PROCEEDINGS OF

The Cedar Symposium

Growing Western Redcedar
and Yellow-cypress on the
Queen Charlotte Islands / Haida Gwaii

Canada
CANADA-BRITISH COLUMBIA
SOUTH MORESBY FOREST
REPLACEMENT ACCOUNT
BRITISH COLUMBIA

The South Moresby
Forest Replacement Account

BRITISH COLUMBIA
Ministry of Forests

P R O C E E D I N G S O F

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Growing Western Redcedar
and Yellow-cypress on the
Queen Charlotte Islands / Haida Gwaii

Greg G. Wiggins (editor)

May 28–30, 1996
Queen Charlotte Islands / Haida Gwaii
British Columbia

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Introduction

Markus Salzl, Allan Sugg, Julian Wake, Greg Wiggins, and Del Williams
Symposium Organizing Committee

The successful regeneration and management of western redcedar (*Thuja plicata*) and yellow-cypress (*Chamaecyparis nootkatensis*) trees on the Queen Charlotte Islands / Haida Gwaii has been an issue of concern for foresters and other scientists for a number of years. These two tree species comprise a significant proportion of the old-growth forests of the Islands, about 30% by volume, and are important commercial timber species. Redcedar is also a keystone species for the Haida, and central to their culture. Various factors affect the successful regeneration of redcedar and yellow-cypress. It is clear that Sitka black-tailed deer, an introduced species, have a feeding preference for redcedar and yellow-cypress. As a result, there are fewer of these trees in the second-growth forests, as well as in the younger age classes of old-growth forests.

Professional foresters and forest science researchers have been aware for some time of the problem that deer pose for cedar and cypress regeneration, and for other plant communities here, but this knowledge has not been generally appreciated by a very large audience. This Cedar Symposium was conceived as a forum for further discussion about the variety of interrelated issues—economic, ecological, and cultural—associated with cedar and cypress management on the Islands.

Forest managers want to ensure that redcedar and cypress continue to be significant trees in Island forests. Both are valuable commercial timber trees. Both are well adapted to the ecosystems of the Islands, and redcedar has a particularly wide ecological amplitude, or ability to grow well under a variety of different moisture and nutrient regimes. This makes it a species of special interest and importance for foresters who plant trees expected to grow for a century or more, when confronted by the vagaries of the climate change predicted over the coming decades.

Redcedar is the "Tree of Life" for the Haida, and they need it to ensure the continuity of their culture and traditions. They need an assured supply of a range of tree sizes—smaller trees for provision of bark for baskets and weaving, and mature trees, 500–700 years old, for monumental totems, canoes, and traditional house construction. In view of their requirements for large mature trees, the Haida are as concerned about the management of mature forests as they are about the current problems and costs of regenerating cedar after logging.

The subject of deer on the Islands is probably important enough to warrant a symposium of its own, and was dealt with in a limited manner here because of the clear relationship between deer and cedar. Introduced species have produced well-documented ecological problems and very large economic costs throughout the world. Island ecosystems such as the Queen Charlotte Islands / Haida Gwaii are often particularly vulnerable to these effects, and that is the case here, where a number of problematic animal and plant species introductions have occurred, and continue to occur.

The first of several deer introductions to the Islands began around 1900, to provide an alternative food source for local people. There are no significant natural predators of deer here, such as wolves or cougars, and the population has grown very large, with deer now found throughout the archipelago. The severity of deer feeding on cedar and cypress seedlings makes it more difficult and expensive for timber tenure licensees to regenerate these species successfully.

Deer also significantly deplete the herb and shrub plant communities of the Islands, with significant ecological consequences that are just beginning to be understood. This behaviour acts to reduce average silviculture costs of regenerating tree species such as spruce and hemlock (to provincially low levels), since competing brush species are suppressed. And so arise the related issues of deer management—population size and growth, the associated ecological impacts, and the various possible methods that might be used to mitigate the problems. The presentation by Dr. Robin Gill provides an interesting view of the similarities between deer management issues in Britain, where natural predators are absent, and here on the Islands.

Eradication of deer is undesirable—many local people still depend on deer for food—yet some means of reducing deer numbers to a lower level seems required. This is particularly important for Islands parks and ecological reserves, where neither logging nor hunting are permitted, so as to preserve a representative range of natural ecosystems. A large, unmanaged deer population in these areas will greatly reduce, and possibly eliminate, cedar and cypress over time, along with other plant species. Management of deer on the Islands is and will very likely continue to be a lively topic, coloured frequently by at least some emotion. Regarding the necessity for some sort of community consensus about such management, one of the attending research scientists cautioned during the concluding portion of the symposium that communities can reach all the consensus decisions they want, but those decisions will be the wrong ones if they ignore ecological conditions and limits.

We enjoyed planning and putting on this symposium. It was a gathering with a wide range of opinions, and with presentations and discussions that were dynamic, interesting, and even riveting at times, and it reflected the "enigmatic nature" of cedar—silviculturally, scientifically, ecologically, and culturally. Such a spirited debate about any other tree species is not easily imagined. Subsequent to the symposium, a number of research and inventory projects have been initiated, to address requirements for further information about both cedar and deer.

Note: Yellow-cypress, cypress, and yellow-cedar are common-name synonyms used for *Chamaecyparis nootkatensis* in British Columbia. Similarly, western redcedar, redcedar, and (usually) cedar are synonyms for *Thuja plicata*.

Acknowledgements

Significant responsibility for the organizing and execution of this symposium was conducted under contract by Ms. Sandra Thompson and the Laskeek Bay Conservation Society. Ms. Thompson was instrumental in organizing and enabling the smooth functioning of the event, and the participation of local businesses and community members. We thank her for her professional capability, dedication, and hard work.

Welcome

Michael Nicoll Yahgulanaas
Moderator

Good morning, friends. Welcome to the archipelago known to Her Majesty's loyal subjects as the Queen Charlotte Islands, known to some others as Haida Gwaii or Haida Gwaiiaay, and to still others as the Gwaiian Archipelago. I'm very happy to see you here at the Cedar Symposium. The idea for the symposium was initiated by a number of people, some of whom are here: Mark Salzl, Greg Wiggins, and Allan Sugg; and two who are unable to be here: Del Williams and Julian Wake.

My name is Michael Nicoll and I've been asked to perform the role of chairperson from time to time, and there are going to be other chairpersons during the 2-day sessions. Sandra Thompson the coordinator is back at the registration desk. If you have any questions, we will do our best to help you out.

Hal Reveley, the Forest Practices Manager in the Vancouver Region of the Ministry of Forests, will be giving us the opening address for the symposium. He is a registered professional forester with an 18-year background in silviculture. And—without further ado—Hal, maybe you could come up and we'll get things started. Thank you very much.

Setting The Stage

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Good morning everyone, and thank you for that warm welcome, Michael.

I am both honoured and pleased to have been asked to give the opening address at this symposium. I am also very pleased with the diversity of the topics covered. No longer do we simply view trees as end products, forests as logging opportunities, or forest management as timber management. We are now in an era where we view trees as only one element of a complex ecosystem, forests as a product of complex disturbance patterns and dynamic ecosystems, and forest management as a balance between ecological, social, and economic values.

It is appropriate that we talk about our provincial tree here in Haida Gwaii, the Queen Charlotte Islands, given its dominant ecological, cultural, and spiritual presence. Western redcedar is sometimes called arbor-vitae, Latin for "tree of life." And it truly was the tree of life. The Northwest Coast peoples held the cedar and its spirit in high regard, believing deeply in its healing and spiritual powers. Some mythology says the Great Spirit created cedar in honour of a man who was always helping others. They believed the cedar tree held powers of healing. It was the cornerstone of the Northwest Coast aboriginal culture. Magnificent cedar canoes, carved from gigantic cedar trees, provided the primary transportation along the coast. Just imagine the amount of skill required to fell and then carve out a canoe from such a large tree. The cedar tree provided the materials for the massive beam houses that provided shelter. The bark from the cedar tree provided the materials for clothing, baskets, and other utensils; the roots and branches the materials for hooks and whaling ropes. Cedar was also used to declare lineage in the form of beautifully carved totem poles. It was also used to address the spiritual world in the form of wooden masks. I have only scratched the surface of how cedar was crafted into usable products that sustained the aboriginal culture and lifestyle. Cedar was also used by early European settlers who used it for shakes, shingles, and planks for home construction. Cedar continues to play a significant role today for both cultures, by providing useful products.

Cedar has a lengthy life span, which can reach 1400 years. Pollen testing suggests that cedar made its appearance in the Pacific Northwest some 6600 years ago. It is a massive tree, with the largest diameter being just over

6 m, with a height of 71 m. On the west coast, it ranges from northern California to Southeast Alaska and from sea level to 1200 metres in elevation.

Clearly, cedar has a strong connection to the past, but it is also strongly connected to the present. Today, cedar is one of the most important trees in the forest industry and continues to play an important role in the aboriginal culture. The wood is light and soft, has a characteristic colour and odour, and is very resistant to decay. Each one of us can picture in our minds the reddish brown colour and recall the distinct smell. It is these characteristic features that give cedar a specific niche in the market place. Cedar is used as exterior siding, roofing, door and window frames, fence posts, pilings, telephone poles, interior panelling, and furniture; and immediately the cedar chest comes to mind. It continues to be used by Haida artists, as you will see and experience during this conference. It currently represents about 23% of the allowable annual cut on the coast, which is about 75% of the cedar cut in North America. Here in the Queen Charlottes, cedar makes up roughly 30% of the timber volume within old-growth forest stands.

Cedar has an ecological role to play as well. The foliage has high concentrations of calcium and provides a good supply of litter to the forest floor. The foliage is well suited to support epiphytes, which are plants that derive their moisture and nutrients from the air and which grow on other plants. Cedar provides habitat for a wide variety of other plants and animals. It often develops butt rot that extends many metres up the trunk. This makes it ideal for many cavity-nesting birds and mammals. It also provides habitat for one of the larger forest dwellers, the black bear, that dens in these old cedars. With its great height and often dead top, it provides a good perch for many large birds of prey. When the cedar finally falls, it provides habitat for a whole host of other plant and animal species. Given its resistance to decay, it lasts in our forests for many, many decades after it has fallen.

