8.0 Monitoring

Monitoring is repeated observation, through time, of selected objects and values in the ecosystem to determine the state of the system.

Monitoring is repeated observation, through time, of selected objects and values in the ecosystem to determine the state of the system. In particular, it entails the comparison of objects (e.g., organisms) and processes (e.g., streamflow) before and after management actions to determine the effect of those actions upon the ecosystem. Monitoring is an integral part of the sequence of management activities that also includes inventory and planning (Figure 7.1). During the inventory, objects and processes are assessed in an area at a particular time to establish the state of a system. Inventory entails gathering baseline information upon which planning is based and to which subsequent monitoring activities are compared.

Monitoring in the forest ecosystems of Clayoquot Sound will have three goals.

In accordance with its mandate, the Scientific Panel has outlined conditions that are required to meet or exceed emerging international standards for forest practices. The objectives of these standards include maintaining ecosystem integrity and the cultural integrity of local peoples. A successful monitoring program must ensure that objectives are being achieved. Consequently, 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* the mechanisms, both natural and those induced by human activity, that cause events and create changes in the ecosystem.

The Panel emphasizes monitoring to evaluate success in attaining objectives.

Information gained from the last two goals must be fed back into the planning process (Chapter 7). This chapter concentrates on the second goal, success in attaining management objectives, and assumes that the Panel's recommendations are adopted. Before considering specific objectives and methods for monitoring in Clayoquot Sound, some general aspects of monitoring require elaboration.

8.1 General Comments on Monitoring

The state of a system (e.g., composition of species present, condition of forest floor) is an indicator of the integrity of the system. Process and state are both aspects of ecosystem performance: processes yield states, which influence further processes. In some cases, processes in the system (e.g., hydrological processes) may be monitored to detect a change of state rather than monitoring the state directly. The choice of whether to monitor states or processes is based on feasibility or cost-effectiveness. Monitoring of processes is most helpful when based on understanding the effect that the process has on states of the system. For some purposes, this will require further research.

Nowhere has sufficient effort been invested in monitoring ecosystem management.

Monitoring activities must be carried out at several scales in Clayoquot Sound. As in planning, monitoring activities at local or site levels must often be designed at regional or subregional levels. Conversely, monitoring observations with regional implications often are made at individual sites. The need to coordinate observations over a range of spatial and temporal scales, juxtaposed on requirements for the program to be practical, meaningful, and affordable, makes monitoring programs difficult to design. The Scientific Panel emphasizes the importance of ensuring that monitoring programs meet their objectives. Nowhere has sufficient effort been invested in this critical aspect of ecosystem management.

The ease of monitoring varies widely from objective to objective. In a few cases, the needed steps are obvious and easily achieved. In others, these steps will be impracticable because of expense. In such circumstances, indirect means must be sought that give the desired answers to an acceptable level of precision. In still other instances, monitoring methods are currently being researched, and only procedures that appear, in the light of existing knowledge, to be the most promising can be recommended. Too little is known about too many ecosystem components to provide a specific protocol for monitoring all features of the forest planning and practices recommended for Clayoquot Sound. This chapter provides a general approach to monitoring and recommends specific methods where information is adequate.

It is worthwhile to devote considerable effort to devising the simplest methods that will give informative results.

For a given monitoring “effort” (time, cost), it may be appropriate to make detailed and precise measurements—perhaps with expensive equipment requiring expert operators—on only a few occasions at widely spaced observation sites. Alternatively, numerous observations may be obtained by less precise methods. Less precise methods allow data to be collected cheaply, at many sites and at short intervals, by observers who have had only minimal training. The ideal is probably some blend of both approaches, allowing simple but extensive observations to be periodically calibrated against complex, intensive measurements. It is worthwhile to devote considerable effort to devising the simplest methods that will give informative results. For ecological and geomorphological data, simple methods are needed in a setting as diverse as Clayoquot Sound: environmental conditions vary so markedly over such short distances that numerous observation points are necessary.

Monitoring of Clayoquot Sound forests requires comparing the state of the ecosystem before and after forestry operations. The dominating goal is

- to ensure that the integrity of ecosystem processes and ecosystem states is maintained. (Scientific Panel 1994a:14)

Detecting the environmental impacts of human activities on natural communities is a central problem in applied ecology.

Detecting the environmental impacts of human activities on natural communities is a central problem in applied ecology (Eberhardt 1976; Schroeter *et al.* 1993). It is a difficult problem because the effects of human activities must be separated from the considerable natural variability displayed by most communities or ecosystems. It is therefore essential that full baseline data be obtained *before* operations begin in an undeveloped area. Deciding when and how often to carry out post-management inspections requires judgement. Unwanted effects should be identified early so that operations can be stopped or modified promptly, before further damage is done. Some effects of forest disturbance, however, take time to appear; for example, slope instability may develop only after the root network of the former forest has decayed and a rainstorm exceeding some threshold has occurred. This time lag means that monitoring must be continued for years after logging operations have ended to ensure that all effects of logging have become apparent.

Monitoring to detect changes caused by forestry activities is best done by comparing conditions at disturbed and undisturbed sites.

Monitoring to detect changes caused by forestry activities is best done by *comparing* conditions at disturbed and undisturbed sites. Such comparisons can be made by comparing conditions: (1) upstream and downstream of a disturbed site; (2) before and after disturbance, at the same site; and (3) in the valley containing the disturbed site and in a nearby similar, undisturbed valley. No one of these three possibilities is best for all purposes. An informed choice must be made for each specific purpose. Consensus is emerging, however, that to detect impacts of human activities, samples should be taken repeatedly and contemporaneously at the potential impact site, and at one or more control sites during periods before and after the impact has begun (Eberhardt 1976; Skalski and Mackenzie 1982; Carpenter *et al.* 1989; Stewart-Oaten *et al.* 1992; Schroeter *et al.* 1993). The objective is to exclude or identify, so far as possible, effects unrelated to human activities.

Monitoring is an essential part of active adaptive management and improving management practices.

Effective monitoring is an essential part of active adaptive management and improving management practices (Walters 1986). Active adaptation is especially important when information is incomplete and social goals are changing—a situation particularly true for forest land management today. Approaches to learning more from management actions are developing (e.g., Walters *et al.* 1988; Walters and Holling 1990) and should be implemented. Acknowledging both the uncertainties and emerging consensus surrounding monitoring, the Panel makes the following recommendations:

R8.1 Initiate a long-term monitoring program that includes both areas that are reserved from land-use practices and areas that will experience land-use practices.

R8.2 Incorporate into the monitoring program the elements summarized in Sections 8.2 through 8.4. Specifically, monitor:

- 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.

R8.3 Use the findings of this program to modify, as required, management strategies as well as individual plans and practices.

8.2 Monitoring Watershed and Coastal Integrity

Monitoring watershed integrity encompasses the hydrological cycle, sedimentation processes, soils, geochemical cycles, and stream environments.

Monitoring watershed integrity encompasses the hydrological cycle, sedimentation processes (including hillslope stability), soils, geochemical cycles, and stream environments. The overall goal is

- to ensure that ecosystem processes and ecosystem states do not depart from the range of natural variability exhibited before disturbance. (Scientific Panel 1994a:Section 4)

Monitoring processes in a manner that reveals information useful for ecosystem management is a challenging task for several reasons. Hillslope failure is a comparatively rare, episodic event which is highly dependent upon antecedent conditions. Many of the properties of streams and rivers (e.g., stage, discharge, velocity, water depth, sediment load, turbidity) undergo enormous natural variation over short periods, making it difficult to recognize changes caused by human-induced disturbances. The tremendous spatial and temporal variation in the landscape makes it impossible to interpret, with high confidence, sparsely replicated measurements. The number of variables that might be observed and measured is vast, but focusing on key management activities will provide useful information.

Results of principal management activities that may affect watershed integrity are measured at the watershed level. These results include the rate-of-cut in individual drainage basins, distribution of cut and regenerating areas, distribution of forest age classes with respect to elevation and physiography, and the extent and layout of the road system.

8.2.1 Monitoring Hillslopes and Forest Soils

The goal for hillslopes and soils is to maintain the integrity of the soil.

Consistent with the guiding principles for ecosystem management, the goal for hillslopes and soils is to maintain soil integrity. This goal requires that two basic objectives be achieved:

- to retain the soil within the ecosystem; that is, to manage the land so that modes and rates of erosion are not significantly changed and individual erosion events are within the natural range of variability; and

- to maintain the physical, chemical (nutritional), and biological characteristics of the soil so that the capability to maintain a wide range of ecosystem states and options for society is not foreclosed or reduced.

