris flows[10] are the most common types of slope movement in Clayoquot Sound. A debris slide is triggered when shallow subsurface water saturates the lower part of the soil zone, reducing soil strength sufficiently that the overlying soil and vegetation cover slides downslope (O’Loughlin 1968; Buchanan and Savigny 1989). Usually, the “slip plane” is the sharp boundary that separates the soil from unweathered surficial material or bedrock. Most debris slides involve only a thin (1–2 m) layer of material, yet they result in significant loss of soil and trees, and exposure of unweathered material—usually till or bedrock—in the slide scar. As the sliding, saturated soil moves rapidly downslope, it commonly changes into a debris flow—a highly viscous slurry of soil, stones, trees, and other organic debris that can travel a considerable distance, even on relatively low gradients. Debris flows and slides often enter steep watercourses where they are augmented by streamflow. Debris flows can also start in steep stream channels during floods, when dams of woody debris fail and the sediments that have accumulated behind them begin to move downstream.

Clearcutting and roadbuilding increase the frequency of debris slides and flows.

Debris slides and associated flows are triggered by heavy rainfall on ground already saturated by rain (Church and Miles 1987); by wind stress transmitted to the ground via trees and by tree blowdown (Chatwin *et al.* 1991); by impacts of other gravitational movements such as rockfall or snow avalanches; and by seismic vibrations, which are common (in geological time) on the tectonically active west coast.

[10] In the Pacific Northwest, including British Columbia, debris flows are commonly referred to as “debris torrents.”

Instability associated with older, poorly constructed roads is still apparent.

It has repeatedly been demonstrated from other parts of coastal British Columbia (e.g., O'Loughlin 1968; Rood 1984; Sidle *et al.* 1985; Howes 1987) that clearcutting and roadbuilding increase the frequency of debris slides and flows. Decreased soil strength due to root decay (Buchanan and Savigny 1989), increased soil water, soil disturbance associated with yarding, and increased tree movement in wind, particularly on the edges of cutblocks, all contribute to slope failures in clearcuts. Road construction has contributed to instability by loading steep slopes with sidecast material. Roads also intercept and redirect shallow subsurface water. Investigation of slides initiated in clearcuts at a considerable distance downslope of roads often implicates changes to slope drainage brought about by roads. Montgomery (1994), using observations of ridgetop roads, has shown that increased surface runoff from the compacted road surface above can initiate surface erosion or debris slides downslope. Although practices of building, maintaining, and deactivating roads have improved considerably over the last decade (Chatwin *et al.* 1991), a legacy of instability associated with older, poorly constructed roads is still apparent.

Other slope processes active in Clayoquot Sound, such as rockfalls and rockslides are largely restricted to rocky bluffs and mountainsides that are too steep for logging; their occurrence is therefore less affected by human activities.

Steep slopes, climate, and hydrology create conditions of potential instability in surficial materials.

Steep slopes, climate, and hydrology create conditions of potential instability in surficial materials at many sites in the Clayoquot Sound region. Assessing slope stability, avoiding activities on unstable slopes, and carefully prescribing appropriate harvesting practices on steep and marginally stable slopes are essential to avoid increasing erosion rates above natural levels. The location, method, rate, and patterns of tree removal, and the location, construction, and maintenance of roads are particularly significant. The local variability of topography, terrain, and drainage necessitates detailed evaluation of these conditions to permit identification and assessment of potentially unstable areas.

Stream Processes

Within each watershed, the drainage network comprises a variety of channel and lake types, each with distinctive ecological habitats. Streams range from tiny rivulets at the highest elevations, to large channels on the floors of major valleys. All drainage components, even ephemeral channels on steep mountainsides, have riparian areas along streambanks where increased soil moisture supports distinctive vegetation. The presence of water and its influence on adjacent vegetation results in high levels of animal use of riparian areas. Riparian areas are most extensive on valley floors where they commonly include the alluvial flats of floodplains, alluvial fans, and deltas. The morphology of these landforms and the variety of ecological habitats that they support—such as side channels, backswamps, bars, and islands—result from the long-term behaviour of the streams.

Photo 2.3

Streams and rivers provide habitat for aquatic organisms, transport sediments and organic debris, and are a major influence on the character of the Clayoquot Sound ecosystem.

The characteristics of stream channels and floodplains are determined by inputs of water, sediment, and organic debris.

The characteristics of stream channels and floodplains are determined by inputs of water, sediment, and organic debris, and by the morphology and materials of the landscape through which the stream flows (Church 1992). Downcutting by water, the dominant process along fast-flowing streams with steep gradients, forms gullies and bedrock canyons in rugged terrain. On lower gradients, streams have deposited sediment, forming floodplains and alluvial fans. Deltas have developed where the major streams flow into the ocean or lakes.

Sediments are supplied to streams from valley sides by debris slides, debris flows, and other mass movements, and by erosion of channel banks and beds.

Sediments are supplied to streams from valley sides by debris slides, debris flows, and other mass movements, and by erosion of channel banks and beds. Abundant organic debris—including whole trees—enters streams as a result of these processes. Accumulations of large wood pieces lodged in the channel regulate the movement of sediments and smaller organic debris (Beschta 1979; Bilby 1981), and provide habitat for stream fauna. Sediments and organic debris move downstream during periods of high flow associated with storms and spring snowmelt. Sandy and gravelly stream sediments are stored in channel bars and riffles during periods of low water. Frequent movement of the gravels keeps them free of fine sediments, and creates the spawning environment required by salmon and trout. A continual, moderate supply of gravel to the stream is necessary to maintain spawning gravels.

Fine sediment in the channel may degrade the quality of spawning gravels.

Stream channel morphology (e.g., width-to-depth ratio, spacing of riffles, and texture of the sediments constituting the channel bed) depends on the characteristics of sediment and woody debris supplied from upstream, as well as the volume and timing of flows (Keller and Swanson 1979). Changes in the supply of any of these three components may change stream morphology. For example, the entry of debris flows into a channel from natural causes, logging, or roadbuilding, brings both fine (sand, silt) and coarse (gravel, boulders) sediments, as well as fine and coarse organic debris (roots, branches, and logs). Over short periods, fine sediment in the channel may degrade the quality of spawning gravels and, in sufficiently high quantities, affects the foraging success, behaviour, and even the survival of aquatic organisms, including fish. In the long run, increased gravel may build up the channel bed (aggradation), produce channel spillage onto the adjacent vegetated floodplain, and create a wider but shallower channel with decreased capability for rearing fish.

Coastal Processes

The stability of beaches may be related to the presence of large organic debris.

In Clayoquot Sound, much of the coast is rocky and beaches are of limited extent except on the outer coast (Clague and Bornhold 1980). Beaches have developed where sandy and gravelly sediments are supplied by wave erosion of bluffs composed of glacial deposits, where wave action has pushed submarine glacial deposits onto low shores, and where streams deliver sediment to the shore. The supply of beach sands and gravels is not prolific on this coast (ibid.). The stability of some beaches may be related to the presence of large organic debris: log barriers are common along the backshore, and in recent decades, more beach logs may have resulted from escapement from log booms and stream- or river-fed debris following logging. Although beaches are not widespread, they are the foci of many activities in Clayoquot Sound. Rocky shores are equally important: the rocky subtidal zone is a productive habitat, the maintenance of which depends on the absence of fine sediments. On both beaches and rocky coasts, the influx of increased quantities of fine sediment may alter the characteristics or reduce the quality of the coastal environment.

Photo 2.4

Logs have accumulated on many beaches and influence beach stability and species present.

Forest Disturbance

Debris slides, debris flows, rockfalls, and shifting stream channels contribute to the natural pattern of forest disturbance.

Debris slides, debris flows, rockfalls, shifting stream channels on floodplains and fans, and coastal processes such as bluff erosion contribute to the natural pattern of forest disturbance. These disturbances range from minor effects, such as the impacts of a single, bouncing boulder, to destruction of the forest over several hectares resulting from a landslide or channel avulsion.[11]

Relatively immature soils and vegetation occupy these small sites of recent disturbance, adding to forest diversity. However, a dramatic change in the rate of disturbance, or rates of erosion—such as can occur with poorly planned forest harvesting—may change the balance of available habitats and affect the viability of many species. Careful planning of the rate and distribution of harvest is necessary to minimize the effect of deliberate forest removal on ecosystems.

[11] Channel avulsion is an abrupt diversion of the stream channel from one course to another during a flood or as a result of blockage of the original channel by sediment or woody debris.

Disturbances other than land-shaping processes, such as windthrow, also significantly affect forest development in Clayoquot Sound (Section 2.2).

2.2 The Ecological Landscape

Knowledge of how ecosystems maintain and renew themselves is a necessary prerequisite to selecting silvicultural systems and determining harvesting and transportation systems.

A distinguishing characteristic of an ecosystem is its natural disturbance regime.

There is a continual turnover of living organisms—even in what appear to be stable ecosystems. Forest trees are long-lived but not immortal. Their deaths are most often due to natural changes such as the land-shaping processes noted, windthrow, and fire. Because forest cover is naturally renewed by events that may dramatically alter or disturb existing cover, the common pattern of these events is called the "natural disturbance regime." One of the distinguishing characteristics of any given ecosystem is its natural disturbance regime, which is governed by the regional climate and physiography. For example, in the wet climate of the west coast portion of the coastal temperate rainforest, fires are smaller on average, and less frequent than on the drier east coast of Vancouver Island. On the west coast of Vancouver Island, windthrow is the principal agent of disturbance, whereas on the east coast of the island, fire often dominates.