But while we are here to learn from experts on what we know about cedar in a biological, ecological, cultural, and economic sense, we are really here to determine its future on the Islands. One of the major threats to its continued dominant presence is an introduced species. History shows us that introduced species often cause disruption to ecosystems until control measures bring stability back to the ecosystem. There are many examples of this problem world-wide. These issues are not easy to resolve but need to be discussed. In significant ways, it is the introduction of deer to the Islands that has brought us together to discuss the future of cedar.

Browsing from deer is probably worse here than anywhere else on the coast. Deer have reached high population levels with no natural predators to control them. Cedar has been seriously depleted and sometimes entirely eliminated from plantations. While cedar regeneration is possible, it can be very expensive. The cost per seedling can range from two dollars to over five dollars, excluding the cost of the seedling itself. Depending upon the system of browse protection used, annual maintenance costs in addition to this may be incurred for several years. The protection techniques available range from plastic tubes and stucco wire enclosures, to fencing, although my cost estimates do not include the latter. There are other implications, however, beyond the costs. There are the legal obligations to establish a free-growing crop of trees. The licensee, while wanting to maintain this valuable tree species, must also evaluate the risks of future non-compliance with these obligations. Other options do exist, including use of larger seedlings, fertilizing at time of planting, and using natural protection from slash. All of these add cost and carry some level of risk.

The Queen Charlotte Islands Forest District, concerned with the trend away from cedar, took action by developing a district policy. Since 1993 there has been an increase in the sowing request for cedar. It now represents 37% of the trees sown. Keep in mind, however, that this does not equate to the number of trees established, since natural regeneration would not be factored into this. This then is the core of the issue to be dealt with.

You have some great speakers here on the agenda. I hope that you can gain the necessary knowledge from them to deal with this difficult issue. I wish you success in your endeavour to explore cedar, and then, with an appreciation of its significance, come to some understanding of a course of action to manage the problem. I hope you all enjoy the symposium and your stay here in beautiful Haida Gwaii.

History of Cedars in Western North America

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Introduction

The coastal temperate rainforests of the northwest coast of North America have an ancient history. Long before the last great ice advances, many now-familiar species formed coniferous tracts under the region's mild and moist climate (Hebda and Whitlock 1997). True firs (*Abies* spp.), western and mountain hemlocks (*Tsuga heterophylla* and *T. mertensiana*), spruces (*Picea* spp.), and Douglas-fir (*Pseudotsuga menziesii*), at one time or another, combined to cover the landscape. Among these, almost certainly, grew the cedars (*Thuja plicata* and *Chamaecyparis nootkatensis*), though their early history remains obscure. Only in the last 10 000 years are we more certain of the records of these remarkable trees. That history is an especially important one, not only because of what it can teach us about ecology and forests, but because of what it teaches us about the role of the natural landscape in the shaping of human societies (Hebda and Mathewes 1984).

In this account, I first describe the ancient history of cedars in general. Then I recount what we know of our two cedar species before the last glaciation. I then concentrate on the dynamic record of cedars since the melting of the last ice sheets. In particular, I focus on the relationship of cedars to changing climate. I briefly touch on the relationship of the development of the remarkable cultures of the northwest coast to the history of cedar. Finally, I consider the future of cedars in the context of global climate change.

Cedars

True cedars (genus *Cedrus*) are natives to the Old World, and belong to the Pine Family (Pinaceae). British Columbia's two species of cedar, western redcedar and yellow-cedar, are both woody members of the Cypress Family (Cupressaceae). This relatively large family of conifers includes almost 20 genera and more than 100 species, which grow in many parts of the world. The main genera are *Callitris* (cypress pine), *Chamaecyparis* (false cypress), *Cupressus* (cypress), *Juniperus* (juniper), *Libocedrus* (incense cedar), *Thuja* (arbor-vitae), and *Widdringtonia* (African cypress) (Willis 1973). Typically, members of this family produce small cones at the ends of branches. The cones usually have few scales (2–12), coloured brown, green, or purplish. The scales are often fleshy and sometimes attached by stalks. The leaves are generally scale-like and may have needle-like points, especially when young.

Some members of the family (like *Cupressus*, common around the Mediterranean Sea) are well adapted to dry sites, but our genera, *Thuja* and *Chamaecyparis,* generally favour moist soils.

Thuja is a small genus with representatives in east Asia and North America. One species (*Thuja occidentalis*) grows in eastern North America, and one, western redcedar (*T. plicata*), in the west. Cypress (*Chamaecyparis*) is also a small genus, with about seven species distributed (like *Thuja*) in North America and in eastern Asia. Two species inhabit the west, yellow-cedar (or yellow-cypress) (*C. nootkatensis*) and Lawson's cypress (*C. lawsoniana*) (Hitchcock and Cronquist 1973). Lawson's cypress, also known as Port Orford cedar, inhabits southern Oregon and adjacent California and is a useful horticultural species (Kruckeberg 1982).

Studying the Past

The fossil history of cedars is revealed through two approaches: extraction and identification of plant macrofossils (those visible to the naked eye) and microfossils (those too small to be identified with the naked eye) (Hebda 1996). The fossils are removed from sedimentary rocks and unconsolidated (not solidified) sediments, ranging in age from a few tens of years to more than 100 million years old.

Macrofossil remains consist of pieces of wood, branchlets, individual leaf scales, cones, and seeds. All these types of cedar macrofossils have been recovered from soft sediments and many from rocks. Cedar macrofossils have a particular importance, because each of the two of the north Pacific coast's two species produces distinctive types.

Microfossil remains consist almost entirely of pollen grains. Cedars produce pollen in great numbers. The pollen is transported by wind and water to sites of deposition such as bogs, lakes, and ocean basins where it becomes entombed in the sediment and preserved. Cedar-type pollen was recognized routinely in sediment only recently, and is now identified and counted on a regular basis (Hebda and Mathewes 1984). These abundant pollen grains are small and spherical, with little granules scattered over the surface in an irregular pattern (Hebda and Whitlock 1997). The pollen grains have a relatively thin wall, split easily (Figure 1), and do not always preserve well. Unlike macrofossil remains, the pollen of individual cedar species is not distinctive. The pollen actually cannot be reliably distinguished from other genera in the Cupressaceae such as junipers (*Juniperus* spp.).

Material for fossil studies is obtained from sediment or rock exposures where samples are collected from different layers. A more common practice, especially in the study of vegetation history over the last 15 000 years, is to extract sediment cores from lake and wetland deposits by using various types of piston coring devices. Macrofossil remains are exposed either by breaking rock open, or by screening out fine sediments with sieves. Microfossils are extracted through a series of chemical treatments of the sediment, which remove the carbonate and silicate mineral fraction, and non-pollen and spore organic debris (Hebda and Whitlock 1997). The residues of these chemical treatments are examined under high magnification (400X, 1000X) in a binocular microscope and the pollen grains identified and counted.

Ancient History

The Cypress family is thought to have evolved as early as 200 million years ago in the upper Triassic Period (Taylor and Taylor 1993). Fossils that appear to belong to *Thuja* and *Juniperus* occur in rocks of the Upper Cretaceous Period less than 100 million years ago (Stewart and Rothwell 1993). Abundant remains of Cypress family occur in deposits of the Tertiary Age. For example, an interesting fossil genus called *Mesocyparis*, from 60–65-million-year-old deposits in Saskatchewan, has scales like cedar (*Thuja*) but cones like yellow-cypress (*Chamaecyparis*) (Taylor and Taylor 1993). *Thuja* fossils are particularly well known from deposits of Miocene age (26–7 million years ago) from western North America (Tidwell 1975). *Chamaecyparis* fossils also occur in western North American Tertiary rocks, but seem to be less abundant (Tidwell 1975).

Late Pleistocene

Today's distribution and genetic constitution of west coast cedars results directly from the history of populations of the past few hundred thousand years. First, glacial ice covered significant areas of the modern range of the two species at several different times. The ice extended along the coast and through the interior into northern Washington State. Perhaps more importantly, drastic and relatively frequent climatic changes of the late Pleistocene must have resulted in significant evolutionary stress as the geographic range alternately shrank or grew and shifted (Hebda and Whitlock 1997). Consequently, what may appear to be representatives of an ancient and relatively stable stock may harbour considerable genetic adaptability as a consequence of a long and varied history.

Sedimentary deposits from southern Vancouver Island of the last interglaciation, the Sangamon Interglacial, preserve cones of western redcedar among those of other familiar conifers such as Douglas-fir and Sitka spruce (Alley and Hicock 1986). These fossil assemblages reveal that forests similar to those of the present grew on our coast before the drastic disruptions of the last major glacial episode.

Western redcedar and possibly yellow-cedar fossil remains from deposits in Oregon reveal that cedars grew in the American Pacific Northwest during the last major non-glacial interval (Worona and Whitlock 1995). This interval, called the Olympia non-glacial interval, lasted from more than 50 000 to about 30 000 years ago. Beds of the same age from southwestern British Columbia suggest that cedars may have been present, but the evidence is not conclusive. Alley (1979) recorded *Thuja*-type pollen from many sites, whereas Armstrong et al. (1985) observed little, or no significant, cedar pollen signal. Because of questions about preservation of the thin-walled pollen and its sometimes difficult identification (Hebda and Mathewes 1984), confirmation of the occurrence of cedar must depend on the discovery of leaf scales, wood, or cones.

The history of cedars during the most severe climates of the late Pleistocene is not well understood. Cedar-type pollen is relatively well represented in Oregon during this interval, but the source of the pollen is not confirmed. This much colder and generally drier (than present) interval intuitively would seem not to have been favourable to either western redcedar or yellow-cedar. On the other hand, *Juniperus* species, especially *Juniperus communis*, which produce very similar pollen, may have thrived under the harsh climate. Obviously, cedars survived somewhere along the coast, with a refugium south of the glacial limits highly likely. But the survival in coastal refugia adjacent to the ice margins is a possibility too. For example, sites on the Brooks Peninsula on northwest Vancouver Island and on the Queen Charlotte Islands (Haida Gwaii), though under the influence of harsh glacial conditions, may have been mild enough to sustain shrubby yellow-cedars (Hebda 1997b).