Construction of roads and landings, borrow pits, and other cleared areas necessitates deliberate and unavoidable loss of productive soil, but inadvertent soil damage may also occur and hillslopes may be destabilized. Soil can be lost by debris slides on hillslope and debris flows in gullies, by erosion from road surfaces and ditches, and from the soils exposed on road cuts and fills. Away from roads, the soil surface can be damaged by yarding, using ground-based equipment during logging and stand tending, and constructing backspar trails and fireguards. Consequently, the forest floor is removed, and surface soil may then erode.

In monitoring slope stability, key indicators are the number of failures and the volume of soil displaced in a unit of time.

Key indicators for monitoring slope stability are:

- the number of failures and volume of soil displaced per unit time

  Because these processes are subject to weather conditions, observations on sites subject to forestry activities should be compared with observations on sites that are undisturbed, and with baseline observations obtained on sites before disturbance. Maintaining slope stability within the regime observed on natural slopes is critical to maintaining soils and soil productivity.

In monitoring soil health, key indicators are forest floor cover and foliar analysis.

Key indicators for monitoring soil “health” are:

- forest floor cover (or the obverse, mineral soil exposure)

  Maintaining the forest floor is critical for mineral soil protection in the Clayoquot environment. Loss of forest floor cover is readily measured, and successful repair of disturbed or damaged sites can be measured by re-establishment of a functional forest floor (re-establishment of grass cover for erosion control is only the first step in this process). The forest floor is key to forest nutrition, so monitoring its cover is relevant to monitoring long-term productivity of the soil system. Maintaining the forest floor cover also greatly dampens soil temperature fluctuations, which ultimately can affect stream temperature regimes.

- foliar nutrients

  In analysis of foliar nutrients, the tree is used as a natural integrator of environmental (including soil environment) conditions; that is, as a bioassay. Maintaining the soil nutrient pool is central to long-term productivity, but extremely difficult to monitor directly. Foliar nutrient content varies less than soil nutrient status, and considerable experience exists concerning what constitutes adequate foliar nutrient levels. Foliar nutrient analysis would be triggered when observable signs of deficiency become apparent (e.g., chlorosis or other changes to foliage colour or form).

- soil biology

  This indicator is also very difficult to monitor directly. Indirect integrating measurements, such as soil respiration rate, exhibit great variability. Consequently, as with nutritional status (with which soil biology is inextricably linked), the use of foliar analysis appears most feasible since it encompasses the links among biological, chemical, and physical aspects of the soil complex.

In monitoring hillslopes, key indicators are debris slides, debris flows, and other mass movements.

The comparison of slope failure between disturbed and undisturbed sites is important.

On hillslopes, the most useful monitoring technique is to maintain a record of all debris slides, debris flows, and other mass movements. For those events detected soon after their occurrence, antecedent weather conditions should be recorded. Unfortunately, most failures probably will be detected retrospectively and will be assignable only to a general period of time. The event record should include location, position and slope gradient of the initial failure (headscarp); measured or estimated length, width, and volume of displaced material; length of runout; ground cover condition; and stream course effects. Actions or conditions known to have caused the failure should be recorded, as should the headscarp position in relation to roads and cutblock boundaries. The most important comparison will be between rates of slope failure on disturbed and undisturbed sites. Analysis should be conducted at watershed and subregional scales or planning levels.

In monitoring roads and other deliberately converted surfaces, erosion is the key indicator.

For roads and other deliberately converted surfaces, the current B.C. Ministry of Forests methods for determining the percentage of land removed from production are adequate. Erosion from these surfaces can be monitored by direct observation (e.g., of rills and ditch-line erosion), if necessary through reference to driven steel pins. Conditions must be monitored often enough to anticipate slides and accelerated surface erosion, and take corrective action. The quality of road drainage water, particularly the content of fine sediment from active roads, represents a generally uncontrolled problem where the water is routed directly into a stream channel. Monitoring should identify sites where this occurs so that corrective action can be taken.

Soil properties are measured at individual sample sites. A monitoring program may be conducted on a site level (as part of documentation of the impacts of site disturbance), or on a watershed level (as part of the assessment of regional disturbance). In the latter case, standard statistical methods of sampling for areal proportions should be used.

8.2.2 Monitoring Stream Channels

The overall goal established for stream channels is to maintain the integrity of aquatic ecosystems.

The overall goal established for stream channels is to maintain the integrity of aquatic ecosystems by managing the watershed system to prevent alterations to hydrological regimes and water quality, loss of riparian vegetation, and changes in channel structure that reduce channel integrity and dependent biological productivity. To this end, the following objectives must be achieved:

1. to maintain waterflows and critical elements of water quality within the range of natural variability on both seasonal and event bases;
2. to maintain the character of the riparian area and the full-length integrity of the stream channel system (see also Section 8.3);
3. to minimize deposition of fine sediment and sand in the channel system and maintain the quantity and quality of spawning gravels; and
4. to maintain the structural diversity of channels by maintaining the volume, stability, and distribution of large woody debris, and to manage the riparian area to assure a continuing supply of this debris.

Changes in forest cover and in the hillslope drainage system change waterflows and quality.

Changes in runoff amount and timing, and in water quality drive significant changes in stream systems. Changes in the forest cover (affecting interception and transpiration of water) and in the hillslope drainage system (as by roadbuilding) change waterflows and water quality. Streamflow and water quality changes are principally monitored in gauging networks designed at the subregional level, and observations must be continued for years to resolve significant changes. Potential approaches are discussed further in Section 8.2.3.

Stream channels are a critical focus for monitoring activity because maintaining natural conditions along the channels is essential for maintaining water quality and aquatic ecosystems. Changes in the stream channel are detected by observations at the site to watershed levels. Land use may induce changes in channel morphology by changing the runoff regime or the influx of sediments, or by directly interfering with the channel. Many physical and biological variables indicate change. The most informative variables are those that give the quickest warning that forest operations should be stopped or modified to avoid serious damage, and those that measure the properties of flowing water that most directly affect the aquatic biota.

The following physical factors damage life in fresh water most rapidly:

- loss of shading causes water temperature to rise, disrupting life cycle timing for some organisms and, in extreme cases, posing a mortal threat;
- increased duration of high flows compels organisms to spend unusual amounts of time and energy seeking shelter, and more frequently washes away populations of drift organisms;

- the deposition of fine sediments smothers streambed organisms by depriving them of dissolved oxygen. Suspended sediment in fast-flowing water kills benthic organisms by abrasion and, if persistent, damages the gills of fish;
- shifting of bed material grinds and destroys egg nests; and
- the washing out of log jams releases substantial quantities of stored bed material which is transported downstream, and destroys the deep, calm pools that provide the habitat needed by many species.

In monitoring life in fresh water, changes in factors such as shading of riparian zones and flow levels should be monitored.

Monitoring efforts should therefore concentrate on changes in the following factors: shading of riparian zones; flow levels; quantities of suspended sediment; turbidity; dissolved oxygen in the water column and in gravel interstices; substrate permeability; abrasion at streambed level; bedload movement; and the dislodging or circumvention of natural log jams. For practical purposes, these factors must routinely be inferred from simple measurements of channel disturbance.

To investigate compliance with the *British Columbia Coastal Fisheries/Forestry Guidelines,* a program of audits has recently been conducted for stream channels in and adjacent to forest cutblocks (e.g., Tripp *et al.* 1992; Tripp 1994a and 1994b). This program demonstrates a practical approach for monitoring stream channel morphology. A sampling approach is appropriate because continuous observations at more than a very few sites are prohibitively expensive, and monitoring environmental conditions by sample data from many sites is more valuable than detailed data from only a few sites. Measurements are made at site level for interpretation at the watershed level. The Panel makes three suggestions for stream channel audits:

A program of stream channel audits should become an integral part of planning and post-development monitoring.

1 a program of stream channel audits should become an integral part of planning and post-development monitoring;

2 the program should incorporate audits of undeveloped stream reaches (including pre-development audits) to provide a growing body of reference data of natural conditions (see Section 8.1, R8.1); and

3 the program should incorporate some observations that are not necessary in all audits.