Wild forests renew themselves naturally in a manner that depends on the natural disturbance regime of their region. Logging is a recent disturbance that inevitably alters the pattern of renewal. Ecological knowledge can be used, however, to ensure that the changes caused by logging, and the forests that regenerate after logging, are not dramatically different from those created by the natural disturbance regimes. Forest practices that approximate natural disturbance regimes help to retain ecosystem processes and maintain ecosystem productivity and connections.

2.2.1 Biogeoclimatic Units

Based on vegetation and climate, the forests of Clayoquot Sound have been classified in terms of biogeoclimatic units (Meidinger and Pojar (editors) 1991), that is, into "zones," "subzones," and "variants" as shown in Figure 2.2. In the Coastal Western Hemlock zone, a fourth hierarchical level (below variant), referred to as the "phase," is commonly recognized. Phases relate to forest patterns resulting from natural disturbances.

All forests of the Coastal Western Hemlock (CWH) zone are recognized as "coastal temperate rainforest."

All forests of the Coastal Western Hemlock zone are recognized as "coastal temperate rainforest." These rainforests occur in widely scattered locations around the world but the global distribution is centred on the Pacific coasts of North and South America. In North America, which accounts for approximately half of the world's coastal temperate rainforest, rainforest distribution is centred on Vancouver Island. Researchers have distinguished four major subgroups of

In North America, rainforest distribution is centred on Vancouver Island.

coastal temperate rainforest (Kellogg 1992). Forests on Vancouver Island belong to two of these subgroups: perhumid and seasonal temperate rainforests. The boundary between these two subgroups is presently uncertain; forests of the Coastal Western Hemlock zone in Clayoquot Sound are predominantly perhumid temperate rainforests. Seasonal temperate rainforests, if they occur, would be restricted to the valley of the upper Kennedy River.[12]

The CWH zone is divided into subzones based on annual and growing season precipitation, and maritime influence.

The Coastal Western Hemlock (CWH) zone includes all forests less than 900 m above sea level in Clayoquot Sound (Figure 2.3). Western hemlock *(Tsuga heterophylla)* is a dominant or codominant tree species throughout; western redcedar *(Thuja plicata)*, amabilis fir *(Abies amabilis)*, yellow-cedar *(Chamaecyparis nootkatensis)*, Sitka spruce *(Picea sitchensis)*, Douglas-fir *(Pseudotsuga menziesii)*, and red alder *(Alnus rubra)* also occur under differing conditions. This zone is divided into subzones based on annual and growing season precipitation, and maritime influence.

The Very Wet Hypermaritime subzone lies along the outer coast of Clayoquot Sound in areas of relatively subdued terrain where the marine influences govern the climate. Temperatures rarely become very hot or very cold, evapotranspiration is low, low cloud and fog are frequent, and the soil remains cool and wet throughout the summer. Extensive bogs with poorly drained organic soils have developed, notably on the low-lying Estevan Coastal Plain. Western redcedar and western hemlock are abundant, lodgepole pine ("shore pine," *Pinus contorta*) and sometimes yellow-cedar occur on bogs, and a band of Sitka spruce forest grows along exposed shores where winds carry salt spray inland. Two variants are described for the Very Wet Hypermaritime subzone; only one, the Southern Very Wet Hypermaritime biogeoclimatic variant, occurs in Clayoquot Sound, at elevations generally below 150 m.

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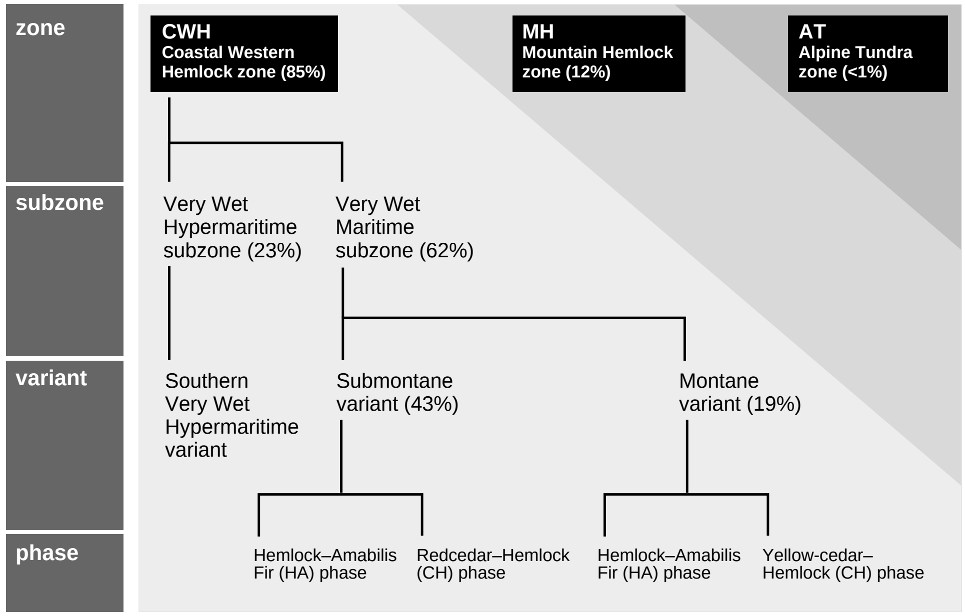
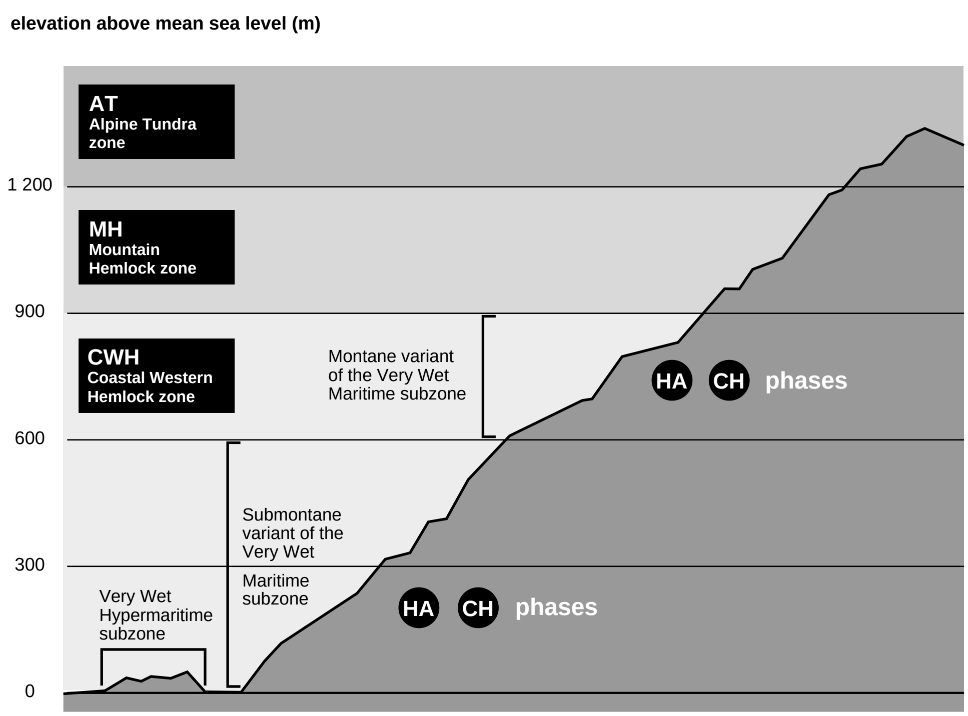
[12] The boundary between the perhumid and seasonal temperate rainforests as illustrated in Conservation International *et al.* (1994) is apparently in error.

Figure 2.2 **Biogeoclimatic units in Clayoquot Sound.**[1]



[1]Percentages calculated from *Clayoquot Sound Sustainable Development Strategy* (Clayoquot Sound Sustainable Development Strategy Steering Committee 1992:31). Lakes cover about 3% of the area.

Figure 2.3 **Location of biogeoclimatic units by representative landscape section.** (Phases defined in Figure 2.2.)



Most of the forests of Clayoquot Sound occur in the Very Wet Maritime subzone; western hemlock, western redcedar, and amabilis fir are characteristic tree species. The subzone is divided into two variants on the basis of elevation. The Submontane variant lies below about 600 m above sea level (Figure 2.3). This variant can be differentiated into two phases (HA and CH) which are associated with different patterns of disturbance.

Windstorms cause major natural disturbances to forests in Clayoquot Sound, and are the most common natural agent of forest disruption and renewal.

The two dominant tree species of the Hemlock–Amabilis Fir (HA) phase appear to be favoured by a disturbance regime in which patches of forest ranging from clumps of a few trees to stands of several hundred hectares are episodically blown down by wind. Blowdowns provide space for the growth of young trees (“advanced regeneration”) that were previously shaded by the windthrown trees. Low mounds of soil produced by the upturned root wads of windthrown trees are a seedbed for western hemlock, amabilis fir and other species. The HA phase appears to be self-perpetuating because the stand structure following windfall (dense canopies with high “sail” area, and shallow-rooted trees often on the tops of hummocks) makes the forest susceptible to further windfall and subsequent recruitment of the same species. Forests of this phase have an understory dominated by *Vaccinium* species and mosses.