The Last 10 000 years

Cedar-type pollen and plant macrofossil records from coastal British Columbia and adjacent United States sites (see Hebda and Mathewes 1984; Hebda 1995) can be divided into three parts, which I designate for convenience of discussion and summary: survival, invasion, and expansion. These intervals correspond more or less to the three major climatic subdivisions of the Holocene (Hebda 1995). Holocene is the name of the geologic time unit for the last 10 000 years, during which we have been more or less in an interglacial climate. The climatic subdivisions, described in Hebda (1995) relative to modern climate in an area, are:

1. 9500–7000 years ago; warm and dry
2. 7000–4500 years ago; warm and moist or transitional
3. 4500–present; modern climate, moderate temperatures, and moist precipitation regime

The record of cedars during the warm dry interval is a sparse one (Hebda and Mathewes 1984), and can be viewed as a time of basic survival for cedars. Some sites, such as those on southern Vancouver Island, record notable cedar-type pollen signals (Allen 1995). But, because of the widely recognized warm and dry climate, this time was likely not favourable to extensive cedar stands in much of British Columbia. The cedar-type pollen may have originated from junipers because similar notable cedar-type pollen signals occur in dry interior sites where neither western redcedar nor yellow-cedar could have been growing (Hebda 1995). However, cedar-type pollen and especially cedar macrofossils have been recovered from a mild moist setting on the Brooks Peninsula on the west side of Vancouver Island.

A relatively stable vegetation assemblage persisted on the Brooks Peninsula from 2500 to 9000 years ago. Forests were characterized by Sitka spruce, western hemlock, Pacific silver fir, and cedars (Hebda, in press). Western redcedar, though present, was not a dominant forest species. Because there is no macrofossil evidence for cedars in more continental, drier sites (see Wainman and Mathewes 1987), it seems that cedars, especially western redcedar, survived in numbers only in the most moist climatic settings immediately adjacent to the coast. Perhaps scattered individuals or small populations occurred inland in drier, warmer regions, but we have yet to verify this possibility with macrofossils.

About 7000 years ago the climate along the coast of British Columbia began to get moister (Hebda 1995; Hebda and Whitlock 1997). This was the beginning of a transitional state from the relatively warm and dry early Holocene to modern moist and mild climatic conditions of the late Holocene. This moistening trend ushered in a series of new species combinations, and new forest types along the coast (Hebda and Whitlock 1997).

Cedar pollen curves along the west coast from the Coast Range in Oregon to Prince Rupert, B.C. show increases in response to this climatic change (Hebda and Mathewes 1984; Worona and Whitlock 1995). At some sites cedar pollen occurs in notable quantities for the first time, whereas at others there is a significant increase in existing populations (Hebda and Mathewes 1984).

Following this initial interval of increase there came more pronounced rises in cedar pollen abundance and, presumably, cedar trees. Many sites on the mainland showed major increases between 6000 and 4000 years ago, whereas others, including several on Vancouver Island and the Queen Charlotte Islands (Haida Gwaii), increased after 4000 years ago. Macrofossil remains reveal that western redcedar was certainly growing in the Fraser Lowland by about 6000 years ago (Wainman and Mathewes 1986). By 2000 years ago, almost all coastal sites supported abundant cedar populations. At many sites, cedar pollen predominated in the pollen spectra, a clear suggestion that cedars were dominant or codominant members of the forest.

Most of the sites for which there are records are from lowlands or from settings with Coastal Western Hemlock (CWH) or CWH-like forests. Consequently, it is assumed these cedar curves actually track the abundance of western redcedar and not yellow-cedar. To date, few yellow-cedar sites have been studied, though it has been recognized that yellow-cedar plays an important role locally in some of the bogs from which the cores were taken. In high-elevation sites on the Queen Charlotte Islands, yellow-cedar macrofossils indicate that this species has been part of the vegetation during the early Holocene (Pellatt and Mathewes 1994).

There is a slight indication by the decline of some of the pollen curves that cedars have become less abundant during the last 1000 years or so (see curves in Hebda and Mathewes 1984). The degree and extent of this decline and its significance is not clear, but the possibility of some impact by First Peoples should be considered.

Hebda and Mathewes (1984) showed that the abundance and variety of archeological artifacts related to cedar use increased after western redcedar became codominant in coastal forests. They suggested that this relationship might be an example of the considerable importance of the environment in shaping human cultures at a fundamental level. In any case, the relationship between western redcedar and First Peoples is a long one (Mathewes 1991).

Cedars and Climate Change

Assuming that future climate will be significantly warmer and effectively drier on the northwest coast of North America, major changes in forest composition and structure must be expected (Hebda 1994, 1997a). Being species of relatively moist settings, both red- and yellow-cedars may be expected to decline in abundance. The fossil pollen record clearly reveals that cedars were not abundant during past warm and dry climatic episodes (Hebda and Mathewes 1984; Hebda 1995). However, the current abundance of western redcedar compared to the near absence of western hemlock in the Coastal Douglas-fir biogeoclimatic zone suggests that redcedar's response to climate change may be complex.

Clearly, western redcedar seems to have more drought tolerance than western hemlock. The factors limiting redcedar's abundance in the early Holocene may have involved disturbance regimes in addition to soil moisture. For example, fires may have been more frequent at that time than in the past few thousand years (Mathewes 1985). Soils may have generally been less mature, especially with respect to the development of A horizons and organic matter content.

More research is needed on the factors affecting the distribution and growth of cedars. As far as climate change goes, western redcedar should not be written off as a poor choice for future forests. Areas that may experience limited drought and warming, such as the east side of the Queen Charlotte Islands (Haida Gwaii), might become highly favourable to the species. Once again, numerous giants may repopulate the Pacific northwest coast as they probably have done intermittently for hundreds of thousands of years.

Figure 1 *Pollen grains of western redcedar. One grain is split open, as it often appears when recovered from sediments. For reference, cedar pollen is about .025 mm in diameter.*

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Update on Silvics of Western Redcedar and Yellow-cedar

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Abstract

- Synoptic comparison of ecological and silvical characteristics of redcedar and yellow-cedar suggested that these species are closely related except for the difference (albeit somewhat overlapping) in climatic amplitude.
- High seed production in redcedars occurred every 4 years, with viable seed available beneath the forest canopy and in adjacent clearcuts.
- Seed germination was influenced by site, seedbed type, and light conditions. Mortality was sufficiently high that only the seedbed affected the number of germinants surviving one year. During the second and third growing seasons, light regimes influenced the number of surviving germinants. Germinant growth was best on the warm-aspect slopes, in clearcut areas, and on forest-floor plots.
- In old-growth stands, advanced regeneration of redcedars was most abundant on decaying wood, but success was greatest on exposed mineral soil. Advanced regeneration was all-aged, but few saplings were >4 cm in diameter, likely due to mortality and survivorship rates different from the more abundant western hemlock and Pacific silver fir.
- Survival and growth of planted redcedar seedlings was greatest in the open and lowest in the forest understory. Acclimation to low light conditions showed that redcedar is well adapted to shade. Redcedar was considered a very shade-tolerant and, in most environments, an exposure-tolerant species.
- Proximity to neighbours affected light availability and side shade, which determines the symmetry and development of the crown of redcedars and can influence the quantity and quality of second-growth redcedars.
- Structural properties of redcedar snags and downed logs were poor indicators of the time since tree death. Dead trees can remain standing for >275 years, and decaying logs remain intact on the forest floor for centuries.

Introduction

Western redcedar (*Thuja plicata* Donn ex D. Don) (Cw) and yellow-cedar (*Chamaecyparis nootkatensis*) (D. Don) (Spach) (Yc) are probably, in the broadest sense, the most valuable species native to the Pacific Northwest. Because their core distributional area is centred on British Columbia, this province has nearly a virtual monopoly over the products produced from both redcedars and yellow-cedars. Although the Queen Charlotte Islands are within the native range of both species, the Islands are likely outside of their climatic optimum, and the Island population of each species likely represents a distinct "hypermaritime" population.

Minore (1990) and Harris (1990) offered the most recent silvical information on redcedar and yellow-cedar, respectively (Burns and Honkala 1990). In addition to this up-to-date compendium, two recent conference proceedings provide additional comprehensive information on the species: Western redcedar—does it have a future? (Smith 1988), and Yellow-cypress: can we grow it? can we sell it? (Lousier 1991).

It appears that there is little to be added to what is known; however, Oliver et al. (1988) stated that relatively little is known about the development of redcedar in either pure or mixed-species stands, and relatively little is known about its potential for silvicultural application. Thus, I present (1) a comparative review of silvics of redcedar and yellow-cedar, and (2) the results from several recent studies conducted on redcedar in southern coastal British Columbia: (2.1) seed supply, (2.2) seed germination and the influence of seedbed and light on survival and growth, (2.3) advance regeneration in old-growth, redcedar-dominated stands, (2.4) growth and light relationships in planted seedlings, (2.5) crown and stem form, and (2.6) age of snags and downed coarse woody debris.

Comparative Synopsis of Ecological and Silvical Characteristics of Western Redcedar and Yellow-cedar

The following tables (Tables 1, 2, 3, and 4) were compiled primarily from the literature, including as the major sources: Krajina (1969) *Ecology of Forest Trees of British Columbia*; Minore (1979) *Comparative Autecological Characteristics of Northwestern Tree Species*; and Burns and Honkala (1990) *Silvics of North America*, and are part of the manuscript entitled The Distribution and Synopsis of Ecological and Silvical Characteristics of Trees of British Columbia's Forests (Klinka et al., in preparation).

Table 1 *Ecological amplitudes of redcedar and yellow-cedar*

Factor	Species	Amplitude
Climate	Yc	hypermaritime - maritime - submaritime (MH - in part CWH)
	Cw	hypermaritime - maritime - submaritime - subcontinental- continental (marginally MH, ESSF, SBS, MS, PP) IDF, ICH, CDF, CWH
Soil moisture	Yc	(moderately dry -) slightly dry - fresh - moist - very moist - wet
	Cw	moderately dry - slightly dry - fresh - moist - very moist - wet
Soil nitrogen	Yc	very poor - poor - medium - rich - very rich
	Cw	very poor - poor - medium - rich - very rich
Soil aeration	Yc	good - adequate - restricted - deficient
	Cw	good - adequate - restricted - deficient

Tolerance to major environmental factors—low light, frost, heat, water deficit, water surplus, and nutrient (mainly nitrogen) deficiencies—were interpreted from the literature and observations using three relative, qualitative classes: low, medium, and high (Table 2). Each tree species was ranked with respect to a particular factor, and arbitrary limits were imposed to differentiate between the three classes.