Basic observations in repeated stream audits for designated reaches should include length of channel along which the forest has been cut to streambank (re. channel shading); length of bank with active erosion, and evidence of scour and sedimentation (re. sediment movement); amount and distribution of large organic debris in the channel; and length of pool, riffle, and glide habitat (re. channel structure). Many of the observations should be photographically recorded. For major channels, consideration should be given to obtaining helicopter-based video or 70-mm stereo photography. Audits should also include basic measurements of channel morphology incorporated into a sketch map of the channel which shows principal pools, riffles, log jams, and side channels. Log jam status and side channel access should be carefully noted.

Additional procedures that should be added to some stream audits include sampling of streambed gravel texture (particularly to determine the content of fine materials; Rice 1995), sampling of dissolved oxygen and permeability within streambed gravels (Terhune 1958), and counting benthic organisms. These observations require special equipment or laboratory procedures, and skilled personnel. The level of training is not, however, prohibitively great. Surrogate measures may substitute for the most expensive procedures. For example, dissolved oxygen concentration tends to vary inversely with the amount of fine sediment in the bed sediments; hence particle size analyses give an approximate inverse measure of substrate dissolved oxygen that need be calibrated only occasionally. In research studies, "gravel bags," samples of clean streambed gravel enclosed in mesh sacks or trays, have been planted in the streambed for later recovery to determine the rate of fine sediment deposition (Carling and McCahon 1987). This technique could provide a useful surrogate for assessing several of the key factors previously listed (e.g., suspended sediment, turbidity, substrate oxygen, and permeability), and should be tested for operational use.

Stream systems integrate source effects from everywhere in the contributing catchment.

Stream systems integrate source effects from everywhere in the contributing catchment. Therefore, the proposed monitoring is best achieved by combining measurements at watershed and site levels. Gauging sites provide measurements of runoff processes that summarize the integrated effects of all upstream conditions. But if a gauge site is far from a severe but local disturbance, the effect may remain difficult to detect. In particular, much of the sediment mobilized at a disturbance site may settle out along the channel before it reaches a gauge point. Therefore, channel audits will be the focus of monitoring activity related to site development. Individual audit sites will cover a reach of channel approximately 100 channel widths in length (which should include 15–20 pool/riffle units if the channel has normal fluvial spacing of pools and riffles). To obtain sharper resolution of stream channel disturbance at sites that have evident impact upon the stream channel, observations should be made upstream of the site, and at a sequence of downstream sites to the point where traces of disturbance disappear. To understand short-term, acute response of the stream channel, observations will be required on a seasonal basis for one or two years.

Audits should be conducted on all channels with gradients less than 8% and on all primary channels known to harbour fish.

Audits should be conducted on all Type 1 channels (see Figure 7.4 and Appendix II) and on all primary channels known or expected to harbour fish. Other channels should be audited on a sample basis, except that audits should be conducted in all community watersheds. The schedule of audits should be random except for acute effects monitoring (discussed previously), when contributing to particular sampling designs (e.g., pairwise comparisons), or in community watersheds, which should be audited for stream channel condition on a regular basis. For channels that must be audited, pre-development, immediately post-development, then once in five years will be a reasonable schedule, except that reconnaissance inspections should also be conducted after regionally extreme flooding (i.e., estimated 25-year event or greater).

8.2.3 Regional Monitoring of Streamflow and Water Quality

In monitoring streamflow and water quality, a key indicator is water balance.

As noted, significant changes in stream systems are driven by changes in runoff amount and timing and by changes in water quality. Flows of water vary with changes in climate (affecting water inputs), forest cover (affecting interception and transpiration of water), and physical changes at the surface (affecting water routing). Monitoring these changes and their effects involves monitoring the water balance. The principal quantities involved are precipitation, evaporation (including transpiration), and runoff. For monitoring, it is necessary to measure precipitation and runoff. Runoff usually is measured as streamflow; precipitation is measured at fixed points by bucket gauges. Both measurements entail continuous monitoring for some years to encompass synoptic, seasonal, and year-to-year fluctuations in weather. Therefore, a program of observations is expensive. Standard analytical methods for dissolved oxygen, specific conductance, and optical turbidity are described in Environment Canada (1981). However, modern field probes allow direct measurement and recording in the field.

A long period of measurement is necessary for water quality parameters.

Water quality varies on time scales similar to runoff, and so a long period of measurement is necessary for water quality parameters as well. In the past, grab samples have sometimes been taken to check water quality. With this method, the chance to sample occasional extreme events, which may be of paramount ecological interest, is relatively low. Sampling that does capture such events entails expensive continuous runoff and water quality monitoring procedures. Both time and cost commitments make these procedures impossible in inventory, planning, and monitoring associated with forest site development. Nonetheless, this information is important for assessing the effects of forest development on watershed integrity.

Within the 3500 km^2 area of the Clayoquot Sound region there is no stream gauge.

Precipitation and stream gauging measurements have been recognized as the responsibility of specialized government agencies (specifically the Atmospheric Environment Service (AES) and the Water Survey of Canada (WSC), both agencies of Environment Canada). For these agencies—which maintain stations for several purposes and ensure that data are obtained uniformly with a high level of quality control—collecting information on a regional scale that is useful for forest land management requirements is impractical. Over the last 25 years, land and water management agencies, including the B.C. Ministry of Forests, have gained experience collecting data for land management purposes, sometimes in cooperation with industry. No stream gauge is installed within the 3500 km^2 area of the Clayoquot Sound region, and reporting precipitation gauges are found only in the main settlements. (An example of an intensive hydrological and water quality monitoring program is available from the research watershed at Carnation Creek, on the south side of Barkley Sound.)

Techniques and instruments developed within the past 15 years make gauging and water quality monitoring programs practical at a scale that would detect the effect of forest land use on streamflow and water quality regimes on a subregional basis. It appears most appropriate for the land management agencies and land users to conduct and finance the program. Regional AES/WSC networks remain important in a monitoring strategy as the long-term reference stations by which additional gauging may be assessed for quality of records and significance of trends, and to detect long-term environmental change.

It is reasonable to expect to have three or four operating stream gauges, and perhaps six precipitation gauges.

Within the Clayoquot Sound region, it is reasonable to expect to have three or four operating stream gauges, and perhaps six precipitation gauges (not counting ones established for research purposes). The planned period of record for a gauge should be 10–30 years. This period corresponds with the time to establish the "normal" climate (Landsberg 1958:91–92), and is consistent with the time to establish the effects on runoff of forest harvest (see Section 7.2.4).

In Clayoquot Sound, it would be useful to establish gauges for a large primary watershed and for a small watershed within one of the protected watersheds (e.g., Megin River), and to seek observations for comparison in a basin subjected to development. Because of the long-range nature of the program, it would be appropriate to establish gauging in a basin that is not, at present, highly developed.

As a minimum, individual stream gauges should measure water stage,[149] water temperature, and optical turbidity. It is also possible to install sensors that measure water velocity and discharge directly. Additional measurements should be considered as they become feasible, particularly dissolved oxygen, specific conductance, major nutrients (particularly nitrogen species, because aspects of nutrient cycling at watershed and subregional levels are best determined by monitoring nutrient loading in drainage waters), and organic drift matter. Measurements should yield continuous records of significant fluctuations; regular laboratory analysis of water samples should assess water quality.

The program will be useful only if it includes ongoing analysis and interpretation of the records.

The measurements are conducted within selected watersheds, but the interpretation is made at the subregional level. The data for the region (none exist except for precipitation) may be interpreted to reveal the variability of natural conditions and the effects of disturbance within the wider region of the west coast of Vancouver Island. The program will be useful only if it includes ongoing analysis and interpretation of the records as they relate to climate trends and land use.

The combination of measurements noted for collection at watershed and site levels, and subsequent interpretation at subregional and watershed levels are designed to overcome constraints of great variability and high cost that otherwise would make stream system monitoring onerous.

[149] Water stage is the level of water (in a stream channel, lake, or the sea) measured relative to a fixed datum (which may be arbitrary). Stage establishes a consistent basis for measuring the variation in water level at a place.

8.2.4 Monitoring the Coastal Zone

The goal in the coastal zone is to maintain the integrity of littoral and inshore marine ecosystems.

The goal in the coastal zone is to maintain the integrity of littoral and inshore marine ecosystems. Accordingly, the objective for the coastal zone is

- to maintain the physical integrity of the littoral and inshore marine zone (including all waters in inlets and embayments with restricted circulation).