The Cedar–Hemlock (CH) phase is dominated by western redcedar with a subcanopy of western hemlock and, frequently, a dense understory of salal. Stands have a more open structure than those of HA-phase forests: the crowns are less dense and many of the western redcedars are spike-topped. Consequently, the canopy offers less resistance to wind. This, along with western redcedar’s somewhat firmer rooting habit, makes CH-phase stands more windfirm than HA-phase stands. Wind is still a major factor in the natural disturbance regime, but the trees blown down in CH-phase forests tend to be isolated individuals; clumped windfalls rarely occur, even along cutblock edges.

Between 600 and 900 m above sea level lies the Montane variant, the second variant of the Very Wet Maritime subzone. This variant is a transition between low- and high-elevation forests. Rising from sea level, the climate becomes steadily cooler and foggier than in the Submontane variant. Fog here is from cloud drift onto mountains; fog at the lowest elevations in the Very Wet Hypermaritime and Maritime subzones (Figure 2.3) results from surface advection over the cool ocean. At higher levels, a short-lived snowpack up to 2 m deep forms in winter; it is often dissipated by major rain-on-snow events. Going upslope, yellow-cedar gradually replaces western redcedar. Two disturbance phases of the Montane variant are discernible as in the Submontane variant. However, in the Montane variant, the HA phase contains a comparatively high proportion of amabilis fir, while the CH phase is dominated by yellow-cedar rather than by western redcedar.

The second major biogeoclimatic zone represented in Clayoquot Sound is the Mountain Hemlock (MH) zone. This zone, where mountain hemlock *(Tsuga mertensiana)* replaces western hemlock, occupies the land above 900 m elevation up to the Alpine Tundra (AT) zone (i.e., to tree line). Yellow-cedar is also abundant, and amabilis fir is common. In the lower part of the MH zone, the forest canopy is closed. Upslope, the forest opens up markedly into a parkland, where individual trees and clumps of trees are interspersed with heath communities. The AT zone occurs above the MH zone and, by definition, is not forested.

The biogeoclimatic classification system reflects ecosystem capabilities and helps to define sustainable limits of resource extraction.

The biogeoclimatic ecological classification system is used to assist planning. By reflecting the capabilities of ecosystems it helps to define the sustainable limits of resource extraction. This classification system guides Pre-harvest Silviculture Prescriptions, including the choice of site preparation method, tree species for regeneration (both preferred and acceptable species), and stocking levels for managed stands (e.g., Klinka *et al.* 1984). It also suggests the natural patterns of disturbance expected on different sites.

2.2.2 Terrestrial Ecosystems: Vegetation

Vegetation development is affected by the natural disturbance regime.

Vegetation development is affected by the natural disturbance regime. Clayoquot Sound forests are shaped by both major stand-initiating disturbances and minor within-stand disturbances. The former are much less common than the latter. The combination of large- and small-scale disturbances creates structurally and biologically diverse environments.

The intensity of disturbance also varies. High-intensity disturbances, such as landslides or very hot fires, kill most of the vegetation in the affected area. Low-intensity disturbances, such as partial blowdown or “cool” wildfires, damage but do not destroy all local vegetation. In Clayoquot Sound, large-scale disturbances such as extensive blowdowns or wildfires are often of low intensity and recur after long intervals—400–1000 years or more. Small-scale, intense disturbances, while more common, are still relatively infrequent; in Clayoquot Sound, hot wildfires are particularly rare.

The big openings created by infrequent large-scale disturbances usually exhibit a high degree of internal heterogeneity. Residual pockets of undamaged vegetation and numerous isolated living trees, as well as abundant standing dead trees (snags) and fallen dead trees (downed wood) often survive these disturbances. These remnants of the old forest provide valuable structural (and, therefore, habitat) diversity within the young, natural forests that subsequently grow in the area (Bunnell and Allaye-Chan 1984; Hansen *et al.* 1991; Swanson and Franklin 1992; Dupuis *et al.* 1995). Individual stumps, logs, and snags can persist for several hundred years.

Clayoquot Sound's almost continuous old-growth forests contain great quantities of biomass.

Clayoquot Sound's almost continuous old-growth forests contain great quantities of biomass, distinguishing them from forests of drier climates, such as interior Douglas-fir forests. The volume of standing live trees on lower slopes of the CWH zone is about 600–900 m^3 / ha, and within the less productive MH zone, about 300–500 m^3 / ha. The comparable volume of downed wood on similar sites can range from greater than 400 m^3 / ha, to less than 70 m^3 / ha, respectively.[13] In addition, substantial volumes of standing dead and decaying trees can be found. This massive accumulated biomass supports the numerous species that depend on large living trees or dead wood, and gives the forests their great economic value.

These forests are characterized by uneven canopies with gaps where old trees have died and young ones are regenerating.

These forests are characterized by uneven canopies with gaps where old trees have died and young ones are regenerating in well-developed understory layers, and by trees of a wide range of ages and sizes. Small openings of less than 0.2 ha, where only a few trees have died, are common in old-growth forests (on average, gaps constitute about 14% of the old-growth area).[14] In such openings, the dead trees—which result from various events (e.g., windthrow, snapping part way up the bole, disease)—are often in different stages of decay. The variety of forms of dead wood provides correspondingly diverse habitats for numerous organisms and facilitates a wide range of ecological processes. Canopy gaps are associated with a well-developed and diverse understory vegetation layer which is often more productive than in adjacent closed canopy areas (Alaback 1984; Inselberg 1993).

Photo 2.5

An ecologically healthy forest includes dead and dying trees. Fallen trees create gaps in forests and provide coarse woody debris. The coarse woody debris and the vegetation that subsequently develops in the gap contribute to the diverse structure of old-growth forests.

Canopy gaps created by tree mortality and the subsequent growth in these gaps of younger trees results in an old-growth forest where the death of old trees is roughly balanced by the growth of young ones. In this way, all the trees in the forest can be eventually replaced without a major disturbance. Estimates of the time for the forest to "turn over" through such gap–phase replacement ranges

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[13] R.J. Keenan and A. Inselberg, unpublished data, 1992.

[14] K.P. Lertzman and A. Inselberg, unpublished data, 1992.

from 300 to 1000 years for a variety of sites in Clayoquot Sound and related forest types on the Lower Mainland of British Columbia (Lertzman and Krebs 1991).[15]

Most stands are dominated by old trees of species that are among the largest and most long-lived in the world.

Because of the long intervals between disturbances, most stands are dominated by old trees of species that are among the largest and most long-lived in the world (e.g., western redcedar and yellow-cedar; Pojar and MacKinnon (editors) 1994:16). Old-growth forests in Clayoquot Sound can represent true all-aged stands. For instance, in one stand containing amabilis fir, western redcedar, yellow-cedar, and western hemlock, ages were distributed continuously from young saplings to trees almost 1000 years in age.[16] These forests are structurally complex and provide microhabitats for a great variety of plants, animals, fungi, and micro-organisms. Some plant and lichen species in Clayoquot Sound do best in, or are limited to, such old-growth forests. In some cases, the association with old-growth or closed-canopy forests is a function of microclimate.

The forest canopy affects wind, light, diurnal variation in temperature and moisture, and seasonal patterns of snow accumulation and melt both within the stand and in adjacent open areas. This microclimatic influence of the forest canopy extends from less than half a tree height[17] to as much as six to eight tree heights into a stand (and likely as far from a stand into an opening), depending on the variable measured. For most variables, the microclimatic influence of the canopy is negligible beyond two to three tree heights from the stand edge (Chen *et al.* 1995). Examples of direct responses to these microclimatic variables can be seen in the distribution, reproduction, and growth of various species of plants.

Forests offer a wide range of habitats, many of which are important to small, non-vascular plants, lichens, and fungi.

Forests offer a wide range of habitats, many of which are important to small non-vascular plants, lichens, and fungi.[18] Unfortunately, very little is known of the non-vascular flora of Clayoquot Sound. One species of lichen, however, is found only near the shores of Clayoquot Sound (Goward 1994).[19] More is known about the area's vascular plants (herbs, grasses, shrubs, and trees), but no comprehensive survey has yet been attempted. Generally, forests of the CWH zone have fewer vascular plant species than the forests in some other biogeoclimatic zones; nonetheless, a 400 m^2 plot typically contains about 20 different species (Pojar *et al.* 1992).

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[15] Also, K.P. Lertzman and A. Inselberg, unpublished data, 1992; A. Arsenault, unpublished data, 1994.

[16] A. Arsenault, unpublished data, 1994.

[17] All references to tree heights refer to average "site potential tree height." Although taller trees are present, the Panel has assumed that 50 m is representative potential for stands growing on productive sites.

[18] Non-vascular plants include algae, mosses and liverworts.

[19] The *Status Report on the Seaside Centipede Lichen* *Heteroderma sitchensis* recommends that the Committee on the Status of Endangered Wildlife in Canada list this species as endangered.

Photo 2.6

Ecosystem management includes maintenance of ecological processes. These processes rely, in part, on contributions made by non-vascular plants such as lichens and fungi.

The ecological importance of the non-vascular flora, the lichens, and the fungi, cannot be overestimated. Slowly decaying mosses contribute to the soil's water-retaining capacity and, after death, form an important component of the soil organic matter. The life of the forest depends on an abundant and active fungal community. Many of the fungal species are partners in mycorrhizae, which are essential for normal growth of trees. Other fungal species decompose dead wood, and hence facilitate nutrient cycling. The life cycles of slime moulds, lichens, and bacteria are also part of the functioning ecosystem.