Table 2 *Tolerances of redcedar and yellow-cedar*

Tolerance to	Species	Class	Comments
Low light	Yc	high	one of the most shade-tolerant tree species
	Cw	high	one of the most shade-tolerant tree species
Frost	Yc	low	absent where the soil is not protected by snow from freezing
	Cw	low-med.	low in coastal populations, medium in interior populations
Heat	Yc	low	cool temperature is required for good growth
	Cw	medium	protection-requiring on the warmest sites
Water deficit	Yc	low	low in spring, medium in fall
	Cw	medium	protection-requiring on the driest sites
Water surplus	Yc	high	common on waterlogged sites
	Cw	high	common on waterlogged sites; tolerates strongly fluctuating water table and flooding
N deficiency	Yc	high	not studied; common on very poor sites
	Cw	high	common on very poor sites; intolerant of ocean spray and saline soils (tidal flats)

Six categories of potential damaging agents were considered: snow, wind, fire, insects, fungi, and other agents. Interpretations are presented using three resistance classes (low, medium, and high) for snow and wind, and three risk classes (low, medium, and high) for fire, insects, fungi, and other agents (Table 3). Again, each tree species was ranked with respect to a particular agent, and after thorough comparison, we set arbitrary limits to differentiate between the three classes. Using data from the literature and ecological surveys carried out in the province by the Ecological Program Staff of the B.C. Ministry of Forests, the value of each life history and silvical characteristic was interpreted according to three relative qualitative classes: low, medium, and high (Table 4). We ranked all tree species for each characteristic (e.g., for longevity from short- to long-lived species), and then arbitrarily set the limits for each class (e.g., for longevity: <100 years for the low class, >100 but <300 years for the medium class, and >300 years for the high class).

Synopsis of Recent Research on Western Redcedar in the Coastal Western Hemlock Zone

The synopsis outlines the results of recent research as summaries of six component studies. The first four summaries give an account of regeneration research. Relationships between crown and stem form and stand conditions are described in the next summary. The last summary addresses the death and decay of trees in old-growth redcedar-dominated stands. The intent was to emphasize implications for management rather than research methodology, so the information presented will assist in selecting biologically appropriate treatments for regenerating, growing, and maintaining redcedar stands.

Table 3 *Damaging agents on redcedar and yellow-cedar (resistance class 1, risk class 2)*

Agent	Species	Class	Comments
Snow	Yc	medium1	less resistant, more resilient, protection-requiring on high-snowpack sites
	Cw	low1	low in coastal populations, medium in interior populations
Wind	Yc	medium1	both species develop dense, profuse root system
	Cw	medium1	with poorly defined tap root and dense mat of fine roots in the upper soil solum
Fire	Yc	low2	low resistance; fire is not a major concern within cool perhumid or subalpine climates
	Cw	low-medium2	low resistance; fire is a concern in drier temperate and mesothermal climates but not a major cocern in wetter climates
Insects	Yc	low2	relatively free of insect pests
	Cw	low2	relatively free of insect pests
Fungi	Yc	low2	butt rot (*Phellinus weirii*) in old-growth stands; Basidiomycetes on dead trees
	Cw	low-high2	major concern in trees that regenerated vegetatively (interior populations) or were damaged
Other agents	Yc	low2	reported dieback in southeastern Alaska, cause unknown
	Cw	low	(high)2 (high risk of browsing)

Seed supply of western redcedar

Feller, M.C. and K. Klinka. 1993. Regeneration of western redcedar in the Very Wet Maritime Coastal Western Hemlock subzone. Contract report to B.C. Ministry of Forests, Vancouver Forest Region, Burnaby, B.C.

The results indicate that high seedfall years occurred every 4 years (1990/91 and 1994/95), and, that during a 4-year cycle, adequate numbers of viable seeds were reaching the ground in both forests and clearcuts (>200 and 1000 seeds/m^2 in the Capilano and Coquitlam forests, respectively, during the 1990–1994 period).

Seed germination and the influence of seedbed and light on the survival and growth of western redcedar

Feller, M.C. and K. Klinka. 1993. Regeneration of western redcedar in the Very Wet Maritime Coastal Western Hemlock subzone. Contract report to B.C. Ministry of Forests, Vancouver Forest Region, Burnaby, B.C.

Table 4 *Life history and silvical characteristics of redcedar and yellow-cedar*

Characteristic	Species	Class	Comments
Reproduction capacity	Yc	low	the proportion of filled seeds in mature cones is low; reproduces vegetatively by layering
	Cw	high	seed-producing at 10 yr of age; heavy seed crops are frequent; reproduces vegetatively by layering, especially in interior populations
Seed dissemination	Yc	medium	within 120 m of a seed source
	Cw	medium	dissemination is adequate within 100 m of a seed source
Potential for natural regeneration in low light	Yc	high	
	Cw	high	
Potential for natural regeneration in the open (unshaded)	Yc	high	present if exposed mineral soil or burnt forest floor
	Cw	high	present if exposed mineral soil or burnt forest floor
Potential initial growth rate (<5 years)	Yc	low-medium	<10 cm/yr on high-elevation sites
	Cw	high	may be as high as for Douglas-fir or western hemlock
Response of advance regeneration to release	Yc	high	
	Cw	high	
Self-pruning capacity in dense stands	Yc	high	strongly dependent on density
	Cw	high	strongly dependent on density
Crown spatial requirements	Yc	low	
	Cw	medium	
Light conditions beneath closed-canopy stands	Yc	medium	
	Cw	low	
Potential productivity	Yc	?	unknown, decreases with increasing elevation
	Cw	high	site index of 37 m (50 yrs at bh) on high-productivity sites
Longevity	Yc	high	possibly 2000 yrs
	Cw	high	possibly 2000 yrs

Study site, seedbed type, and light condition all significantly influenced the number of germinants during most of the first growing season (1991). By mid-October, however, mortality was sufficiently high that neither area, nor light condition, significantly affected the number of living germinants. Seedbed type was the only factor of influence. Germination success was improved by disturbance to the forest floor, with burning improving germination to a greater extent than scarification to mineral soil.

The number of living germinants peaked early in the first growing season (early June), then declined steadily during the remainder of the season, with the greatest declines occurring in July and September–October. Identical trends were found for both Capilano and Coquitlam forests, with germination success being better at the Coquitlam forest. In terms of treatments, germination success declined in the order: burned forest floor > mineral soil > undisturbed forest floor. Germination success was greater in forest than in clearcut areas, but survival has been better in the clearcut than in the forest areas.

During the second (1992) and third (1993) growing seasons, germinant mortality continued, but at a much lower rate than during the first growing season. The trends established during the first growing season generally persisted throughout the subsequent two growing seasons. The only exception was light condition. In terms of light regimes, the number of living germinants was significantly higher in clearcut than in forest plots during 1992 and 1993, in contrast to the first growing season, although mortality rates were slightly higher in the clearcut than in forest plots. This trend became established only at the end of the first growing season.

With respect to the treatments, the number of surviving germinants continued to decrease consistently in the order: burned forest floor > mineral soil > undisturbed forest floor. Throughout both years, the number of living germinants in the burned plots remained significantly greater than those in the mineral soil and the undisturbed forest-floor plots. Germinant growth was also significantly better in clearcut than in forested areas. This is consistent with the results of a shade tolerance study in the same study area but is not consistent with other studies, which suggest that shade can be beneficial to growth in warmer environments (e.g., Adams and Mahoney 1991).

These results suggest that the mortality of redcedar germinants in the study area is relatively high; however, those seedlings that do survive grow relatively well. These trends were particularly true of germinants on forest-floor seedbeds. The optimum seedbed is not clear. Germination success and germinant survival are clearly greater in disturbed seedbeds, consistent with the results of other studies (e.g., Minore 1983), but growth of young seedlings appears somewhat better in forest-floor seedbeds.

Advance regeneration in old-growth, western redcedar-dominated stands

Daniels, L.D. 1994. Natural regeneration dynamics of western redcedar in coastal forests. *In* Interior cedar-hemlock-white pine ecology and management conf. proc., Spokane, Wash., March 1992. D. Baumgartner, J.E. Lotan, and J. Tonn (editors). pp. 319–26

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Redcedar was present in the understory of all study stands, although it was less abundant than western hemlock and Pacific silver fir (Table 5). Age counts for redcedar seedlings and saplings ranged from 5 to 89 years. The old age of some seedlings and saplings is not surprising, given the shade tolerance of redcedar (Carter and Klinka 1992). Age structures showed that ingress had occurred over the past 30 (or more) years on each site. On all sites the majority of regeneration was less than 15 years old. Diameter distributions showed a similar trend: few redcedars grew >2.5 cm in diameter. Past 4 cm, the diameter distribution was intermittent, as was the diameter and age distribution of canopy trees of the species. These observations suggest that once established, there was a high chance for successful recruitment of redcedar regeneration to the canopy (Franklin 1988; Keenan 1993).

Within stands, redcedar regeneration was aggregated. Clustering was greatest at small scales and on exposed mineral soil, followed by decaying wood substrates. Although regeneration was numerous on decaying wood, it was most dense on exposed mineral soil. Vigour and success of regeneration was highest on exposed mineral soil.

Table 5 *Species composition (trees per hectare) of advanced regeneration in four old-growth, western redcedar-dominated stands*

Species	Stand 1	Stand 2	Stand 3	Stand 4
Seedlings				
Western redcedar	1 303	426	122	302
Western hemlock	25 500	21 400	11 800	12 000
Pacific silver fir	300	10 600	14 100	8 200
Saplings				
Western redcedar	49	0	0	8
Western hemlock	1 069	525	1 144	775
Pacific silver fir	138	1 301	81	1 600

Growth—light relationships in western redcedar

Wang, G.G., H. Qian, and K. Klinka. 1994. Growth of *Thuja plicata* seedlings along a light gradient. Can. J. Bot. 72: 1749–57.