Most of the coastline is rock, and the exposed coast has exceptionally high wave energy. The main threats to coastal integrity arising from forest activity are increased fine sediments in the water column and sedimentation around certain river mouths (especially near the heads of inlets), and physical damage and sedimentation of bark and wood debris at log dumps, booming grounds, and storage sites. It is unlikely that increased stream-delivered sediments would pose considerable marine problems before concerns had been identified in the contributing stream system. Hence, in both cases, sites where specific attention is required can be identified. Effective monitoring will be site-specific, and may require underwater inspections, depending upon the nature of the marine resources threatened (e.g., herring spawn sites, shellfish beds; see also Section 8.3.5).

The security of beaches and of the intertidal zone is subject to a more widespread concern. Drift logs, or a locally changed pattern of longshore sediment drift created by facility installation, may influence patterns of natural scour and sedimentation in the long term. Aerial photographic surveys about every five years may provide the best early warning of change.

8.3 Monitoring Biological Diversity

Definitions of biological diversity consider three levels of organization: genetic, species, and community or ecosystem levels.

Maintenance of biological diversity is inextricably related to the long-term maintenance of healthy, productive ecosystems.

Almost all definitions of biological diversity (or "biodiversity") consider biodiversity at three levels of organization: genetic, species, and community or ecosystem levels. Many definitions, particularly those of management agencies, recognize ecological processes or functions as well. Careful reading of international agreements and other policy statements indicates that definitions of biological diversity attempt to encompass four major public concerns or goals through maintenance of biological diversity: (1) reduce rates of species extinction, (2) retain future options, (3) maintain healthy ecosystems, and (4) respect other species (Bunnell 1995b). In both reality and policy, maintenance of biological diversity is inextricably related to the long-term maintenance of healthy, productive ecosystems. The Panel recognized this relation in its goals for maintaining biological diversity:

- to maintain all naturally-occurring species and genetic variants such that they are able to persist over the long term and adapt to changes in their environment within the normal range of variation;

- to maintain the functional integrity of ecosystems recognizing the connections between terrestrial, freshwater, and marine processes. (Scientific Panel 1994a:36)

The maintenance of biological diversity thus consists in maintaining ecosystem integrity and connections, and ensuring the survival of all the species and species' variants of plants, animals, and fungi that together form the natural indigenous biota of an area. Biodiversity objectives thus depend upon attaining objectives for watershed integrity (Section 8.2). In framing objectives for these goals, the Panel acknowledged relations between ecosystem function and biological diversity, and the role that maintenance of diverse habitats must play in maintaining biological diversity. These objectives are as follows:

- to maintain ecosystem function by protecting the integrity of riparian areas from the terminus to the headwaters of watersheds;
- to protect habitats of known importance to particular species;
- to maintain old-growth and forest-interior habitats; and
- to use forest management techniques that produce stand structures, species composition, and landscape patterns similar to those generated by the natural disturbances of forests in Clayoquot Sound. (Ibid.)

Maintaining habitat is the first step in maintaining biological diversity.

Monitoring for these other objectives might be pursued by focusing on the organisms themselves, or on habitat availability. Panel recommendations for planning (Chapter 7) and silviculture (Chapter 4) are intended to maintain habitats either through reserves or retention of habitat elements during harvesting. These recommendations are meant to avoid habitat fragmentation and the consequent isolation of small populations of normally widespread species, and to produce stand structures and landscape patterns similar to those generated by natural disturbances. Unnaturally small and isolated (fragmented) populations are at risk of extirpation or extinction for two reasons: they may simply die out, because of chance fluctuations in population size; and inbreeding may have deleterious effects on population viability by altering natural heterozygosity. Approximating naturally occurring stand structures and landscape patterns should maintain habitat, the first step in maintaining biological diversity.

Nowhere has an effective approach for maintaining biological diversity within a managed forest been demonstrated.

Because many species are either poorly known, or unknown, and Panel recommendations focus on habitat, monitoring also focuses on habitat. That approach invokes a major assumption that current measurements of habitat usefully represent the organisms themselves; this assumption must be evaluated by research and long-term monitoring. Hence, both organisms and habitats must be monitored in complementary contexts. It is important to recognize that, although widely believed to be possible, an effective approach for maintaining biological diversity within a managed forest has never been demonstrated.

Monitoring for biological diversity must initially test two major assumptions made by the Panel in its efforts to make maintenance of biological diversity an attainable, practical goal in managed areas: (1) the assumption that maintaining recognized habitats serves to maintain biological diversity; and (2) the assumption that Panel recommendations for planning of reserves and maintenance of a diverse forest through new silviculture strategies, which centre on habitat, will serve to attain the goals and objectives noted on the previous two pages.

Monitoring will necessarily be largely indirect.

Though organisms and habitats must both be monitored, monitoring of biological diversity at the species and genetic levels will necessarily be largely indirect. It will concentrate on the maintenance of representative habitats and connectivity among habitats. Monitoring at all levels of planning has consistent elements because movement or dispersal abilities of organisms span an enormous range of spatial scales. What constitutes an appropriate distribution or sufficient amount of habitat to facilitate movement and interbreeding is distinct for each species and unknown for most species. Management will have failed if the range of any species gradually shrinks, or if naturally well-distributed species are absent from large areas for several decades.

Concentrate on the maintenance of representative habitats and connectivity among habitats.

Other than the indirect monitoring to ensure that representative habitats are retained without barriers to movement between them, monitoring should exploit approaches offered in Sections 8.3.2 through 8.3.4. It should be augmented, however, with a concerted inventory and research effort in a selected group of watersheds (some contiguous) to ascertain if Panel recommendations serve to maintain genetic exchange among populations and genetic diversity across the landscape.

8.3.1 Monitoring Genetic Variation

Genetic variation is the underlying basis for biological diversity.

Although genetic variation is the underlying basis for biological diversity, direct monitoring of genetic diversity for all species is wholly impracticable. Moreover, maintaining the processes that create and maintain genetic variation within and among populations is more important than preserving a “snapshot” of existing genetic diversity. Nonetheless, actions that deplete known genetic diversity contravene the *United Nations Convention on Biological Diversity* (June 1992).[150] To attain the complex goal of maintaining both genetic richness and the processes creating genetic variation, three objectives must be attained:

1 to maintain known genetic variation within the biota;

2 to ensure sufficient connectivity within naturally widely distributed populations such that viable populations of all indigenous species and their genetic richness are maintained; and

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[150]One of four documents produced at UNCED ’92 (the “Earth Summit” held at Rio de Janeiro in June 1992). The *United Nations Convention on Biological Diversity* commits signing nations to conserve biological diversity, to use biological resources sustainably, and to fairly and equitably share the benefits of biodiversity. It is the first international agreement to cover all genes, species, and ecosystems.

3 to maintain the *total* genetic variation within species comprising naturally isolated populations.

Usually, genetic diversity is undetectable without costly and time-consuming work.

Patterns of genetic variation within the biota are poorly known for most species. Visible polymorphisms and subspecies could be monitored relatively easily; in most instances, however, the degree to which visible differences reflect genetic variation is unknown. Usually, genetic diversity is undetectable without costly and time-consuming laboratory work. Such effort could be justified for only a few species. The first step should be to maintain visible variation. Monitoring for this step is the same as that needed for monitoring biological diversity in the general sense (e.g., Section 8.3.3), but recognizes visible distinctions within species.

A key indicator is the dynamics of species ranges.

With respect to the second objective, for species with large continuous geographic ranges, scientists believe that maintaining the ranges of these species (i.e., preventing the loss of local populations and preventing peripheral erosion of the ranges) will maintain the genetic richness of the species. Maintaining connectivity within such populations helps to maintain viability by ensuring that small, isolated, and vulnerable subpopulations are not created. A key indicator is the dynamics of species ranges: appropriate monitoring should focus on detecting whether ranges are shrinking, or new gaps are appearing in the interior of the range. In large part, that monitoring must initially be accommodated through approaches described in Section 8.3.3, but interpreted at the subregional level. At the watershed and subregional levels, a key indicator to evaluate apparent connectivity is the continuity of habitat. This approach is necessarily indirect, and must be augmented by research to ensure that habitat linkages that ensure connectivity are effective in allowing movement of organisms.

The most species-rich habitat islands are hydroriparian systems in deep valleys.

The first two objectives focus on maintaining existing genetic richness; the third objective directly addresses some processes creating genetic variation within discontinuously distributed species. Many species do *not* have extensive continuous ranges. These species survive only in isolated, sometimes widely separated “habitat islands” where conditions are right for them; and they rarely, if ever, migrate from one “island” to another. In Clayoquot Sound the most species-rich habitat islands are hydroriparian systems in deep valleys, enclosed by the sea on one side and surrounded on the landward sides by high mountain ridges (Sections 2.2.3 and 2.2.4). The majority of species confined to such areas have existed as local, reproductively isolated populations for such long periods that the local populations have diverged genetically. The *total* genetic diversity of a species with many independent populations that rarely interbreed is likely to be considerable.