Many of the area's plant species are used by the Nuu-Chah-Nulth people. For example, salal berries (*Gaultheria shallon*), salmonberries (*Rubus spectabilis),* red huckleberries (*Vaccinium parvifolium*), evergreen huckleberries (*Vaccinium ovatum*), and oval-leaved blueberries (*Vaccinium ovalifolium*) are important edible wild fruits still used by Nuu-Chah-Nulth families. Woods of yew (*Taxus brevifolia*), yellow-cedar, western redcedar, and red alder are important materials for carving by Nuu-Chah-Nulth artists. Basket-makers still harvest tall basket sedge (*Carex obnupta*), American bulrush (*Scirpus americanus*), and the inner bark of western redcedar and yellow-cedar. Important medicinal plants are numerous, and include species such as wild lily-of-the-valley (*Maianthemum dilatatum*), skunk cabbage (*Lysichiton americanum*), red alder, yarrow (*Achillea millefolium*), devil's club (*Oplopanax horridus*), and cascara (*Rhamnus purshiana*).[20]

A very high proportion of Clayoquot Sound forests are in late successional stages as a result of the region's natural disturbance regime. For example, in three undeveloped watersheds (Ursus Creek, Sidney River, Clayoquot River) the percentage of forests in age classes 8 and 9 (greater than 141 years) exceeds 98.5%.[21] This greatly influences the region's biological diversity (see also Section 2.2.3). To maintain biological diversity an ecosystem management policy is required to ensure retention of extensive areas with old-growth attributes and retention of some old-growth attributes across the managed landscape.

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[20] Appendix V of the report *First Nations' Perspectives Relating to Forest Practices Standards In Clayoquot Sound* (Scientific Panel 1995c) contains a detailed list of species important to the Nuu-Chah-Nulth of Clayoquot Sound.

[21] Data supplied by B.C. Ministry of Forests Inventory Branch.

2.2.3 Terrestrial Ecosystems: Fauna[22]

Large, structurally complex trees provide habitats for a wide range of animals.

The diversity of forest fauna is governed by the species and structural diversity of the vegetation. Plants are at the bottom of all food chains; and plants, especially the large, structurally complex trees, provide the required habitats for a wide range of animals, both vertebrates (e.g., small mammals, cavity-nesting birds, amphibians) and invertebrates (e.g., insects, gastropods). The plants of the hydroriparian ecosystem (Section 2.2.4) are an especially diverse component of the vegetation. Non-forest vegetation, such as that found in bogs, on rock outcrops, in subalpine parkland, and in the alpine tundra of Clayoquot Sound, contributes much to the region's diversity of ecosystems and animal species.

Photo 2.7

Tree frogs are part of the biological diversity of Clayoquot Sound. Most amphibians require specific aquatic and terrestrial habitats, including a moist microclimate.

As elsewhere, most of the terrestrial or land-dwelling fauna of Clayoquot Sound is comprised of invertebrates. These species make critical contributions to ecosystem processes such as soil building, decomposition, nutrient cycling, pollination, and seed or spore dispersal. Invertebrates also are key components of terrestrial and aquatic food chains, being important food for vertebrate species. Despite their importance to ecosystem functions, very little is known about the invertebrates of Clayoquot Sound. The Panel is aware of no studies of the soil-dwelling fauna in Clayoquot Sound, but work has occurred in similar ecosystems on northern Vancouver Island (Battigelli *et al.* 1994). Recent work in the Carmanah watershed on canopy-dwelling insects quickly discovered species new to science.[23] Carmanah is close to Clayoquot Sound and similar in vegetation; it is reasonable to assume that the tree canopies of Clayoquot Sound are equally rich in insects and spiders.

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[22]This section is adapted from Bunnell and Chan-McLeod (1995).

[23]R. Ring and N. Winchester, pers. comm., March 1995. Preliminary work in the Sitka spruce canopy in Carmanah indicates a complex community containing many more species than found in Douglas-fir–western hemlock canopies of Oregon (see Schowalter 1989).

Photo 2.8

Bald eagles are common throughout Clayoquot Sound. Impacts of forest harvesting activities can be reduced by ensuring eagles are not disturbed during sensitive periods.

Clayoquot Sound is particularly rich in vertebrates, especially birds.

The vertebrates of Clayoquot Sound (i.e., amphibians, reptiles, birds, and mammals) are better known. Like the invertebrates, vertebrates are important components of ecosystem processes, particularly decomposition, nutrient cycling, and seed and spore dispersal. They are also links in the food chains that permit a diversity of species to exist in an area. Clayoquot Sound is particularly rich in vertebrates, especially birds. Of the 368 vertebrate species known for the region of coastal temperate rainforest between Alaska and northern Oregon, 297 have been observed in Clayoquot Sound (Table 2.2). Bats have not been studied in the area and several species, as yet unrecorded, may well occur there. About 20 species of marine mammals have been reported from near-shore waters.

Table 2.2 Number of native land-dwelling vertebrates in Clayoquot Sound region and related forest types.

Zone	Amphibians	Reptiles	Birds	Mammals	Total
Forests of Coastal Western Hemlock zone[1]	11	6	138	64	219
Forests of Mountain Hemlock zone[1]	7	4	69	58	138
Coastal temperate rainforest (Alaska to Oregon)[2]	24	6	259	79	368
Clayoquot Sound:					
all species[3]	7	3	258	29	297
blue-listed species[4]	-	-	31	3	34
red-listed species[5]	-	-	8	3	11

[1]Breeding species only. Includes mainland British Columbia as well. All but eight species in the MH zone are also found in the CWH zone.

[2]Includes non-breeding species.

[3]Includes non-breeding species; many birds use the area primarily during migration.

[4]Species considered to be vulnerable or sensitive.

[5]Species that are candidates for designation as endangered or threatened.

Much of the richness of terrestrial vertebrates is attributable to the forest cover.

Among terrestrial vertebrates of Clayoquot Sound, much of the richness in the resident fauna is attributable to the forest cover. Most of the area is classified as Coastal Western Hemlock, which has one of the richest vertebrate faunas among the 14 biogeoclimatic zones in British Columbia. Because of their isolation on Vancouver Island, Clayoquot Sound forests do not show the same richness in amphibian or mammal species as do similar forests on the mainland. The richness is equivalent, however, for the more mobile bird species, many of which feed in the area during migration but are not resident there. Overall, about 62% of the vertebrate species recorded for Clayoquot Sound are forest-dwelling.

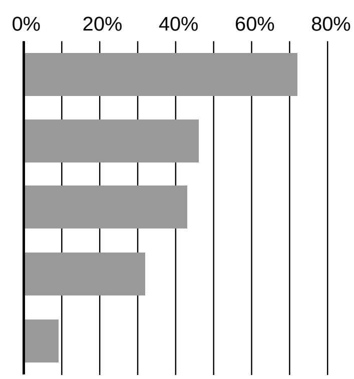
About 72% of the forest-dwelling vertebrates use riparian areas.

The native vertebrate fauna of Clayoquot Sound is shaped by and adapted to an environment strongly influenced by water and dominated by near-continuous, long-lived forests. About 72% of the forest-dwelling vertebrates make significant use of riparian areas (Figure 2.4). Use by all vertebrates of either riparian or shore habitats is still higher—76% for birds and 86% for mammals. Even snakes, such as the common garter snake and western terrestrial garter snake, are predominantly riparian species. The moist environment favours skin breathers such as the terrestrial salamanders. Of the 20 amphibian species found in the entire province, seven are found in the limited area of Clayoquot Sound—again emphasizing the moist, water-dominated character of the environment. Species not closely associated with forest cover, such as the eight loon and grebe species present, are intimately associated with the water systems of the area. Moreover, loons and other lake-dwellers often select waterbodies surrounded by older forests rather than by cutover or open areas.

Many species exploit the estuaries as staging or foraging areas (e.g., sandpipers, godwits, dowitchers), or forage and breed in the near-shore environment (e.g., cormorants, ducks, mergansers). Several of these species are only indirectly affected by forest cover. Nonetheless, the connections from headwater to estuary and intimate linkages between forests and water in riparian areas mean that even loons and gulls can be influenced by the nature and extent of forest practices (see Sections 2.2.4 and 2.2.5).

Figure 2.4 Percentage of forest-dwelling vertebrate species in Clayoquot Sound using different forest components for breeding.

Breed in riparian areas	72%
Breed primarily in older forests (greater than 140 years old)[1]	46%
Breed in downed wood (excludes birds)	43%
Breed or hibernate in cavities (excludes amphibians, reptiles)	32%
Breed primarily in regenerating forests (less than 20 years old)[1]	9%



[1]Few species breed only in one age class of forest, but many breed primarily in older or in younger forests.

Features of the vertebrate fauna reflect close associations with the area's large, long-lived trees and complex forest structure.