Three-year mortality was <27% and most mortality (>85%) occurred in the forest understory at <20% of the above-canopy light. The low survival in low light might be explained by our use of nursery-grown seedlings acclimated to high light conditions. The growth of surviving seedlings improved with increasing light, with the most vigorous seedlings occurring under full light conditions in the open. Morphological acclimation to varying light conditions by the surviving seedlings included changes in three traits typically associated with shade adaptation: specific leaf area, height/caliper ratio, and above-ground/root biomass ratio. Specific leaf area and height/caliper (diameter) ratio decreased and above-ground/root biomass ratio increased with increasing light. Thus, relative to seedlings in the open, the understory seedlings had (1) a larger leaf area per unit of foliage mass, (2) a greater height growth compared to caliper growth, and (3) somewhat greater allocation of net biomass production to roots. We consider redcedar in the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) variant to be a very shade-tolerant and exposure-tolerant species, requiring neither protection by the canopy of the parent stand nor exposure for establishment.

Crown and stem form of western redcedar

Klinka, K., Q. Wang, B. Sivak, G.G. Wang, and D. Elstone. 1993. Ecological and supplementary height growth analysis for Experimental Projects 368 and 571. Contract Report to B.C. Ministry of Forests Research Branch, Victoria, B.C.

Elstone, D.A.O. 1994. Height growth of western redcedar and western hemlock and growth form of western redcedar in naturally regenerated unmanaged coastal stands. B.Sc. thesis. Faculty of Forestry, University of British Columbia, Vancouver, B.C.

An undesirable crown and stem form was observed in immature (about 40-year-old), poorly stocked, nearly open-grown, redcedar stands established by planting on several sites on western Vancouver Island, as well as by silviculturists in other areas (Oliver et al. 1988). Our study sites, all parts of Experimental Projects (EP) 368 and 571, we relocated in the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) variant and had soil moisture regimes in the range from fresh to moist, and soil nutrient regimes from poor to rich. The trees had buttressed (swelled) and fluted boles, long, conical, and open live-crowns (typically extending to 1 m above the ground surface), damaged or sinuous leader growth, and poor taper. The most conspicuous and unusual features were many large, excessively long (up to 5 m), sparsely foliated, upward turning (sweeping) live branches. Similar branching characteristics were observed in younger, naturally regenerated redcedar within the study area. All these appearances lead to degradation of wood quality; and the high quality of wood of old-growth redcedar appears to come from its large size after the tree has outgrown these defects.

This atypical crown form is a sharp contrast to that developed in naturally regenerated, unmanaged, fully stocked, immature, even-aged (about 65-year-old), redcedar-dominated stands examined by Elstone (1994) in the Malcolm Knapp Research Forest. What could be the reasons for these differences? According to Oliver et al. (1988), the taper of redcedars and excessive branching seem to result from both their shade tolerance and their peculiar lower stem shape. Live lower limbs stay in redcedars when grown in understories; similarly they can stay alive when grown at wide spacing. In both cases these lower limbs contribute photosynthate and allow the lower stem to grow more. The butt swells up to about 1.5 m above the ground, which is probably inherent in the species.

It appears that the Malcolm Knapp stands have always been near, or at, the maximum density levels, and have experienced overcrowding and density-related mortality. In consequence, their mean density of 903 stems per hectare is considerably above the level recommended for managed stands at this age on intermediate sites (Hamilton and Christie 1971). The establishment of 2000–2500 seedlings per hectare was recommended for the development of a good crown form on medium sites (McArdle et al. 1961; Minore 1983; Oliver et al. 1988). The initial spacing level of 2.44 m (1680 seedlings per hectare) in the EP 368 stands, and 2.7–4.6 m (1370–472 seedlings per hectare) in the EP 571 stands might have been too low (1) for initially slow-growing redcedar to reach a free-to-grow stage, particularly on high brush hazard sites, and (2) to reach early crown closure and to enter a zone of suppression (O'Conner 1935) in order to develop a narrow, symmetric, finely branched, constantly rising, functional live crown (Oliver and Larson 1990).

Studies of shade tolerance (Carter and Klinka 1992; Wang et al. 1994) and observations of the crown form of shade-tolerant redcedars across a range of stands suggest the following trends in crown form development: (1) when grown in low light in forest understories or in full light in the open, redcedar develops long branches and a live crown, (2) when grown in uneven side shade in the forest canopy it develops an asymmetric live crown, with branch development depending on the proximity of neighbouring trees, and (3) a symmetrical, constantly rising, functional live-crown will develop only if redcedars are growing in an evenly spaced stand, which provides for a nearly 100% side shade. The non-functional crown (i.e., the portion of the crown with shaded branches) does not make a net positive contribution to the stem; instead, photosynthates are allocated to lateral branch growth (Oliver and Larson 1990).

There is reasonable evidence to indicate that (1) the yield of pure, second-growth, redcedar stands on some sites can be greater than that of Douglas-fir, especially when considering intermediate or long rotation, and (2) with proper stand management, second-growth stands are capable of producing clear wood of acceptable quality (Nystrom et al. 1984; Oliver et al. 1988). Taper, bole, fluting, branch, and crown development of redcedars, as in many other tree species, are influenced by stand density (e.g., Evert 1971; Kramer et al. 1971; Hattemer et al. 1977; Smith 1977; Carter et al. 1986). The development of the undesirable stem and crown form with initial wide spacing, delayed crown closure, and low stand density appears to be more profound in shade-tolerant redcedar than in other species (Nystrom et al. 1984). Considering the unique silvical characteristics of the species, we suggest the viable strategy to achieve both high quality and volume production is (1) to establish and maintain high initial stand densities, then (2) to carry out low-intensity thinning after crown closure, when natural branch mortality has occurred on the lower stem and while crop trees still have sufficient live crown to respond vigorously.

Death and decay in western redcedar

Daniels, L.D., J. Dobry, K. Klinka, and M.C. Feller. 1995. Age of logs and snags of *Thuja plicata* in coastal British Columbia. Submitted for publication in Can. J. For Res.

Coarse woody debris (CWD), including standing dead trees (snags) and downed logs, is an important component of forest ecosystems (Harmon et al. 1986). Redcedars grow to large sizes and form a significant component of CWD within low-elevation old-growth forests of southern coastal British Columbia. Previous studies have shown redcedar decay rates similar to those for western hemlock and Douglas-fir (Sollins et al. 1987), but these results contradict the known decay resistance of western redcedar wood (Barton and MacDonald 1971). This study uses dendrochronological methods to document tree death and decay of snags and downed logs of redcedars.

We sampled 15 logs in decay classes I, II, III, and IV, and 17 snags in decay classes III, IV, V, and VI in Capilano, Seymour, and Coquitlam watersheds. Stages of decay were determined from the physical structure of each bole using modification of the standard decay classification for CWD in western North America. Wood samples from decay class IV logs were aged by carbon dating. Year of death and age (time since tree death) of class I, II, and III logs and all snags were obtained by dendrochronological methods. We cross-dated increment cores from logs and snags to estimate years of tree death. For logs, these data were supplemented with dates of scars, reaction wood, and release of neighbouring trees, and with the ages of seedlings and saplings growing on logs, to determine the exact year of tree death.

Log ages, determined by carbon dating, were 550, 590, and 1200 +60 years, and log ages, determined by dendrochronological methods, ranged from 1 to

279 years. Snag ages ranged from 2 to 276 years (Figure 1). The temporal relationship between age (time) and stage of decay was more distinct for logs than it was for snags. There was little overlap in log ages between the four decay classes, but variation within each class was high, and the range in ages increased with decay class. There was no significant relationship between decay class and mean diameter for logs. Although we were able to discriminate snags based on their physical features, the decay classes showed little relationship to the time. Again, there was no significant relationship between snag decay class and mean diameter at breast height.

The longevity of redcedar downed logs and snags is consistent with known heartwood chemical properties (Barton and MacDonald 1971) and slow decay rates (van der Kamp 1986; Sollins et al. 1987) of this species. However, the duration of 279 years for logs and 276 years for snags dated by dendrochronological methods and 1220 +60 years for logs dated by carbon dating was much greater than that previously studied (e.g., Larsen et al. 1982; Sollins et al. 1987). The large size of logs and snags in this study relative to those studied by others can explain this difference, because larger trees require more time to decay and larger snags tend to stand longer. Moreover, decay rate has been shown to be negatively correlated to tree size for some species (Harmon et al. 1986). If this relationship was true for redcedars, the decay rate of the snags and logs that we studied would be low.

Based on our results, it appears feasible to conduct chronosequence studies of redcedar logs, but we recommend one of two approaches. The first approach is to use the age of individual logs, determined by dendrochronological methods, for calculating rates of change, rather than using class mean ages. Although time and labour intensive, cross-dating, supplemented by other tree-ring data, yields precise and reliable results (see also Dynesius and Jonsson 1991). Alternatively, chronosequence studies of redcedar can be conducted using the class means determined in this study. A four-class log decay classification may be more appropriate than the more common five-class system that we used. We propose a new classification scheme, in which class II and III logs would be combined for redcedar logs that have no twigs and needles but that are round and support their weight. The other classes would remain as defined in the literature.