The challenge is to avoid increasing the rate at which naturally small and localized populations become extinct while not decreasing the rate at which similar, but new, populations are established. Meeting that challenge will maintain genetic variation and the processes creating it. Researchers and practitioners face a dilemma: isolation occurs naturally and produces genetic variation, but isolation also can reduce existing genetic richness and lead to local extinction. Currently, there is little guidance regarding potential outcomes of isolation for different species (e.g., Slatkin 1987). The first step must be to evaluate the interchange within species known or suspected to have continuous distributions (e.g., most birds, bears, and deer), and to maintain the scattered habitats of species naturally occurring as largely isolated populations (e.g., sedentary amphibians, resident fish populations, and flightless invertebrates).

A key indicator of probable success is the degree to which the natural range of habitats is represented within reserves.

Given that all species occurring naturally as small, genetically distinct populations are not known in Clayoquot Sound, a key indicator of probable success is the degree to which the natural range of habitats or ecosystems is represented within the reserve system. Monitoring the success in attaining this objective initially must focus at the subregional and watershed levels to ensure that the full range of natural habitats are represented in reserves. Given that hydroriparian systems tend to be isolated from other ecosystems, it follows that both species and habitats should be monitored diligently in those systems.

Maintaining riparian ecosystems contributes significantly to maintaining biological diversity at larger scales.

Monitoring of genetic variation must be indirect and should focus on the maintenance of representative habitat and connectivity among habitats. Although not fully tested, it appears that maintaining the integrity of riparian ecosystems contributes significantly to maintaining components of biological diversity at larger scales (e.g., subregional and watershed levels; Naiman *et al.* 1993). Intact riparian networks not only maintain many small, genetically distinct populations, but likely permit movement within larger, more widely distributed populations as well. Monitoring generally relies on approaches of Sections 8.3.2 through 8.3.5 but usually is interpreted at the larger scales (subregional and watershed levels). Because it is especially indirect, augmentation by a concerted, more intensive inventory and research effort is particularly important.

8.3.2 Monitoring Vulnerable and Rare Indigenous Species

Monitoring effort required is not the same for all species.

In Clayoquot Sound, the monitoring effort required is not the same for all species. One monitoring objective is

- to ensure that particular species known or suspected to be at risk are monitored and their habitats protected.

The Panel's recommendations for planning of reserves and maintenance of habitat during harvesting cycles are intended to maintain sufficient old-growth habitat.

To meet this objective, species at greater risk may require greater monitoring effort. These species are largely restricted to late seral (old-growth) forest habitat. Such habitat is not currently limiting these species in Clayoquot Sound, but it is impossible or requires very long periods to replace once removed. Moreover, current logging in Clayoquot Sound removes older forests. The Panel's recommendations for planning of reserves and maintenance of habitat during harvesting cycles are intended to maintain sufficient old-growth habitat that no such species are placed at risk.

It is important that habitats and species be monitored jointly.

All the *known* endangered, threatened, or rare species of the province are currently red- or blue-listed. For some of these species, relationships with specific habitats are poorly known; all merit special attention. There are no generalizable indicators for monitoring these species. Each species is unique, and advice on monitoring procedures must be sought from appropriate experts. Given that forestry practices usually alter habitats rather than impact species directly, it is important that habitats and species be monitored jointly. There also will be several as-yet undiscovered rarities among the vast collection of organisms for which monitoring procedures are poorly defined (e.g., insects, spiders, microfungi, and soil organisms). These species can only be monitored indirectly, by maintaining Clayoquot Sound's great diversity of habitats.

Very intensive monitoring, including measures of genetic and population dynamics, may be appropriate for some vulnerable species. Morphological characteristics can be useful (e.g., regression of weight upon length of the young in some amphibian species reflects population health and may presage population declines). Monitoring of vulnerable and threatened plant species could include measures of growth or reproductive output. But, for many species, a checklist approach (Section 8.3.3) must suffice until they are well enough understood that efficient alternative means of monitoring are developed.

8.3.3 Monitoring Terrestrial Environments

The Panel considers the sustained, widespread distribution of indigenous species and their habitats to be an operational, but untested, strategy for maintaining genetic diversity (Section 8.3.1). Species at risk merit special attention (Section 8.3.2). Persistence of most species, however, must be assessed by other means. This section discusses the general monitoring of species and their habitats to meet objectives of Section 8.3 directly relating to the goal of maintaining all naturally occurring species, and contributes to the more specific objectives of Sections 8.3.1 and 8.3.2.

Monitoring contributes to evaluating the success of the proposed forest management system, and to determining potential thresholds of habitat change.

Indicators that should be monitored fall into two broad categories: (1) those that research indicates are detrimental to maintaining biological diversity (e.g., forest fragmentation and isolation, deleterious edge effects, invasive introduced species); and (2) species and their distributions that relate directly to the goal of maintaining natural species and their genetic variation. Monitoring can thus contribute not only to evaluating the success of the proposed forest management system, but also to determining potential thresholds of habitat change and early warnings of population declines. Processes contributing to the maintenance of biological diversity operate over a wide range of spatial and temporal scales (Soulé 1985; Bunnell and Kremsater 1994), and monitoring must incorporate those scales.

Subregional Level

Analysis of species' distributions as a strategy for maintaining genetic richness occurs at the subregional level.

At the subregional level, managers must assess whether objectives for forest age-class distribution, rate-of-cut, and connectivity among habitats are being achieved. Variables that can be measured at the subregional level include the frequency distribution of patch sizes and age-class distributions for major forest types; location and extent of linkage areas between habitat units (conversely, degree of fragmentation); frequency and extent of major disturbances (such as fire and wind); rate of forest removal by all causes; road density; and amounts of edge. Some of these measures involve only map and air photo interpretation. Others require more effort. For example, determining the effectiveness of cross-watershed linkage areas requires monitoring the use of these corridors by particular species. Analyzing the distribution of species as a strategy for maintaining genetic richness also occurs at the subregional level.

Watershed Level

At the watershed level, appropriate variables are similar to those of the subregional level, with additional measures of patch shape, more detailed records of events contributing to the natural disturbance regime, and indicators of watershed integrity noted earlier (Section 8.2). For example, the objective of maintaining the soil nutrient pool partly depends on the soil biota, but that biota is not itself monitored; its general health is monitored by foliar analysis (Section 8.2.1).

Comparisons of data collected at different levels can reveal trends important to management.

Detailed accounts of wildfires, windstorms causing blowdown, landslides, stream avulsions and other such events that influence the natural disturbance regime should be recorded for developed and undeveloped areas. These latter records will document the range of natural variation. Interpretation of potential habitat effects (e.g., amounts of edge, forest age-class distribution, snag abundance) on species should occur at this level. Acquisition of data on species, however, will occur at the site level and be aggregated at the watershed level.

Site Level

Most work to acquire species-specific information must take place at the site level.

At the site level, indicators of habitat diversity and utility include patchiness; vertical structure of the forest; and presence of habitat elements such as snags, wildlife trees, and downed wood. An important index of biological diversity is species composition, including the frequency and extent of any invasive exotic species. Most species-specific information must be acquired at the site level (see Species, below). It is important to monitor both habitats and their elements, and the amount and kind of use that these habitats or elements receive. For example, measuring the use of wildlife trees by wildlife is far more useful than simply counting the numbers of wildlife trees. Where individual wildlife trees are retained, a representative sample should be monitored to determine what species are using them before and immediately after logging or stand tending, and at intervals thereafter.

Wetlands are an important component of the natural forest. The location and extent of wetlands should be mapped, and their type (e.g., lake, pond, swamp, fen, bog) recorded; any unusual species they contain should be noted. Also, changes in the extent and flora of wetlands may indicate undesired hydrological changes.

At the watershed and site levels, monitoring activities generally will require on-the-ground assessments.

Species

Species are monitored at the site level for interpretation at all three levels. For general monitoring of species present (see Section 8.3.2, Rare Species), the Scientific Panel recommends two approaches: using indicator species and using checklists. The two approaches address different questions. For each approach the level at which assessments are conducted is important, and comparisons of data collected at different levels can reveal trends important to management.

An indicator species is intended to document trends occurring in a number of species.