Other features of the vertebrate fauna reflect close associations with the area's large, long-lived trees and complex forest structure. The small forest gaps and abundant understory support numerous shrub nesters, such as Wilson's warbler and gray-cheeked thrush, along with cavity-nesting woodpeckers and nuthatches in the adjacent forest. At least 47 species (37 birds and 10 mammals) in Clayoquot Sound use the cavities of large trees—living and dead—to raise their young or hibernate. These species constitute about one-third of the forest-dwelling vertebrate fauna (Figure 2.4). Still more species rely on trees that have fallen to the ground (downed wood). Within the CWH zone, more species than in forests of any other biogeoclimatic zone use downed wood as breeding sites; about 40 of these species occur in Clayoquot Sound. Winter wrens, marten, and black bears nest or den in the root wads or hollows of windthrown trees. A remarkably high percentage (43%) of the amphibians, reptiles, and mammals in forests of Clayoquot Sound use downed wood to breed (Figure 2.4).

About 45% of the area's forest-dwelling vertebrates breed primarily in older forests, while less than 10% breed best in young forests.

Both abundant cavity-sites and significant amounts of downed wood are products of older forests and long intervals between disturbances. Some species in Clayoquot Sound, such as breeding marbled murrelets, are largely restricted to old-growth forests. Others depend on old-growth attributes. For example, bald eagle and great blue heron require large, structurally complex trees as breeding sites, while black-tailed deer profit from closed, older forests with small openings during years of deep snowfall. A few species, such as the western red-backed salamander, require at least limited areas of closed forest tall enough to maintain a humid microclimate. Among forest-dwelling vertebrates in Clayoquot Sound, about 45% breed primarily in older forests, while less than 10% breed best in young forests less than 20 years old (Figure 2.4). Other species are more general in their habits.

Effects of forest openings on animal behaviour vary widely. Many species that use both forest and open areas prefer edge habitats where canopy influence is substantial. For instance, black-tailed deer often feed on early seral vegetation[24] in openings, but prefer to stay within two to three tree heights of the canopy edge (Kremsater and Bunnell 1992). Some smaller mammals usually stay much closer to the edge. Provided appropriate habitat structures are available (e.g., wildlife trees[25] of sufficient diameter), forest birds such as woodpeckers will use openings with minimal canopy influence.

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[24] Early seral vegetation is vegetation appearing soon after disturbance (e.g., fireweed).

[25] Wildlife trees are dead, decaying, deteriorating, or other designated trees that provide present or future critical habitat for the maintenance or enhancement of wildlife.

Photo 2.9

Different ages and species of trees occur in old-growth forests of Clayoquot Sound. These uneven-aged stands provide the variety of habitats needed by the many species of plants and animals that inhabit coastal temperate rainforests.

Thirty-three species of vertebrates are largely restricted to the environment and range of coastal temperate rainforest in North America. Populations of these species in the rainforest are thus globally significant. At least 13 of these 33 species occur in Clayoquot Sound. Four of these species are largely restricted to older forests or their attributes (e.g., downed wood) during breeding. Forest practices that significantly modify riparian or aquatic ecosystems or simplify the complex structure of the forest can adversely affect these, and less restricted, species. Retaining some near-continuous forest cover, including large live trees, snags, and downed wood, is particularly important.

2.2.4 The Hydroriparian Ecosystem

Waterbodies and the immediately adjacent environment are intimately linked.

Water and the adjacent terrestrial environment have traditionally been treated as two separate systems: aquatic and riparian. This separation disregards the ecological reality that waterbodies and the immediately adjacent environment are intimately linked by the exchange of water, material, and organisms, and by the special character of ecosystems that develop in or around waterbodies. Such ecosystems depend upon the timing of water levels and flows, and the quality of water present. Because of this relationship, the waterbodies and immediately adjacent terrestrial environment should be treated as a single system, here termed the "hydroriparian ecosystem."

Photo 2.10

The hydroriparian ecosystem consists of both aquatic and riparian components.

The hydroriparian ecosystem consists of waterbodies and the adjacent terrestrial environment that is influenced by, or influences, the aquatic system.

The hydroriparian ecosystem has two components, each consisting of an intricate network of connections both above and below ground. The aquatic component comprises the open waters of lakes, streams, and rivers, together with their biota,[26] plus the groundwater with its biota. The terrestrial riparian component, consisting of all land that is adjacent to waterbodies, is both influenced by and influences the aquatic system and its associated biota.

While it is convenient to consider the hydroriparian system in terms of its two major components, the aquatic component blends into the riparian component where small headwater streams begin as seepage from saturated soil in and around the apparent streambed. Similarly, the aquatic and riparian components blend laterally across sloughs, marshes, bogs, and other wetlands.

The aquatic and riparian components of the hydroriparian ecosystem influence each other strongly.

The aquatic and riparian components of the hydroriparian ecosystem influence each other strongly. Riparian vegetation shades the stream and influences its temperature. It provides the large woody debris that helps to form the structure of the stream channel, and the leaf litter that supports heterotrophic production.[27] The bedrock and surficial material contribute dissolved ions that determine water chemistry. The stream, on the other hand, influences the land by depositing sediment upon it during floods, and by eroding its banks. Around bogs and other wetlands the links are particularly strong and the two components merge.

Trophic processes[28] and aquatic insect faunas strongly reflect the stream and riparian conditions. These processes and faunas gradually change from headwaters to ocean, forming a continuum of changing physical conditions, trophic processes, and communities (Vannote *et al.* 1980). Because various species of fish are adapted to various habitat conditions, they tend to occur in zones

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[26]"Biota" refers to all organisms—plant, animal, microbe, and fungi—that inhabit a specific region or time period.

[27]Heterotrophic production refers to the production of nutrients from complex organic substances (e.g., leaf litter), as compared to the production of complex nutritional organic substances from simple inorganic substances such as carbon dioxide ("autotrophic production").

[28]Trophic processes refer to the manner and form by which individuals and communities obtain energy (e.g., photosynthesis, scavenging, grazing).

within the stream continuum. This zonation reflects connections with both the riparian and aquatic environments.

Small streams are critically influenced by the surrounding vegetation.

Small headwater streams in Clayoquot Sound usually are heavily shaded. Most nourishment for animals in the stream comes from outside the stream itself. The trophic processes within these streams are based on input of insects, leaves, and twigs from adjacent riparian areas. Water temperatures tend to be relatively stable and low throughout the day, and there is relatively little algal growth or primary production within the stream. Small streams are critically influenced by the surrounding vegetation.

Progressing downstream, the nature of trophic processes changes. The stream channel becomes less shaded, the daily range of temperature increases, algal production increases, and more food energy is produced within the stream itself. Insect faunas contain more species that graze algae from stream bottom stones and more species that collect drifting organic matter. The increased daily range of water temperature permits greater diversity of insect lifestyles and species. These small organisms form the bases of several food chains—at the top of which are the commercially or culturally valuable salmonid fish, and herons, eagles, and bears. Maximum faunal diversity tends to occur in the largest, low-gradient streams in Clayoquot Sound, such as the Megin or Kennedy rivers. In these larger streams, the trophic system is driven primarily by processes within the stream, although linkages between streams and adjacent riparian areas are still evident.

In the upper estuary, insect faunas change dramatically and species composition shifts to other forms of macroinvertebrates, particularly crustaceans. The upper part of the stream system, although distant, influences the estuary and the near-estuary marine environment; for example, by providing organic matter ranging from detritus to whole trees.

Forestry activities may alter not only stream channel morphology and hydrological and sediment regimes, but may also modify trophic processes. In causing these changes, forestry activities may modify life histories and success of various riparian and aquatic species, shift the zones in which maximum biological diversity occurs, and change the distribution of fish (Hartman and Scrivener 1990).

Forests in riparian areas play critical roles.

Forests in riparian areas play critical roles beyond shading, food production, and food-gathering processes. In upslope and riparian areas, plant roots that die and decompose leave channels through the soil, which transport water rapidly to the stream channel. The presence and condition of forest vegetation thus affect the rate of water movement through the soil. Trees along streambanks are the source of whole trees and smaller wood fragments that, when they fall into the stream and lodge, help to store gravel in the stream channel, regulate stream velocity, and influence stream channel morphology. Woody debris in the stream channel provides a variety of habitats for aquatic organisms.

Effects of the aquatic system on the riparian area are no less strong. An obvious factor is the proximity of two distinct habitats (water and land), both critical to semi-aquatic species such as American dippers, mink, and river otter, as well as to aquatic species. An equally strong effect is the continuous or seasonal influence of water which encourages a productive and diverse plant community different from communities found on adjacent hill slopes. This diversity and productivity is reflected in the use of riparian areas by many animal species.

Subterranean water is newly recognized as an important habitat.

Subterranean water is newly recognized as an important habitat containing its own unique communities; groundwater forms two contrasting zones, each with its own biota (Stanford and Ward 1988). The hyporheic (flowing water) zone provides habitat for the immature stages of several insect species which, on reaching maturity, join the biota of the riparian area. The phreatic zone, where groundwaterflows much more slowly, is the habitat of several species of permanently subterranean crustaceans. The waters of these zones are continuous with each other but, except in a narrow transition zone, quite distinct in their chemical properties and their speed of flow. Floodplain plants, part of the riparian biota, obtain their water and mineral nutrients from the hyporheic and phreatic waters beneath them.

Four points about the hydroriparian ecosystem merit emphasis.

The hydroriparian ecosystem is the skeleton and circulation system of the ecological landscape.

- The hydroriparian ecosystem is the focus of activity for a large portion of all fauna, and the site of the most diverse flora in a watershed. The hydroriparian ecosystem is the major travel corridor for many terrestrial and all aquatic organisms—essentially the skeleton and circulation system of the ecological landscape.