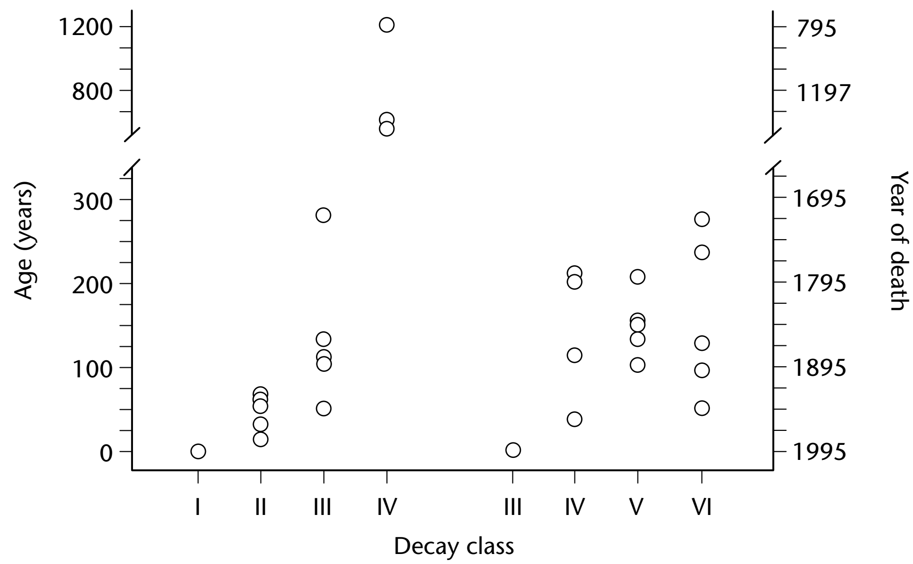

Figure 1 *Age in years (left axis) and year of death (right axis) for 15 logs and 17 snags of redcedars.*

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Growth Performance of Western Redcedar in Relation to Ecological Site Quality

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Abstract

We described the pattern of mean site index for western redcedar (*Thuja plicata* Donn. ex D. Don.) in relation to a drier and wetter cool mesothermal climate, and categorical variables of soil nutrients and moisture as identified by the field procedures of the biogeoclimatic ecosystem classification. We sampled 105 plots from stands having western redcedar as the major tree species; the plots were distributed in a drier and a wetter cool mesothermal climate in southwestern coastal British Columbia near Vancouver, B.C. Within each of the two climates we sampled plots on sites having various combinations of soil moisture and soil nutrient conditions. Heights and ages were measured on five dominant trees on a 0.04 hectare plot, and the height at a base age of 50 years was calculated to give site index. The highest western redcedar site index occurred on sites field-identified as having no moisture deficit or excess and high nitrogen availability; site index decreased with increasing moisture deficit or excess, and decreased with decreasing nitrogen availability. The mean site index was greater in the drier climate than in the wetter climate on sites identified as having similar soil moisture and nutrient conditions. Where growing timber is the objective, these results are useful for tree species selection as a preliminary approximation to estimate timber productivity.

Introduction

The measurement of the potential timber productivity of a forest stand helps in decisions on tree species selection and silviculture practice investments. Site index (height of specified dominant trees at a reference age) is the most common indirect estimate of timber productivity. In British Columbia, attempts have been made to use the provincial biogeoclimatic ecosystem classification (BEC), a classification currently used as an ecological foundation for all silvicultural activities, to recognize sites with different vegetation and timber productivity potential (Pojar et al. 1987). Rather than attempting to quantify all the individual factors and interactions separately in a factorial approach, an heuristic approach based on soil properties aided by vegetation is used to identify site units. Thus, site units are characterized by indirect categorical measures of climate, soil moisture, soil nutrients, soil aeration, and, if appropriate, by other environmental factors strongly influencing the development of vegetation. Since the site units are identified from a vegetation classification and on a combination of environmental factors thought to directly influence vegetation, there is an expectation that these derived units will be related to timber productivity.

The relationship between timber productivity and site units of the biogeoclimatic ecosystem classification has been successfully investigated for several species. The categorical measures of soil nutrient and moisture conditions are useful variables for describing and predicting site index in coastal British Columbia for Douglas-fir (*Pseudotsuga menziesii*) (Klinka and Carter 1990), western hemlock (*Tsuga heterophylla*) (Kabzems and Klinka 1987; Kayahara and Pearson 1996) and Sitka spruce (*Picea sitchensis*) (Kayahara and Pearson 1996). Such results provide a description of mean site index and associated variation in site index for various combinations of soil moisture and soil nutrient conditions. This potential productivity description is necessary in silvicultural decision-making where timber productivity is of primary interest.

The objective of this study was to describe the pattern of mean site index and the associated variation of western redcedar (*Thuja plicata* Donn. ex D. Don.) in relation to a drier and wetter cool mesothermal climate, and categorical variables of soil nutrients and moisture as identified by the field procedures of the biogeoclimatic ecosystem classification.

Methods

The study sites were located in southwestern British Columbia, Canada (latitude 49° 20'N, longitude 122°35'–123°05'W, elevation 160–295 m). Plots were located in dry maritime and wet maritime cool mesothermal climates as delineated by the Dry Maritime and the Submontane Very Wet Maritime Coastal Western Hemlock subzones (CWHdm and CWHvm1, respectively) of the biogeoclimatic ecosystem classification (Green and Klinka 1994). The climate of both subzones is characterized by cool wet summers and mild wet winters, although frequent hot dry spells are more frequent in the CWHdm subzone (Meidinger et al. 1991). The mean annual precipitation is 1827 mm for the CWHdm subzone and 2787 mm for the CWHvm1 subzone, and the mean annual temperature is 9.8°C for the CWHdm subzone and 8.2°C for the CWHvm1 subzone (Environment Canada 1982).

One hundred and five western redcedar sample plots were located in naturally established, unmanaged, immature, even-aged stands (35 plots in the CWHdm subzone and 70 plots in the CWHvm1 subzone). The study stands had a relatively wide range in age (see table below) and were uniformly stocked (60–90% tree layer cover), without a history of damage and suppression.

Western Redcedar (n=105)	Range	Mean
Stand age (years)	37 – 88	56
Site index (height in metres at 50 years b.h. age)	13.0 – 33.8	25.8

Each stand had a more or less uniform, single-tree layer that featured dominants of the study species. The stands in both areas originated from logging during the early 1900s followed by operational fires. Unusual for the stand development in the coastal area of British Columbia, a large component of western redcedar regenerated naturally after the burn rather than the usual western hemlock and/or Douglas-fir. This regeneration pattern resulted in relatively extensive areas of even-aged western redcedar stands with a minor component of Douglas-fir and western hemlock.

Plots 0.04 hectare in area (20 x 20 m) were sampled from the study sites and were located to represent an individual ecosystem relatively uniform in soil, understory vegetation, and tree layer characters. Topography, understory vegetation, and soils of each sample plot were described using the site diagnosis procedure outlined in Green and Klinka (1994). Sites were identified to one of seven soil moisture regimes (SMR)—classes framed along a soil moisture gradient ranging from sites having a prolonged water deficit (very dry) to sites having no water deficit (fresh) to sites having a water excess (wet)—and to one of five soil nutrient regimes (SNR)—classes framed along a soil nutrient gradient ranging from sites having low amounts of available nitrogen (very poor) to sites having high amounts of available nitrogen (very rich). The combination of SMR and SNR forms a cell on an edatopic grid. Identification of SMR and SNR was based on an heuristic synthesis of topographic and soil morphological properties, augmented by indicator plant analysis (Klinka et al. 1989).

The timber productivity of each site was estimated by site index (height at 50 years breast height age). In each sample plot, the five largest-diameter (dominant) trees of the study species with no obvious evidence of growth abnormalities and damage were measured for age at breast height, using an increment borer, and height, using a clinometer. Site index was taken from height growth tables of Kurucz reported in Mitchell and Polsson (1988). For each subzone, the mean and 95% mean confidence intervals were calculated for each combination of the SMR and SNR, and summarized on an edatopic grid.

Results

The mean site index and associated confidence intervals are summarized on edatopic grids for western redcedar sampled in the CWHdm (Table 1) and CWHvm1 (Table 2) subzones. Site index of western redcedar in both zones increased from very poor to rich or very rich sites. Site index increased from dry sites (very dry or moderately dry SMRs in the CWHdm subzone, and slightly dry SMR in the CWHvm1 subzone) to a maximum at the moist sites, and then decreased at wet sites. Maximum site index for western redcedar in both subzones occurred on the moist/rich sites. Generally, the mean site index was greater for the same SMR/SNR combination in the CWHdm subzone compared to the CWHvm1 subzone.

Discussion

There are two limitations to this study:

1. The sample size was small. A sample of at least 12 plots for each cell of the edatopic grid within both climates should be collected. (At a sample size of 12 and at $p = 0.05$, the t-value used for the mean confidence interval calculation is less than 2.2.) This minimum sample size and distribution on all combinations of SMRs and SNRs on the edatopic grid would result in smaller confidence intervals about the mean and standard deviation, and allow statistical comparisons of the effects in the prediction of site index by including SMR, SNR, climate (subzones), and interaction factors (SMR x SNR, climate x SMR, climate x SNRm, climate x SMR x SNR). However, extensive even-aged stands of western redcedar are rare in British Columbia.
2. Quantification of SMRs and soil aeration regimes is still required in order to relate the field properties to actual soil moisture and aeration conditions; at present, only quantification of SNRs, relating the regimes to mineralizable nitrogen, has been achieved (Courtin et al. 1984; Klinka et al. 1994). Therefore, the results here should be viewed as preliminary.

For operational use we offer tables presenting values for the mean, standard deviation, and respective 95% confidence intervals of measured site index. Based on this limited sample size, our descriptive preliminary results are similar in nature, but in a different format, to the results on overall productivity on different sites reported by Pfister et al. (1977). The height growth of western redcedar on sites with similar moisture and nutrient levels (as identified by field properties) was greater in the drier and somewhat warmer climate of the CWHdm subzone compared to the wetter and somewhat cooler climate of the CWHvm1 subzone. Presumably, since the supply of available moisture and nutrients is the same, the increased height growth is likely the result of warmer temperatures and a greater amount of solar radiation due to less cloud cover during the growing season. The greatest productivity occurred on sites without a growing season water deficit or excess (fresh and moist SMRs), with high nitrogen availability (very rich SNR). In both subzones, site index was above 20 m, even on the poor SNR.

Where growing timber is the objective, these results are useful for tree species selection as a preliminary approximation to estimate timber productivity.

Conclusion

If we are to learn one lesson from our experience of forest management on the Queen Charlotte Islands / Haida Gwaii, it is that there are unforeseen consequences to our intervention in the natural ecosystem. Consider that when deer were introduced here at the turn of the century, those responsible had no idea of the consequences of their actions. Now we have to live with the impact of browsing on both old-growth and managed forest lands. However, this past mistake should teach us that any intervention, no matter how seemingly inconsequential, may have huge unforeseen impacts in the future. And today, here we are changing vast portions of the landscape of the Queen Charlotte Islands / Haida Gwaii from coastal old-growth dynamics to even-aged, managed on some 100-year-old plantations! As limited as our knowledge of these ecosystems is, we do know that our plantation management scenario, even if carried to perfection, will result in large-scale forest ecosystem dynamics completely different from the natural forest ecosystem. And if a small intervention such as introducing some deer has had such a large impact, do we really want to chance living with the consequences of converting old-growth forests to plantations on the vast scale that we are consciously implementing today? The Haida ask us to listen and understand what they are telling us about the folly of our current forest management practices. I hope we will listen, understand, and change soon.