An indicator species is intended to document trends occurring in a number of species (e.g., cavity nesters of a particular size class). Ideal indicator species occur widely in the region of concern; have changes in population size that foreshadow habitat change; are easy and inexpensive to observe during all seasons; and respond differently to natural and human-induced environmental changes. No such ideal indicators exist and one species never fully indicates the requirements or responses of many other species (Sidle and Suring 1986; Landres *et al.* 1988). The Panel suggests realistic and moderate expectations of indicator species and a broad use of the indicator species concept, including monitoring key species, key habitats (e.g., old growth), and key components of structure and function (e.g., forest floor cover). Candidate indicator species should be selected to evaluate known potential threats. Some species have large area requirements, some are sensitive to human disturbance, and some rely on particular structural elements of the forest (potential candidates are presented in Appendix III). Attention should focus on such species. Each indicator species will be subject to specific monitoring techniques.

Indicator species should be selected to evaluate known potential threats.

Checklists are a simple listing of all species found in an area. They should provide a comprehensive listing of species and are particularly informative when compared to baseline checklists from large natural areas. When checklists are used for monitoring their shortcomings should be kept in mind. Checklists are strongly affected by the extent of the area and the mobility of species monitored; cannot indicate the future viability of any species; have little predictive value themselves for impending problems; and show decreasing sensitivity to changes in distribution and abundance as the sample area within which data are collected increases.

Despite their limitations, checklists provide an overview of species diversity.

Despite their limitations, checklists provide an overview of species diversity. When applied at the site level in conjunction with habitat measurements they indicate relations among monitored habitat elements (e.g., snags, downed wood) and individual species. When compared across a range of sites they help to address questions concerning how much of each element should be retained. At the watershed and site levels they help to evaluate the role of reserves in maintaining species and permit evaluation of the distribution of forest type and age class, including forest patch size and potential edge effects. At watershed and subregional levels the interpretation of repeated and well-distributed site-level checklists can reveal growing "holes" or empty areas in a species range, thus potential problems.

Number of species is not a satisfactory indicator.

Checklists should be analyzed primarily for the identities of species present. Number of species is *not* a satisfactory indicator because it can include undesirable invasive species, such as starlings, cowbirds, or Scotch broom, that may have been absent formerly. Moreover, the number of species present in an area varies naturally among ecosystems; more is not necessarily better. Upward trends in pioneer species, such as savannah sparrows or fireweed, in areas intended to maintain old-growth characteristics would indicate that the intentions likely were not being met.

Checklists can be compiled for the following non-motile organisms: vascular plants, mosses, macrofungi, liverworts, and many lichens. Motile organisms that can be checklisted include all mammals, birds, amphibians, and molluscs. Checklisting is impracticable, however, for many kinds of organisms, in spite of their ecological importance and abundance. Current lack of taxonomic knowledge and sampling difficulties make it impracticable to use a checklist approach for organisms such as: insects, spiders, and other arthropods; microfungi, including moulds; and the soil biota generally. Epiphytes restricted to higher levels of the canopy are practically inaccessible.

Locations must be coordinated with habitat monitoring to permit effective interpretation.

Standardized methods of collecting data, must be established and used consistently by checklist compilers. A growing body of literature on the approach (e.g., Kremen 1992; Green and Young 1995) can be adapted to conditions in Clayoquot Sound. Locations must be coordinated with habitat monitoring to permit effective interpretation. The most effective approach is likely a nested hierarchy with focal sites in selected watersheds (monitored seasonally to annually) nested within more extensive monitoring done every two to five years.

8.3.4 Monitoring Old-Growth Characteristics

One of the Panel's objectives in maintaining biological diversity is to maintain old-growth and forest-interior habitats.

One of the Panel's objectives in maintaining biological diversity is to maintain species associated with old-growth and forest-interior habitats.

As noted in Section 8.3.3, interpretation of checklists at the watershed and site levels helps to evaluate the success of reserves in maintaining such species. Old-growth forests represent distinct habitat types for two reasons: they sustain a distinct biota, and once removed they are impossible, or require long periods, to replace. Considered as a whole, old-growth characteristics comprise the characteristics of: the trees themselves, all other life forms in the forest, and many distinctive habitats and their elements (e.g., large downed wood), as well as distinctive aquatic habitats associated with old-growth forests. Trees are treated separately from other species because big, old trees themselves provide a variety of habitats for other species and form the major structural elements in the forest. These features are considered in turn.

1 The size class and age class distributions of each tree species are inevitably altered within cutting units. To meet the intent of the variable-retention silvicultural system recommended by the Panel, these changes in size class and age class distributions must be constrained to ensure that the forest within a watershed does not lose species from its natural fauna and flora. The stringency of constraints necessary to achieve these objectives is poorly known.

Monitoring should address two broad questions:

Does the current system defining forest age classes accurately reflect changes in biological diversity among stands of different age?

- First, does the current system defining forest age classes accurately reflect changes in biological diversity among stands of different age? The Panel considers age classes 8 and 9 (141 years plus) as late successional, but recognizes that some old-growth features likely become common only in forests much older than 140 years (e.g., large branches high in the canopy with their associated flora and fauna). For practical monitoring, a subdivision of the oldest age class (e.g., 400 years plus) may be important. Alternatively, because forests attain recognizable old-growth features at different rates on different sites, some index of old-growth features may be more useful. Moreover, old-growth features tend to appear at different rates: canopy gaps at 100–200 years, well-developed multi-storied canopies at 250–300 years, large snags at 300–400 years. Given the all-aged nature of natural forests in Clayoquot Sound (Section 2.2.2), an old-growth index will be more accurate and should be developed and tested for these forests, but designation of one or more new, older age classes may be more practical in the short term.

At what rate are microhabitats or habitat elements created within aging forests?

- Second, at what rate are microhabitats or habitat elements (e.g., decayed snags) created within aging forests? Projection of future habitats is relatively easy in even-aged forests, but natural forests of Clayoquot Sound appear all-aged and rates of habitat development are poorly known. Plots (likely larger than any appropriate for checklisting) should be established to estimate rates of habitat development in an array of harvested and unharvested forest types, including reserved areas. These plots would be broadly equivalent to permanent sample plots, but would incorporate elements of items 2 and 3 following. After initial concentrated efforts to establish an old-growth age class or index of old-growth, they should be sampled every five years.

Information should be acquired at the site level for interpretation at the watershed level to monitor success in maintaining old growth and its associated biota.

2 Monitoring all other forest life is the same as monitoring biological diversity, and has been described in Sections 8.3.2 and 8.3.3. Most species can only be monitored indirectly because they are numerous; are mostly unseen or unnoticed; occupy an enormous array of different habitats and microhabitats; or are presently unknown to science. As discussed earlier, the only feasible way to monitor them is by monitoring habitats.

The diverse array of microhabitats and their elements is a defining characteristic of old-growth forests.

3 The diverse array of microhabitats and their elements is a defining characteristic of old-growth forests, and offers promise for creating an index of old-growth features. Most simply, the diversity of habitats within old-growth forests results from the range of tree sizes and ages; the presence of dying, dead, or fallen trees, among healthy, growing trees; and consequent canopy gaps with associated, productive understory. Until research provides specific focus, the range of these habitats is best monitored by means of checklists of features known or suspected of being important to maintaining biological diversity and associated functions. These lists should be compiled at the same time as those described in Section 8.3.3. Items to list include gaps and larger openings created by the death of a tree or group of trees; dead-topped and dead trees; downed trees and logs, classified by degree of decay; root wads of blowdowns; wide branches of living trees that support beds of moss; hollow trees; and trees of distinct structure.[151]

Monitoring these features (many of which are in the vegetation inventory methodology being developed by the provincial Resource Inventory Committee) contributes to planning by estimating the rate (age) at which habitats develop and the period that they last (snag and downed wood decay), and by evaluating the utility of age-class or habitat elements in assessing resident biological diversity.

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[151]For example, large trees (often remnants from an earlier stand) which are broad-crowned, dominant, and very limby, or trees with “witch’s broom” (an abnormal tufted growth of small branches on a tree or shrub caused by dwarf mistletoe or viruses).

Special habitats are associated with the streams and rivers of old-growth forests.

Equally important are the special habitats associated with the streams and rivers of old-growth forests: submerged logs of various sizes and other woody debris; log or debris dams and the pools they create; pools under overhanging, root-bound banks; backwaters and side channels; flood channels; and stable, long-established floodplains. These features are related to both the physical (Section 8.2) and biological components (Section 8.3.5) of streams. The rationale for monitoring these features is the same as for terrestrial components of old growth: to establish linkages between ecosystem structure and biological diversity, and to focus monitoring on practically measurable features of the system. In addition to periodic sampling, these habitats and their features should be surveyed after major floods.