- These land-water systems are strongly affected by logging and roadbuilding (Hartman and Scrivener 1990). Such activities can alter channel morphology (Section 2.1.4), hydrology, and shading or thermal regimes. Changes in the riparian environment that modify physical processes influence the invertebrate faunas and thus may alter fish species composition or shift fish species zones within a stream system.

Natural paths and regimes of subsurface waterflow are important to plants and animals, as well as to slope stability.

- The maintenance of natural paths and regimes of subsurface waterflow is important to plant and animal biological diversity, as well as to slope stability. This is particularly true for wetlands and steep slopes, and for subterranean organisms.

- Each watershed contains its own hydroriparian ecosystem, largely isolated from the hydroriparian ecosystems in other watersheds. Many species in hydroriparian ecosystems, especially wingless aquatic invertebrates, cannot survive outside the system even for short periods. These species are genetically isolated from those in other watersheds for most of the time. Genetic exchange is possible only when uncommon events, such as when exceptionally high floods dilute seawater sufficiently for freshwater organisms to survive drifting between stream mouths, permit intermingled populations. The result is genetic divergence in the isolated populations, leading to high genetic diversity.

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.

2.2.5 From Stream to Sea

Linkages from terrestrial riparian systems to streams continue to the sea.

Linkages from terrestrial riparian systems to streams extend beyond watersheds and continue on to the sea. The stream system is connected to the ocean through physical processes of water, wood, sediment, nutrient and particulate matter export. The ocean is connected to the stream through migration of fish. All salmonids depend on the freshwater environment for reproduction, and most depend on the ocean environment for their growth. Conversely, some sculpins depend on freshwater environments for growth and on the ocean or estuaries for reproduction.

Stream systems in Clayoquot Sound may contain fish from the following groups of species: Pacific salmon (coho, chum, pink, sockeye, and chinook); trout (steelhead and cutthroat, and non-anadromous forms of these species); char (Dolly Varden); cottids (prickly and coast range sculpins); minnows (peamouth chub); sticklebacks; and lampreys. Within Clayoquot Sound, individual species occur in some stream or stream-lake systems, but not in others. The number of fish of any species varies among stream systems depending upon drainage size and stream characteristics.

Photo 2.11

Streams provide critical spawning habitat for sockeye and other species of salmonids. Activities on land, natural and human, can cause siltation of spawning beds and reduce salmon productivity.

About 100 streams in the Clayoquot Sound area have been identified as containing one or more species of salmon.

About 100 streams in the Clayoquot Sound area have been identified as containing one or more species of salmon; sockeye, chum (in lower stream reaches), and coho are the species most commonly found (Canada 1991). Streams usually contain only one or two species (e.g., chum or coho salmon, cutthroat trout). Some streams and lake systems support several species of fish with populations numbering in the tens of thousands. In most streams, however, populations of individual species are small, less than 100 adults.

Escapement[29] data represent spawning adult numbers rather than accurate measures of fish production.[30] The trends in escapement of salmon reported by the Department of Fisheries and Oceans (Canada 1991) are, for many populations, similar to the trends in run strength reported by the Nuu-Chah-Nulth members of the Panel.

The numbers of some species of salmon in Clayoquot Sound streams have declined.

Estimated average escapements to Clayoquot Sound streams differ among species of salmon (Table 2.3) and have varied widely from year to year. Sockeye and chum have been the most abundant species, and chinook the least abundant (Figure 2.5). Estimated numbers of some species of salmon in Clayoquot Sound streams have declined while those of other species appear to have remained about the same. These data are not precise, but indicate the relative magnitude of runs and long-term trends in populations.[31] Average annual coho and chinook numbers, based on five-year intervals, declined from 1968 to 1992. Available data suggest that pink salmon became virtually extinct after the 1978–82 estimates (Figure 2.5). No trend is apparent, or numbers appear stable, for sockeye and chum salmon.

Table 2.3 Average annual escapement to Clayoquot Sound streams, Area 24, Tofino, 1968–1992.

	Chum	Sockeye	Coho	Pink*	Chinook
Average	55 070	26 232	6 278	2 701	424
Range	9 506–117 795	6 275–93 960	940–21 875	1 600–26 700	52–1 079

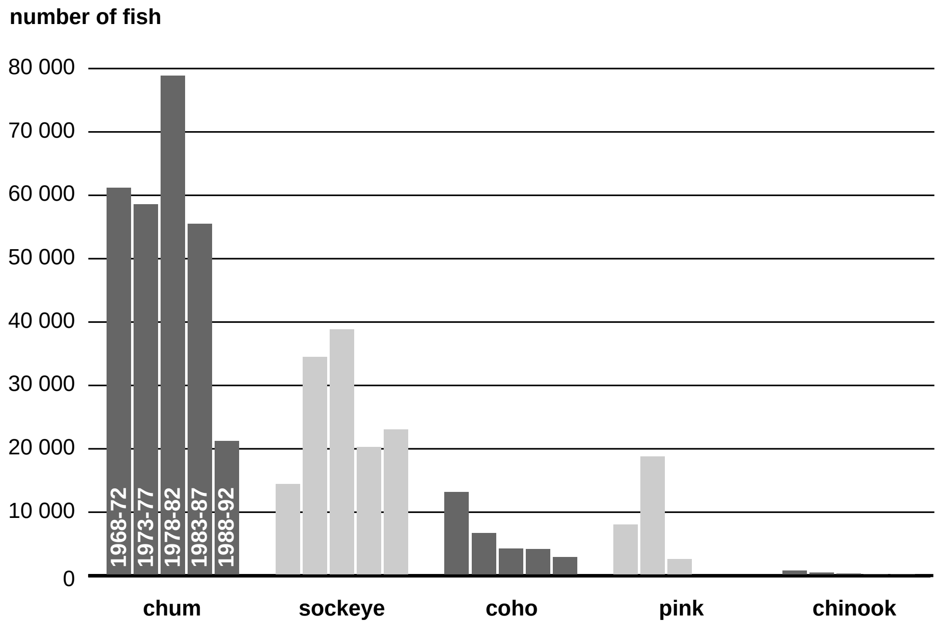
*Data are shown for the “high” years; 0–50 fish for “low” years. No information available for steelhead.

[29]Escapement is an estimate of the numbers of adult fish returning to a stream to spawn.

[30]Data of Table 2.3 and Figure 2.5 are derived from Canada (1991) and other records from the Department of Fisheries and Oceans.

[31]Because escapement data may not be based on estimates from the same streams each year, interpretations must be made cautiously. Effective data gathering and interpretation to estimate spawning runs has been hindered by the limited extent of local monitoring. Nuu-Chah-Nulth experience is that formerly productive streams, excluded from some estimates, are now barren.

Figure 2.5 **Average annual escapement estimates based on five-year intervals, Area 24, Tofino, 1968–1992.**



Streams, lakes, and estuaries of Clayoquot Sound all provide incubation and rearing environments for trout and salmon.

Streams, lakes, and estuaries of Clayoquot Sound all provide incubation and rearing environments for trout and salmon. Streams provide incubation environments for five species of Pacific salmon. Coho and chinook salmon remain in streams for a few months after emergence, while young sockeye rear in lakes. Some juvenile coho salmon and cutthroat trout seasonally enter very small tributaries and ponds which are safe aquatic habitat during winters characterized by severe storm events but which are dry riparian areas in summer. In some years, this habitat produces almost one-quarter of all coho smolts (Brown and Hartman 1988).

Many streams contain small resident populations of cutthroat trout and Dolly Varden. The life histories of fish in these resident populations differ from those of the trout and salmon that migrate to and from the sea. Resident populations occupy relatively short lengths of stream channel, typically in low gradient reaches which are located above barriers that block upstream migration. Their migrations are restricted to short movements into and out of nearby side channels or lakes to spawn or to avoid extreme waterflow conditions during winter. Their connections to stocks below the barriers are limited to situations in which fish move, or are washed, downstream below the barriers.

Resident fish may require the highest degree of protection.

Resident fish, such as Dolly Varden, have been isolated from downstream fish for thousands of years, and the population in each stream where resident populations occur may be genetically distinct (Northcote and Hartman 1988). Because resident populations spend most of their life within relatively short reaches of stream channel, and are genetically isolated, they are especially vulnerable. They have no refuge from damage to their stream channel, and no opportunity to rebuild their populations by immigration from the sea or adjacent streams. For these reasons, resident fish may require the highest degree of protection. However, because the fish are small and do not provide a commercial or recreational fishery, they generally have been overlooked in protection measures. It is likely that many such resident fish stocks have suffered from habitat damage resulting from past logging practices.

Although we tend to think of fish as occupying either a marine or freshwater environment, or migrating from one environment to the other, the distinction in habitat use is often less clear than that. Chum salmon spawn in the lower reaches, within 0.6 km of the sea in most streams where they occur, and spawn in the intertidal zone in some streams (e.g., Carnation Creek, Barkley Sound).[32] Chum egg-to-fry survival in the intertidal zone is comparable to that in freshwater sections of the creek (Groot 1989). A part of the juvenile coho population in coastal streams may undergo some maturation in the estuarine zone. Prickly sculpins may use both estuarine and stream environments at different times in their lives. Other species, predominantly marine, move into estuaries during some phases of their life history (e.g., herring use estuaries as feeding areas). Such combined use of freshwater-marine, estuary-freshwater, marine-estuary, or marine-freshwater systems reveals that these environments are functionally linked for many species of fish, and emphasize the important role of estuaries.