Table 1 *Mean site index (metres at 50 years breast height age), 95% confidence interval (metres), and sample size for each combination of SMR and SNR for western redcedar in the Dry Maritime Coastal Western Hemlock (CWHdm) subzone*

Actual soil moisture regime	Soil nutrient regime				
	Very poor	Poor	Medium	Rich	Very rich
Very dry	13.4 ±5.1 n=2				
Moderately dry		22.2 ±7.6 n=2			
Slightly dry		24.4 ±0.7 n=5	26.7 ±1.5 n=4		
Fresh			29.7 ±0.8 n=9		
Moist			30.3 ±2.9 n=3	32.2 ±3.4 n=3	29.0 n=1
Very moist			29.1 ±1.5 n=3	32.0 n=7	
Wet			16.5 n=1	25.4 n=1	

Table 2 *Mean site index (metres at 50 years breast height age), 95% confidence interval (metres), and sample size for each combination of SMR and SNR for western redcedar sampled in the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) subzone*

Actual soil moisture regime	Soil nutrient regime				
	Very poor	Poor	Medium	Rich	Very rich
Very dry					
Moderately dry					
Slightly dry		20.9 n=1	22.0 ±6.4 n=2	24.8 ±0.5 n=3	
Fresh		23.0 ±0.6 n=5	24.7 ±0.9 n=6	26.2 ±0.8 n=7	
Moist			26.3 ±0.6 n=5	28.3 ±0.5 n=16	
Very moist		21.8 n=1	25.2 n=1	27.9 ±1.6 n=7	27.5 ±0.6 n=5
Wet			17.8 ±2.0 n=7	22.5 ±0.6 n=3	26.2 n=1

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Speaking about Lootaa

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My proper name is Gitsga. My Nunni called me that, and I would appreciate it if you called me that. As I said to someone earlier, to address an aboriginal person by his given name, is to do honour to that person. The name Gitsga was given to me by my great-grandmother on my father's side and it was her right to designate that name for me. She was 103 years old at the time and had forgotten the English translation for the name, but she told me it was the best name she knew to bestow upon me, and for me, that's good enough. It will be my name until such time as I become Cumshewa.

Welcome to the home of Lootaa. Lootaa is the name of this vessel. Lootaa was once a 700-year-old redcedar. When I stood beside that tree, the first day it arrived at the carving shed, I reached out my arm and I thought, some day somebody's going to ask me, "How big was that when you started?" I reached out without looking so I would know it was this high. It was a beautiful cedar. There aren't that many out there that are big enough to make a canoe like this. There never were. That's why you hear about so many CMTs (culturally modified trees) that have these holes bored into them. They were checking to see if the tree was sound enough to be made into such a vessel. More often than not, they would go onto the next tree because not very many of them were sound. As was stated this morning, cedar develops rot and you can't always see it from the outside. Despite what seems to be an obviously large forest, there aren't that many trees out there that would serve the purpose of creating another vessel like Lootaa. So how many trees would I like for canoes like this? I would like every one that is of this quality made available to us, the aboriginal people of Haida Gwaii.

The Bank of Hong Kong commissioned Lootaa to be carved for display at Expo '86 in Vancouver. It was carved during the winter of 1985 and it took somewhere between 3 to 4 months to complete. There were upwards of 20 people who worked all day long and half the night—every day. It was a learning process from start to finish. We have a small fiberglass half model here, that was created to see how it might look after it was finished. They took measurements of canoes in Vancouver, in New York, and wherever canoes happened to be now. There are a few old large canoes, which they measured, and then crunched the numbers in a computer to produce this model. They built a couple of models like that in fibreglass—full models—and put them into tanks to see if they floated. Would they be stable in the water? I guess the old-timers knew what they were doing, because, as a result, I'm now standing in Lootaa.

We paddled ahead of the royal entourage for the opening ceremonies. We were the only people allowed ahead of Prince Charles and Diana. We anchored Lootaa out for the duration of Expo, which was 6 months. During that time, it was not cared for in a manner that befits such a beautiful vessel. As a result, it developed some really bad cracks. They have them filled in with strips of wood and fibreglass. The fellow who did the repair work put some stainless steel ribs in first. You don't see them because he covered them up with oak.

Lootaa was supposed to have been put on display in the foyer of the Bank of BC. They said they wanted a 50-foot canoe. From the end here to the end up there, it is exactly 49 feet, 8 inches. When they brought it to the foyer, it was too big. But somebody knew how to make a good PR move. They sold it back to us for a dollar.

To make a long story short, we paddled it back from Vancouver. No one had made such a trip for over 100 years, so we didn't know the logistics of such a trip. People sat up here and said, "It's a long way, a thousand kilometres." So they made allowance for the inexperience of the paddlers, the distance, the possibility of bad weather, and on and on. They came up with a 3 week time frame to make the trip.

During that trip we had to pass through the territories of all the aboriginal peoples along the coast. We had to stop in each community and get their permission to pass through their territory. And they'd throw a potlatch, welcoming us to their territory and giving us permission to pass through. Including all this partying, paddling, and bad weather, the trip was made from Vancouver to Skidegate in 3 weeks. Actual paddling time was 11 days. But I recall sitting on the beach one day because we were so far ahead of schedule.

Up until this past year we used Lootaa for canoe races. We have what's locally referred to as "Skidegate Days," which will be taking place in a week, where we race this canoe against the clock. The team with the best time wins. Our council has since retired Lootaa, because it may never be replaced, given that all the forestry companies are taking all the huge redcedars away. We've got to look after this one. We probably won't get another tree like it.

We now use the LooPlex for our canoe races. That's the pet name we've given to the fiberglass copy. It's an exact copy of this. They made a mold of the outside of this one and created five copies. This one is specifically to test how it would work under power with an outboard motor. A well was created in the stern and a hole cut to accommodate an outboard motor. It goes like stink. I don't think there's realistically any limit to the size of outboard motor you could put in it. As I said, the old-timers knew what they were doing.

An interesting question came to my mind this morning, when someone was talking about how the cedar trees have been growing locally on the coast for what, only 4000 years? This technology didn't develop overnight.

Does anyone have any suggestions as to what they could have done before that? I remember from my own youth that this building was covered with cedar shakes. I remember spruce shakes, but nobody does them anymore. They fit better than cedar shakes and lasted longer. Maybe the early canoes were made out of spruce. They would be bigger than this. But as I said earlier, I would still like all the big redcedar trees, and yellow-cedar. When we were making this one, Bill Reid's son-in-law at the time wanted a smaller canoe for his children and we made a 12-foot yellow-cedar canoe. It is still sitting in a garage; it never got steamed open. But yellow-cedar is every bit as viable a wood for canoes.

We carved this canoe, as I said, over 3 months. We steamed it open, put some chicken wire in the bottom to protect it, put water in up to about the depth of this decking in here, and then we built some fires. Actually, the fires were only on this side and they heated the rocks till almost white hot. We mixed some ammonia in with the water to make the wood more flexible. Before you could buy bottles of ammonia, everyone would pee in it. Natural ammonia. Someone went and bought a few jugs of ammonia. We put tarps over it to retain the steam from the hot rocks. You take a pitch fork and dump the rocks in there and tie the tarp down.

Before we steamed it, it was 4 feet wide at the widest point. After steaming it for a couple of hours, it just kind of relaxed and opened up, but not quite to 6 feet. Everybody was standing around, like you are now, and Bill said, "Everybody just grab hold." Everybody just grabbed hold of the gunnels and very slowly moved back until it reached those stop points. These four crosspieces just dropped into place when we let go. And we all sat back, absolutely amazed at ourselves. It hadn't split, so luck was with us.

On our voyage from Vancouver back to Haida Gwaii, about halfway up the coast, somebody said, "Hey can this thing tip?" He picked a fine time to think of that. Four guys stood on the gunnels, with guys inside holding their hands and they jumped. They tried but they couldn't even ship any water, never mind tip it over. It is that stable in the water. I've never been in any vessel where I've been so comfortable in the ocean.

A beautiful vessel like this is no good unless you can move it. We thought the knowledge of how to do the proper paddles was gone. Fortunately all we had to do was ask. One of my older cousins happened to have been given the job of keeping that information until it was needed. When I went to him with my first redcedar paddle, I said, "How's this?" and he smiled at me and he shook his head. I said, "Well, you know how to make them. How?" and he smiled at me again and he shook his head and said, "Go make another one." "Well, what's wrong with this one," I asked. Another smile, another head shake. I just about went nuts. He is older than me so I had to respect what he said. That is one of our customs. I brought back another one. "OK, is that any better?" I ask. More smiling, more shaking head. This goes on and on. I'm thinking, "What am I doing wrong? It's a fresh piece of wood, there's no knots in it." Well, what was wrong, was that I was using flat-grain wood. What I needed to learn was that it needed to be edge grain. Once I stumbled upon that, he smiled again but he didn't shake his head at me. He said, "Now you're getting it."

What difference does it make—it doesn't look better, compared with the other one—what have I done different? More smiling. I know every way to make this thing, but I know the right way now. I know it good and solid. I teach kids how to make paddles now; I've done it with the grade seven Haida Studies class. I have a system for making paddles. Now, that system requires that I have the absolute best wood out of the forest; edge grain, dead straight, no knots. Even a pin knot is too much. So again, how many more trees do I need? All of them. Realistically, I have been told about the plans to set aside areas specifically so that 400 years from now, my descendants—Haida people—will be able to go out there and track down a tree and will be able to identify it as a canoe tree.

Who can guarantee that that tree won't have rot in it? All those trees out there are survivors; even the ones with rot are survivors. There's no way to guarantee that you can set aside a stand and get trees that are straight and sound right through. Even the trees not in good condition are still standing there. They're survivors.