Monitoring for biological diversity must be undertaken through all stages of forest development.

Biological diversity must be monitored through all stages of forest development. Old-growth characteristics will develop in managed forests as they age. Structures typical of old growth will gradually appear and should be present to some degree within all stages of managed forests developed by the variable-retention silvicultural system.

8.3.5 Monitoring Aquatic Environments

The freshwater aquatic environments of Clayoquot Sound comprise rivers, streams, lakes, ponds, bogs, fens, and swamps.

The freshwater aquatic environments of Clayoquot Sound comprise rivers, streams, lakes, ponds, bogs, fens, and swamps. The Panel's objective in managing and monitoring these areas is to maintain a functioning ecosystem without significant loss of biological diversity. Monitoring of physical habitat characteristics has been considered under watershed integrity (Section 8.2). Biological monitoring also is necessary to ensure that organisms are flourishing in the environment. Sampling will take place at the site or stream reach level. Synthesis and interpretation should be at the watershed level for resident organisms (e.g., plants and amphibians), and at the watershed and subregional levels for migratory animals (e.g., anadromous fishes, many species of waterfowl, and shorebirds).

Indicators are intended to serve as biomonitors of the viability of the environment.

In aquatic environments, as for terrestrial environments, the Panel recommends both an indicator and checklist approach. Indicators are intended to serve as biomonitors of the viability of the environment. For example, the effect on organisms of increased streamflows, or of sediment movement cannot be observed directly. Criteria that include only physical and chemical measurements are presently insufficient to measure biological integrity. The most useful biomonitoring program would record several major taxa and would be very expensive. Micro-organisms and invertebrates are difficult and time-consuming to sample, sort, and identify, and life-history information is often lacking. But extensive life-history information is available for many fish species, representing various trophic levels. In areas where communities of fish are relatively complex, species composition has been used to provide an index of biotic integrity (Karr 1981; Karr *et al.* 1986). As indicators or biomonitors, fish represent a potentially useful, but incomplete, element of a monitoring program. Sampling must be representative of the fish community and include a representative survey of riffles, pools, and other habitat units.

As biomonitors, fish represent a potentially useful, but incomplete, element of a monitoring program.

The protocols that already exist for monitoring salmonid stocks have been inconsistently applied in Clayoquot Sound (Section 2.2.5). Because of the commercial and cultural importance of salmon stocks, consistent monitoring of wild salmon escapements on a watershed and subregional basis is desirable in any case, and a consistent sampling program should be established which also serves ecosystem monitoring purposes. To distinguish the effects of the oceanic environment and harvesting pressures on anadromous fish from those related to the Clayoquot stream environment, sampling of juvenile fish may be required at some sites. Juvenile fish also are often more sensitive to environmental changes than are adults.

Fish are not present in all streams; for completeness a checklist approach is necessary.

Fish, however, are highly mobile, difficult to count, and many are subject to various external factors (especially fishing pressure); they do not represent ideal biomonitors. Nor do fish appear to accurately reflect the state of other aquatic organisms. Moreover, they are not present in all streams. Because the plants and animals of rivers, streams, and lakes form part of the Clayoquot Sound region's biological diversity, for completeness a checklist approach is necessary. For aquatic invertebrates, standard methods for sampling are available. Identifying captured invertebrates to the species level is impracticable, but that precision may be unnecessary for monitoring environmental conditions. A coarse classification into taxonomic orders and families may be sufficient. Changes in the relative proportions of animals in specific groups are potential indicators of changes in water quality and other environmental stresses (Newbold *et al.* 1980; Murphy and Hall 1981). Appropriate indicators have been developed for other areas (e.g., Plafkin *et al.* 1989; Kerans and Karr 1994), and are being explored for south coastal British Columbia.[152]

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[152]W. Neill, J. Richardson, pers. comm., March 1995.

Brackish-water and saltwater environments also require monitoring.

Brackish-water (i.e., estuarine) and saltwater (i.e., marine) environments also require monitoring. Development of appropriate monitoring protocols for estuaries, the intertidal zone, inshore waters, and offshore waters has proceeded rapidly since the oil spills in Prince William Sound (see Dethier 1991, Schroeter *et al.* 1993, and their references). As with other efforts to detect environmental impacts of human activities on natural communities, sampling any aquatic environment encounters the problem of separating human-induced changes from the considerable natural temporal variability of most populations. It is, however, evident that disturbance produced by land-based activities, by logs escaped from booms, and by fish farms can influence the physical environment of the intertidal and shallow subtidal zone, hence the viability of eelgrasses, shellfish, herring spawning areas, and other important inshore marine habitats. Correspondence with individuals developing protocols elsewhere suggests that while research from other areas will prove helpful, a protocol specific for Clayoquot Sound is required.[153] Sources dealing specifically with wood waste, benthic organisms, and log dumps include McDaniel (1973); Levings *et al.* (1985); McGreer *et al.* (1985); and Stanhope and Levings (1985).

One lesson from elsewhere on the Pacific Coast is that frequent sampling of organisms that are long-lived and recruit young sporadically (many marine organisms) will introduce serial correlations,[154] making data difficult to interpret (Schroeter *et al.* 1993). The Panel recommends that the period between censuses for any protocol in Clayoquot Sound should initially be once in every five years, but more frequently in areas of suspected degradation. Monitoring required in connection with maintaining production levels of marine products in the region is discussed in Section 8.4.3.

It is essential that monitoring of the forest not be divorced from monitoring of the sea. Forest and sea are interacting parts of a single ecosystem (Section 2.2.5).

8.4 Monitoring Human Activities and Values

8.4.1 Monitoring Areas and Sites Important to First Nations

First Nations people should participate actively in monitoring.

A detailed consideration of First Nations' perspectives in relation to forest practices standards in Clayoquot Sound, including monitoring, is presented in the third report of the Panel (Scientific Panel 1995b). First Nations people should be requested to participate actively in all aspects of monitoring. Areas and resources of special significance to them should be monitored by them or under their direction.

Many cultural areas and resources should be monitored, including sacred, historic, and current use areas, and a variety of populations and habitats of

[153] For example, M. Dethier, C. Levings, pers. comm., March 1995.

[154] Current status of the population is associated more closely with previous status than with new impacts.

culturally important plants and animal species. Some areas contain sites where visible artifacts, such as unfinished canoes, culturally modified trees, and pictographs require protection. Others—for example, places featured in traditional stories, used for spiritual training, or providing important medicines—are less obvious. Knowledge of such places may be restricted to a very few individuals. Thus it is essential that those people directly affected by possible impacts to such areas participate in monitoring and ensuring their protection.

A complete inventory of culturally important areas and resources is required to enable appropriate planning and monitoring in the context of ecosystem management. Some of this inventory has been completed.[155]

8.4.2 Monitoring Scenic, Recreational, and Tourism Values

Because of the strong interrelationships among scenic, recreational, and tourism values, it is efficient to monitor them jointly. This section describes goals and objectives for scenery and recreation, and monitoring methods to determine the degree to which the objectives are accomplished.

The two goals for maintaining scenic values, first presented in the Panel report *Progress Report 2: Review of Current Forest Practice Standards in Clayoquot Sound* are:

- to manage scenic resources to maximize the enjoyment of those present by ensuring that opportunities for tourism and recreation reflect the inherent quality of resources in an area; and
- to ensure that First Nations [peoples] and other residents are satisfied that the essential elements of the scenery around them are maintained. (Scientific Panel 1994a:43–44)

An abbreviated set of Panel objectives from the same report includes:

- to provide for a range of visual landscape experiences, and to plan these experiences in relation to existing and potential recreational routes;
- to conduct sustainable forest practices and related educational and interpretive programs [for the benefit of the public];
- to apply landscape design principles in all areas; and
- to maintain examples of different types of landscape in a relatively unaltered state.

The two goals for recreation and tourism (ibid.:49) are:

[155] For example, see *First Nations' Perspectives Relating to Forest Practices Standards in Clayoquot Sound Appendices V and VI* (Scientific Panel 1995c).

- to manage resources to protect features that are important to tourism and recreation; and
- to provide recreational and tourism opportunities that reflect the inherent quality of the resources in Clayoquot Sound and the recreational desires of residents and visitors to the area.