Events far upstream, well removed from spawning areas, can influence downstream characteristics and organisms.

The number and importance of land-to-sea connections are becoming better understood. Events far upstream, well removed from spawning areas, can influence downstream characteristics and organisms. Transport of organic material (e.g., detritus, twigs, small woody debris, and whole trees) downstream to estuaries enforces both trophic and structural links among freshwater, estuarine, and marine environments. Activities carried out upstream or on the shore zone may affect marine conditions and organisms. The Nuu-Chah-Nulth have observed that upstream or onshore activities that affect water quality, by addition of sediment or dissolved organic material, may disrupt herring spawning. They are strongly concerned that log dumping may affect herring spawning and geoduck numbers.

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[32] Barkley Sound is a source of detailed data on instream fish natural history. Because Barkley Sound is immediately adjacent to Clayoquot Sound, the Panel deems that this information is relevant to Clayoquot Sound. See Hartman and Scrivener (1990) for a summary presentation.

Woody debris, far out at sea, provides cover and food for more than 100 species of invertebrates and 130 species of fish.

Some relationships between the terrestrial and marine environments have been recognized only recently. Large, sunken woody debris plays a vital role in the ecology of the ocean. As well, windrows of debris and trees, far offshore where water converges and downwells, provide cover and food for more than 100 species of invertebrates and 130 species of fish (Sedell and Maser 1994). These observations emphasize the importance of maintaining the integrity and natural processes of stream systems along their entire length. Forestry practices need to retain sufficient vegetative cover and natural drainage patterns to maintain soil stability, natural stream discharge regimes, and habitats of stream-dwelling organisms.

Some of the watersheds within Clayoquot Sound contain lakes. These waterbodies reflect the regional climate and geology, and are relatively oligotrophic or low in nutrients. Lakes within the drainage systems modify the conditions of the streams that pass through them. They dampen floods, alter water temperatures, intercept sediment, and store large woody debris. Trophic processes in lakes differ from those in the streams. Production, almost entirely autotrophic, maintains planktonic algae in the lakes. The insect and crustacean faunas of the lakes are almost entirely planktonic as opposed to being benthic, as in streams.[33]

Fish faunas within lakes include commercially and recreationally valuable species.

Fish faunas within the lakes include some of the commercially and recreationally valuable species, such as sockeye and coho salmon juveniles, trout and Dolly Varden, as well as non-commercial species such as three-spined stickleback, peamouth chub (Kennedy Lake), and sculpins. The peamouth chub and stickleback are, predominantly, lake species. The stickleback is a significant species because it may compete with juvenile sockeye in Kennedy Lake.

Lakes, as a whole, may be less vulnerable than streams to ecological impacts from logging activities. However, high levels of suspended sediment in the streams may lead to increased suspended sediment in the lakes. At high concentrations such material would reduce plankton production in the lake. Shore zones, in much the same way as streams, are vulnerable to the effects of forest removal at the shoreline.

2.3 Human Values in the Landscape

Clayoquot Sound is important to people for cultural, spiritual, and scenic values, and for recreational and tourism use.

Many aspects of the Clayoquot Sound environment are important to people—both First Nations and others—for cultural, spiritual, and scenic values, and for recreational and tourism use. The resources in Clayoquot Sound also provide economic benefits for residents and the province of British Columbia.

[33] Plankton are the chiefly microscopic organisms drifting or floating in the sea or fresh water; benthic organisms are the flora and fauna found at the bottom of a sea, lake, or stream.

2.3.1 First Nations' Values

First Nations' values are discussed more fully in the Panel report: *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound* (Scientific Panel 1995b).

Nuu-Chah-Nulth people represent roughly half of the area's current resident population.

The Nuu-Chah-Nulth, traditional landowners and resource users of Clayoquot Sound, represent roughly half of the area's current resident population. Nuu-Chah-Nulth people view the forest and its resources as gifts of the Creator, to be used with respect and to be maintained by careful stewardship through the legislative power of tribal government found within "***h̲ah̲uulhi***."[34] Traditional practices of resource management include harvesting of selected trees and other forest products; highly selective controlled burning to promote production of berries, to provide grazing areas for deer, and to produce firewood; and monitoring and controlled use of all lands and waters and their resources through stewardship of hereditary chiefs.

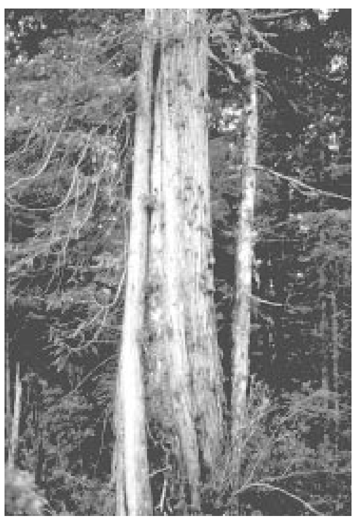

Photo 2.12

A culturally modified western redcedar tree from which a strip of bark was removed many decades ago.

Within each community, chiefs' territories—rivers and fisheries, hunting and gathering areas, and portions of the ocean—are delimited by boundary markers such as easily recognizable topographic features. While permanent Nuu-Chah-Nulth villages are situated along the coast of Clayoquot Sound, economic and cultural activities (e.g., hunting, fishing, plant gathering, and spiritual practices) occur throughout the region, from the ocean and offshore islands to remote places in the mountains. For example, culturally modified trees,[35] places of spiritual significance (especially caves, streams, pools, waterfalls, and offshore islands) which are often personal to individuals and families, and areas used for traditional activities are scattered widely across the

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[34] ***H̲ah̲uulhi*** refers to the plenary authority exercised by Nuu-Chah-Nulth hereditary chiefs over the people, land, and resources of their tribal territories.

[35] Trees with evidence of bark stripping, planking, or test holes.

landscape. These places *and* the area's forests and water resources are essential for Nuu-Chah-Nulth economic, cultural, and spiritual well-being, yet both have been threatened, depleted, or damaged by the activities of non-indigenous peoples.

2.3.2 Values of Non-Indigenous Peoples

Most residents are economically dependent on local forest and marine resources.

In addition to the Nuu-Chah-Nulth, Clayoquot Sound is inhabited by non-indigenous people who live primarily in or near Tofino and Ucluelet. Most of these residents depend on local forest and marine resources which form the basis for timber, tourism, fisheries, and aquaculture industries (Clayoquot Sound Sustainable Development Strategy Steering Committee 1992). The economic importance of these resources extends to Port Alberni and the Alberni Valley, where jobs are supported by the forests of Clayoquot Sound. Many of these people accept clearcuts, associated roads, and other scenic modifications as part of using the forest resource for timber.

Photo 2.13

Forest harvesting provides economic benefits for many people in Clayoquot Sound. To some, clearcuts are an acceptable consequence of resource extraction.

Ecological integrity of the forest ecosystem is essential to meeting economic, spiritual, and recreational needs.

Besides the economic benefits, non-indigenous residents value many aspects of the environment and scenery of Clayoquot Sound and some people choose to live in Clayoquot Sound for other than financial reasons. The environment contributes to their quality of life and is important for their spiritual and social well-being.[36] Like the Nuu-Chah-Nulth, the future of non-indigenous people is intimately tied to the landscape. The long-term viability of these communities and livelihood of the population depend upon sustaining the resources of Clayoquot Sound. Over the long term, ecological integrity of the forest ecosystem is essential to meeting their economic, spiritual, and recreational needs.

[36] The Panel's discussion of the values of non-indigenous peoples is largely limited to those values associated with scenery and recreation or tourism. That limitation is not intended to deny other values (see Sections 1.1 and 6.0).

2.3.3 Scenic Values

Landscape appearance is important to residents and visitors to Clayoquot Sound, for aesthetic reasons and as an indicator of forest health.

Landscape appearance is important to Nuu-Chah-Nulth, other residents, and visitors to Clayoquot Sound, both for aesthetic reasons and as a potential indicator of the health of the forest resource. In a study of marine tourism opportunities and during focus groups held as part of tourism resource inventories, most tourists and recreationists in British Columbia identified scenery as the resource that is most important to their activity (ARA Consulting Group 1991, 1993).

Photo 2.14

Coastal vistas are an important resource which draws many visitors to Clayoquot Sound.

Clayoquot Sound has highly valued scenic resources. Dramatic mountain topography, and alpine, river, and lake landscapes are visible from Pacific Rim National Park and Highway #4. Both lakes and streams provide opportunities for specific uses and for appreciation of particular types of scenery. Some rivers are important for fishing, and many are used as sources of fresh water. Because of the riparian vegetation, rivers provide a diverse and intimate landscape experience. Lakes, especially those which are easily accessible, can also be important as sources of fresh water, and for fishing, swimming, and boating. The coast includes major fjords, distinctive islands, and archipelagos, and numerous smaller features such as beaches, waterfalls, and rock formations. In some locations, steep terrain drops directly into the water; in other areas, lower land in the foreground allows views to alpine peaks in the distance.

Logging has had major effects on scenery in parts of Clayoquot Sound. Some mountainsides have been so extensively clearcut that it will take years to recover their former scenic values. Nuu-Chah-Nulth people speak often about the wounds that logging has inflicted on the land. Photographs of past logging activities have been used effectively by environmental groups in their lobbying to change forest practices. There are two primary sources of negative visual impacts in Clayoquot Sound: the size of many previous clearcuts, and unvegetated slopes resulting from sidecasting[37] and slides associated with roads on steep slopes.