The recreational and tourism objectives most relevant to monitoring are:

- to provide for a range of recreational and tourism opportunities…that are sensitive to and based on the area's natural resources;
- to protect valuable resources for recreation and tourism; and
- to integrate into recreation planning the use patterns and needs of tourist and resident groups including First Nations.

Any alteration or development has an effect on scenic values.

Any alteration or development affects scenic values. The effect can be minimal (e.g., a small clearing in an area not visible from high-use areas) or significant (e.g., large cutblocks adjacent to major use corridors). In areas where there is existing or potential recreational use, alteration, development, and other activities (even recreation) can affect recreational values. For both scenic and recreational values, one major alteration or activity can have significant effects, or incremental use can cumulatively affect the values.

What to Monitor

Monitor perceptions and experiences of people and the physical condition of resources.

Monitoring for scenic and recreational values includes investigating the perceptions and experiences of people in the area, and analyzing the physical condition of the resources perceived and used.

The way people feel about scenery and recreation indicates their sense of the "health" of the resources. A range of groups, including First Nations and other residents, recreationists and tourists, and tourism operators, must be interviewed to determine: their enjoyment and level of satisfaction with scenic and recreational resources in specific areas; satisfaction with the range of experiences and opportunities available; factors contributing to positive and negative perceptions; and their future interest in areas with given characteristics. An important topic is the level of alteration, development, and use that people consider appropriate to specific activities or key areas. In addition to logging and other development, factors such as a high level of recreational use can have negative effects on resources and perceptions.

Use is a strong indicator of the capability of resources and of how people perceive resources.

Use, especially by the recreation and tourism sectors, is a strong indicator of how people perceive resources. Monitoring use over time is particularly important in areas where scenic and recreational resources are changing (either because of new logging or development), or where visually effective green-up of previously logged areas is occurring. This monitoring will show the interrelationship between existing levels of alteration and actual use.

The perceived physical condition of scenic and recreational resources must be monitored where logging or other development has occurred. The resources are analyzed to determine if the alteration meets the stated visual landscape management and recreational objectives (e.g., maintaining examples of different types of natural landscapes in a relatively unaltered state, protection of recreational resources, development of areas with sustainable forest practices suitable for interpretation and education). Landscape design must be assessed, noting items such as compatibility of cutblocks with the landform, visual dominance of structures, and visual prominence of roads. The detailed effects of alteration and development should be analyzed to determine their influence on the perceived quality of recreation sites.

The actual physical and biological condition of scenic and recreational resources should also be monitored. Areas reserved from harvest for other reasons (e.g., Section 7.3.2) may have high or low scenic value commensurate with their purpose, and may also become “destinations” for ecotours or wilderness experience. Reserves designated to maintain ecosystem integrity are not meant to provide scenic values or recreational opportunities: some reserves (e.g., to protect sensitive soils or wildlife sensitive to disturbance) may be harmed by relatively low levels of human use. Physical and biological consequences of recreation and tourist activity should be monitored where working units are specifically designed to host such activity and especially where reserves become sites of such activity.

Methods of Monitoring

Monitoring of perceptions and experiences is accomplished by asking the appropriate people. The perceptions of recreationists, tourists, and the general public, can be obtained from questionnaires given to clients by tourism operators at the end of a trip, distributed at tourism information centres, and administered in local areas such as Tofino or Hot Springs Cove. Photo-questionnaires are useful in assessing perceptions about scenic resources. To obtain the perceptions of tourist operators and local residents, questionnaires and workshops are potential monitoring methods.

Use patterns can be monitored with questionnaires to recreation groups and tourism operators or by conducting user counts in the field. User counts require more effort than questionnaires but are a more accurate survey method.

Monitoring the perceived and actual physical condition of scenic, recreational, and tourism resources involves inventory and analysis. Some of these activities are best conducted by landscape and recreation experts; others, by individuals familiar with the techniques of Sections 8.2 and 8.3. Experts can provide detailed information on how resources have been affected by alteration or development, and can identify what steps might be taken to meet specific objectives (e.g., rehabilitation). Local people can be trained to assist in the analysis.

The forms and methods of monitoring are the same at all planning levels.

Most forms and methods of monitoring are the same at all planning levels. Monitoring at all three planning levels and using that information as appropriate at all levels is critical. At the subregional level, resources over large areas (e.g., major use corridors) must be considered as a whole to account for the cumulative effects of changes on scenery and recreation. This information is relevant in guiding watershed- and site-level activities. Watershed-level monitoring will provide important detailed information on the effects of alteration. Site-level monitoring will be useful in guiding design criteria. Most assessments of potential negative impacts of recreation and tourism will occur at the site level.

8.4.3 Monitoring Regional Production

Determining whether sustainable development has been achieved requires monitoring the flow of resource products over the long term.

The viability of local communities and sustainable development of the land and sea resources of the Clayoquot Sound region are inextricably linked. The Scientific Panel has asserted that developing the resources of Clayoquot Sound sustainably depends on adopting an ecosystem approach to resource management. Determining whether sustainable development has been achieved requires monitoring the *flow* of resource products over the *long term*—in terms both of quantity and quality, the latter being particularly important in an assessment of sustainability. Assuring sustainability of all forest values will be difficult because the growing population in the region will steadily increase the pressure for land and resource uses. Furthermore, changing social priorities, both within and beyond the region, will influence the ways in which resources will be used. The Panel cannot give a detailed discussion of criteria for monitoring regional production due to these economic and social complexities. However, it does make some observations related to its charge to consider sustainable forest practices.

Production of commodities from the forest will remain a significant factor in the overall regional productivity.

Production of commodities from the forest will remain a significant factor in the overall regional productivity. Monitoring the production of forest commodities differs from monitoring the flow of "forest products" as that term has usually been used in British Columbia. Wood and fibre constitute only a part, albeit a major part, of the resources of Clayoquot Sound forests, and their estimated harvest is noted as one objective of subregional planning (Section 7.3.1). Other products from the land include the many natural foods, medicines, and materials traditionally used by the First Nations population; tourist and recreation "products" which have growing economic importance; and non-traditional forest products that are, or may become, useful to small, local enterprise, such as edible mushrooms and other botanical forest products (see B.C. Ministry of Forests 1995a). Clean fresh water, and major subsistence, commercial, and recreational fisheries are also products of the forest. All of these "products" need to be monitored in any comprehensive assessment of regional production.

In Clayoquot Sound, the products of the sea are as important as those of the forest. In addition, a potentially major aquaculture industry is being established in the inlets of Clayoquot Sound, despite opposition. These circumstances make it imperative that forest operations do not harm the marine environment or marine resources. Monitoring the regional production of the sea will require keeping complete records of fish, shellfish, and other marine resources harvested. This monitoring has not been achieved in the past, and the Panel acknowledges the difficulty in establishing a comprehensive records system due to the diverse nature of marine activities.

8.5 Implementation

Because monitoring requires substantial labour it must be undertaken or directed by the public or by public agencies.

Environmental monitoring is a labour-intensive and expensive task if undertaken entirely by professionals. Because monitoring is obviously in the general public interest (i.e., it helps to guarantee the integrity and productivity of the land in the long term), but possibly not entirely in the interest of any individual resource user, it must be undertaken or directed by the public or by public agencies. Beyond basic programs of regional interest, however, it probably is unrealistic to expect continuous close attention to monitoring programs from public agencies over long periods of time. Therefore, local interest and involvement in monitoring (as mobilized, for example, in follow-up committees) are essential to ensure a successful monitoring program.

Some aspects of monitoring require technical expertise. To assure attention to the organization and technical excellence of a monitoring program, a professional land manager with a broad mandate is required. This individual must be charged with effective coordination of all monitoring programs at the subregional level to assure timely collection and archiving of data and, more importantly, to continue data analysis and take appropriate actions as the results indicate. Effective coordination includes on-the-ground familiarity with the area and involvement with programs.

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

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 who are interested in working regularly and conscientiously. This approach will entail training and an administrative structure that includes such individuals and their communities. The establishment of wardenship of community watersheds would be an effective first step in this direction: the interest of the local community is obvious in such a case. The Streamkeepers and Water Stewardship programs of the provincial Resources Inventory Committee can provide training for school and community groups. In Clayoquot Sound the traditions, experience, and concerns of the Nuu-Chah-Nulth people help to ensure that they will understand and respond to the need for wardens within a comprehensive program of monitoring for environmental integrity. Clayoquot Sound is an excellent place to test the concept of local responsibility for sustainable ecosystem management.

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