[37] "Sidecasting" refers to the release or placement of earth materials downslope from a road, landing, or facility excavation; it is the means for building the filled portion of "cut-and-fill" surfaces.

Photo 2.15

Scenic resources can be greatly diminished through inappropriate forest practices.

People in the forest industry rated logged scenes with the same low scores as other respondents.

There is a growing amount of literature focused on how landscapes are perceived, and relating perceptions to psychological factors. Perception studies most often use photo-questionnaires, in which respondents rate a series of photographs. This method provides a reliable measure of preference (Kaplan 1979). While some studies have noted minor variations in preferences among different socioeconomic groups (e.g., members of environmental groups had a lower than average preference for dominantly altered scenes; Dearden 1984; McCool *et al.* 1986), more remarkable is the similarity of preferences among respondents. For example, in a study in the Kootenays, people in the forest industry rated logged scenes with the same low scores as other respondents (Berris and Bekker 1989).

Natural-appearing landscapes are preferred over dominantly altered ones.

Studies that have focused on forested landscape scenes have found that natural-appearing landscapes were preferred over dominantly altered ones (Miller 1984; McCool *et al.* 1986; Berris and Bekker 1989). Scenes with depth, distant views, steep mountain faces, snow-capped peaks, water, and especially a combination of these attributes, were particularly liked. Generally, logging meeting the B.C. Ministry of Forests visual quality objectives of “retention” or “partial retention” was found to be significantly more acceptable than cutblocks which are rated “modification” or greater.[38]

[38]Visual quality objective (VQO) defines a level of acceptable landscape alteration resulting from timber harvesting and other activities. In the “Preservation VQO” class, alterations are not visible. In the “Retention VQO” class, alterations are not visually evident to the casual forest visitor. “Partial Retention VQO” is when alterations are visually subordinate to the natural landscape. In the “Modification VQO,” alterations are visually dominant, but should borrow from natural line and form. In the “Maximum Modification VQO,” alterations are dominant and out of scale, but appear natural in the background. “Excessive Modification” is not a VQO, but may be used to describe a presently unacceptable visual condition.

Selection silvicultural systems are perceived as unaltered landscapes.

The least preferred scenes contained recent, ill-fitting, and / or dominant human-caused alterations in the foreground or middleground. Ill-fitting cutblocks are characterized by straight edges and rectilinear corners, large size, high colour and texture contrast, and notched skylines. Individual cutblocks are not as noticeable in areas where landform and vegetative cover are diverse, or where there is already a high level of alteration or development. Studies have also shown that selection silvicultural systems are perceived as unaltered landscapes (McCool *et al.* 1986; Bekker 1987).

Although perceptions based on purely visual factors are generally consistent across the population, the types of scenery that people seek for their activity vary among tourist and recreational groups (ARA Consulting Group 1992; Catherine Berris Associates Inc. 1993). To some groups (e.g., kayakers), unaltered scenery is the most important consideration. To other groups, such as those on cruise boats, varied dramatic scenery such as diverse topography, water, and mountain peaks is most important.

Perception is an active process in which people obtain and interpret information.

In the consideration of scenic values, implications go beyond the purely visual. Perception is an active process in which people obtain and interpret information about their environment based on their knowledge and experience. In addressing scenic values, the perceptions of people are being considered; what people know about forest practices will affect their response. The goal of scenic resource management, therefore, in striving to satisfy visual preferences, is also to provide a personal and social comfort level with what is happening in the landscape.

Given the importance of scenery to resident and non-resident users of Clayoquot Sound and the existing and potential economic value of tourism to the area, it is critical that the scenic resources be appreciated, understood, and properly managed in the long term. This will provide people with a desirable environment for their activities and indicate that spiritual and forest health also are being acknowledged in planning.

2.3.4 Recreational and Tourism Values

There are outstanding opportunities for recreation and tourism in Clayoquot Sound.

There are outstanding opportunities for recreation and tourism in Clayoquot Sound. Natural history excursions along coastlines and to old-growth forests, wildlife tours, air tours, and activities such as kayaking, sailing, and hiking are well established and expanding. These activities depend greatly on the natural resources of Clayoquot Sound, including vegetation, wildlife, and scenic resources. They also provide economic opportunities.

Photo 2.16

Kayaking is a popular recreational activity enjoyed by both residents and tourists in Clayoquot Sound.

Tourism, an extremely important industry in British Columbia, generated $5.81 million in 1993 (B.C. Ministry of Finance and Corporate Relations 1994:97). The province has strong international appeal for tourism, particularly because of the dramatic coastal and mountain scenery and natural resources. There have been major recent international trends towards ecotourism. A proposed definition for ecotourism in Canada is "an enlightening nature travel experience that contributes to conservation of the ecosystem while respecting the integrity of host communities" (Scace *et al.* 1992). By definition, then, ecotourism is sustainable development. It can also provide an economic justification to conserve areas that might not otherwise be protected. Clayoquot Sound has the potential to expand its ecotourism activities.

Tourism can have significant negative impacts on terrestrial and marine resources and on local communities.

Ecotourism is a highly vulnerable activity because it has the most to lose when practised in an ill-conceived, uncontrolled, or insensitive manner. In the face of explosive growth in international tourism, many of the world's most beautiful and valued places are being overrun by visitors and suffering incalculable damage. Examples include extensive human pollution in the waters of the Mediterranean Sea and Acapulco Bay, garbage and overuse of wood in the Himalayas, and destruction of wildlife habitat in the Galapagos. Both the number of visitors and their activities have contributed to problems. Because tourism can significantly damage terrestrial and marine resources, and local communities, the impacts of tourism should be monitored.

Distinctive trends in recreation and tourism have resulted from new technology and changes in public interests. New technology in kayaks, surfboards, and wetsuits has been one source of increased participation in sea kayaking and surfing, especially on "boogie" boards, on the west coast of Vancouver Island. Changes in public interests have made activities such as wildlife-viewing tours more popular in recent years. When managing resources, it is important to recognize that demands will change over time.

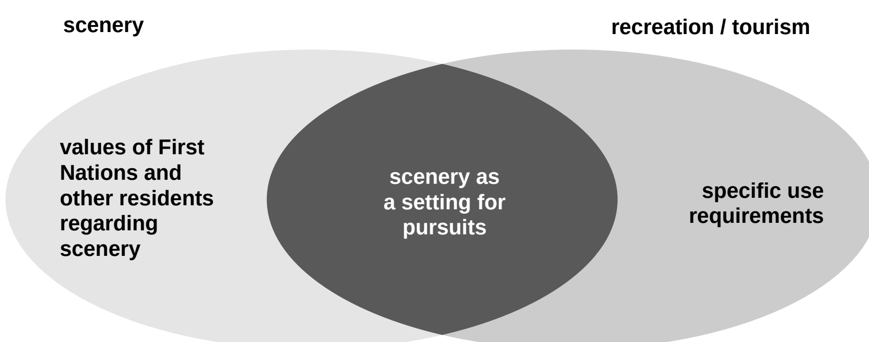
Recreation and tourism overlap considerably in Clayoquot Sound.

Recreation and tourism overlap considerably in Clayoquot Sound. Traditionally, recreation has been considered the non-commercial pursuit of activities, while tourism has been considered to be commercially based, involving expenditures for items such as travel, accommodation, meals, or guided activities. Different groups use various methods to define tourism, including time or distance away from home, or dollars spent. No matter which definition is used, recreation and tourism overlap because most recreational pursuits also involve travel and some expenditures. Tourist activities generally require the same resources as recreational activities. For example, kayakers on their own and those with a guide seek the same resources to support their activity. In this report, where the term recreation is used alone, it is intended to include recreation and tourism.

Recreation and tourism rely strongly on scenery.

Recreation and tourism rely strongly on scenery, as described in Section 2.3.3. Figure 2.6 shows the interrelationship of recreation, tourism, and scenery in Clayoquot Sound. Recreation and tourism are represented as one circle. The interests related to recreation or tourism and scenery overlap because recreational and tourist groups value scenery for their activities. Additional considerations about scenery include the values of First Nations and other residents. Concerns that are specific to recreation and tourism include use factors such as a sufficient landbase to support activities, an appropriate level of activity in key areas (e.g., a high level of use is not acceptable for wilderness activities), and infrastructure for specific activities (e.g., docking facilities for sport fishing).

Figure 2.6 The interrelationship of tourism/recreation and scenery in Clayoquot Sound.



Forest practices can affect recreational values.

Forest practices can affect recreational values in a range of ways and to varying degrees, depending on the location, extent, and rate at which trees are removed and new growth is established. Specific sites can become unattractive for recreation if logging occurs too close to them. Wilderness values can be diminished if logging becomes too noticeable. Sounds that accompany logging can be a problem if recreation and logging are occurring simultaneously in one area. Depletion of the resources that support a specific activity (e.g., sport fishing) create a major problem for recreation and tourism. Conversely, previously cut forests, and possibly depleted streams, can regain recreational values as trees mature and streams recover.

Many people form an impression of forest practices through recreational activities.

Many people form an impression of forest practices through their recreational activities. In the past, many recreationists have been alarmed by the effects of logging. Appropriate forest practices provide an opportunity for interpretation and education, another form of recreation, in areas where people can be shown sustainable forest practices.