I need big trees. I also need smaller trees for paddles. I'll get only a couple of paddles out of a tree, but a paddle made out of a tree that size will be so much stronger than a paddle made out of a tree the size Lootaa came from. It's still got flexible strength. Redcedar, we use every size; again, for paddles, for medicine, for hats—almost every use comes from a different size of tree. So I'm here to tell you that I don't need just the big ones, I need a range of sizes.

I also need yew wood, which makes the ultimate paddle. The Haida name for this is "ahl." A-H-L is the English spelling for that word. Made out of yew wood, they were used as weapons. Now this paddle here used to have a real pretty point on it, but I loaned it and somebody stabbed it into the beach. It was used much as a broad sword was used in Medieval times, to behead someone. The edge was fire hardened, and abraded with a smooth rock. The point was used like a spear, to run someone through. But the first reason for the point—if you look out there in the Pacific Ocean, there's a lot of kelp out there. You take a round-tipped paddle like this and you try to paddle through that kelp—it could run across the path of the kelp just like that. And once you wiggle it down through, it can catch on the kelp on the way back; you lose your momentum completely. Notice the difference on this one; no flat end, no shoulder. It'll slide easily down through the kelp, and then back up too. That didn't develop overnight either. That's many, many years of doing it the wrong way, unlike my few months, and together it was an amazing, complementary... what do they call it? It's a part of my life, my past, my future.

Laskeek Bay Conservation Society

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The Laskeek Bay Conservation Society is a non-profit organization based in the Queen Charlotte Islands / Haida Gwaii. The Society provided contract services for the planning and organization of the Cedar Symposium, and provided a presentation during the symposium about its activities. A synopsis of that presentation follows:

Who We Are

The Laskeek Bay Conservation Society (LBCS) is a community-based group of volunteers on Haida Gwaii (Queen Charlotte Islands) dedicated to increasing public understanding of the natural world. Since 1990 we have conducted a diverse program of long-term research, monitoring, and interpretation at our field station on remote East Limestone Island. In this program, volunteers and students from the Island community and from around the world work alongside experienced field staff. By participating in the Society's program of environmental monitoring, students and volunteers come to understand the importance of protecting native plants and animals in order to maintain a healthy environment.

The Society is also a major participant in the Research Group on Introduced Species (RGIS), a consortium of government and university-based researchers, managers, and environmental groups. RGIS studies are currently mainly focused on the variety of impacts of introduced black-tailed deer on the rainforest ecosystem of Haida Gwaii.

What We Do

Since inception, the Society has been committed to involving volunteers, school children, and adult visitors in a long-term program of research and monitoring at the LBCS research station on East Limestone Island in Laskeek Bay, on the east coast of Moresby Island.

The research station operates for approximately 4 months every year, from late March through the middle of July, using volunteers and a staff of two. We maintain biological monitoring programs for the following species: Ancient Murrelets, Cassin's Auklets, Black Oystercatchers, Peregrine Falcons, Glaucous-winged Gulls, four species of woodpeckers, songbirds, and Steller's sea lions. We keep records of observations on many other species, including whales. Volunteers receive extensive instruction in monitoring techniques, data collecting, and record keeping, which enables them to contribute effectively to the program.

At the field research station we provide an interpretative program to students and to visitors touring the nearby Gwaii Haanas National Park Reserve and Haida Heritage Site. The students come from all of the Islands' high schools. The visitors come from many walks of life, and different countries. The students, volunteers, and visitors are given a unique opportunity to observe and appreciate the incredible features of Laskeek Bay. They also learn about the threats of introduced predator species, oil pollution, changes in the marine environment, and improper tourism development and resource extraction. Visitors leave our research station on East Limestone Island with an increased understanding and commitment to protecting the coastal temperate rainforests and surrounding marine waters. Through the East Limestone outreach program we are encouraging volunteers, students, and visitors to advocate for the protection of natural ecosystems within their own communities, and to become ambassadors for a positive conservation ethic.

We communicate our activities and research findings through newsletters, a Scientific Report, talks, and presentations. We have a significant community profile, and many people contact us seeking information regarding introduced species and forest conservation.

Recent reductions in government-funded research and the generally short time horizons adopted by most academic research make it increasingly necessary for communities to monitor environmental changes for themselves, if they wish to understand what is happening to local ecosystems. Through summarizing and publicizing the Society's achievements over the past decade, we hope to encourage other local non-governmental organizations (NGOs) to develop their own environmental monitoring programs. In the long run, we hope to be able to export our local model to people with similar concerns up and down the coast, so a network of similar monitoring organizations can be developed.

Brief Organizational History

The Laskeek Bay Conservation Society is a volunteer organization founded by a group of local residents concerned with the environmental challenges facing Haida Gwaii and is incorporated as non-profit society under the *Society Act of British Columbia*. We began in 1990 and took over a 6-year-long research program on Ancient Murrelets, initiated by the Canadian Wildlife Service. In the 7 years since we began, the Society has continued the Ancient Murrelet program and has developed a diversified but coordinated focus on the terrestrial and marine ecosystems of the Laskeek Bay area. The numbers of volunteers involved, the length of the field season, and the number of programs has increased almost every year. Our priorities continue to be those of a grassroots, volunteer-based society, dedicated to conservation of the unique island ecosystems of Haida Gwaii.

Brief Mission Statement

The objectives of the Laskeek Bay Conservation Society are:

- to undertake and support research and long-term monitoring of native wildlife populations of nesting seabirds and other marine birds, forest birds, marine mammals, and introduced species of the Laskeek Bay ecosystem (LBE);
- to provide information on all aspects of the biology of the LBE for residents of Haida Gwaii and visitors to the area;
- to encourage students and residents of Haida Gwaii to participate in field programs; and
- to undertake and assist in presentations and other activities that promote better understanding and conservation of the natural world.

Major Programs

The Society has three major program areas:

1. long-term, low-impact research and monitoring on a variety of birds, mammals, and introduced species;
2. education, interpretation, and hands-on training at our field research station on East Limestone Island; and
3. advocacy and public education to a wider audience using publications, slide presentations, and liaison with a variety of government and non-government organizations, as well as with the media.

Each of these programs has several sub-components.

The Sacred Workplaces of Our Ancestors

Guujaaw
Artist
Skidegate, Haida Gwaii

I didn't prepare a presentation because, well... a lot of reasons—too busy. But I thought I could bring some things to you that would be of interest to the topic. I wanted to start by talking about the Kiigaawaay people. They are the people from Bolkus Islands, they call it now. Those people used to put pine branch in their hair at potlatches. They said it was their crest because they had found the first tree that grew on the island .

In recent years, they've been doing pollen studies in the mud. They would bore down and look at all the different kinds of pollen. They know that the first trees to get here were pine trees and that was about 14 000 years ago. And the archeological work that has been done here shows that our people were here for at least 10 000 years. But they also know the sea levels have fluctuated and in the earlier times our people would have lived in an area that is now under water. There were some other stories that add up with the scientific work that's been done. There was one story about how the Honna used to be like a valley and people had a little canoe, not like the ones they use now, but this guy was going up the little inlet there and he heard a voice telling him not to go any further. But he kept going. And it warned him again not to go up any further. So he pulled his little canoe up onto the bank and he climbed up a hill and he looked up just as the ice and water and everything let loose and came pouring in and filled up that little valley and that little inlet. And just last year they were drilling for water at the other end of Queen Charlotte, by the next creek down from the Honna, and they hit a solid branch of wood down about 50 feet and they dated it at 8000 years. So 8000 years ago something happened there. There were also stories that had been passed on about Kalgajad—that's ice woman—and how she had flown down in front of ice that was coming out of the Honna River. The point to be made here is how the history and our identity has passed on through the generations and how now a lot of that oral history, things that once seemed farfetched even 10 years ago—like the notion of being here before trees—has been proven out by science.

They also know now that cedar has been here for only about 8000 years and there are stories about the people out at the Naikoon area that used grasses to make their shelters, and also skins. So the culture changed a bit and then changed that much more once there was cedar.

The biggest changes that have happened on the Islands are happening now. And it's not the deer, as this symposium seems to be designed to make it look like. I was quite disappointed with the organizers for putting it that way. Because the biggest changes are being made by man.

Over the years we have been locating and doing whatever we can to protect the cultural sites where our people worked in the forest and we've been trying to stop them in a lot of other places for different reasons. And it seems like it's an endless fight to try and save every little tree. And I know there are people here that have been on the opposite side of the table while we've been doing that and every little piece that we save now has become so precious that I know that what we're doing is the right thing.

The cultural sites that we've been protecting in recent years... fortunately during the war when they were after wood on the Islands they were after the spruce mainly so a lot of the cedar stands are still intact. But I have a map here, which some of you have seen. The one on the far side with the yellow shows what has been logged already. In the Culturally Modified Tree (CMT) inventories that we're doing, basically we've written off everything that's in the yellow there and we know that a lot of the old cultural sites have been destroyed already.

Only in the last 2 or 3 years has the province of British Columbia recognized CMTs to be worthy of protection. Prior to that we had—to give an example, one was up in MacMillan Bloedel's Bird Lake where there were probably 100 test holes and canoes; one of the canoes we took out of there. And we registered it with the Archaeology Branch. Later we found out that they were logging it and so I called the Archaeology Branch to report it and they acted surprised. I went up to MacMillan Bloedel and asked them what's going on and they said: "Well, that's strange, we got that guy's name right here on the approval saying go ahead and log it." And, not to mention any names, someone had directly lied to us and he's still there quite high up in the Archaeology Branch.

So, over the years, I know that some of the timber companies had been filling out the archeological site forms and sending them to Victoria and just logging the sites. And for a long time the policy was to cut the tree above the test hole if it was safe to do so. Anybody who has ever fallen a tree knows that the safest place is with your feet on the ground and so there weren't very many of them protected in that way.

Some of the bigger sites that we found, that we clearly knew about, politically the Ministry stayed away from them but kept them in the inventory to keep the rate of harvest high. Some of these sites are around the Ain River. And there's quite a few that still remain, that would have been logged off now, but still contribute to the inventory.

Recently we made an agreement that they wouldn't cut within 50 m of a CMT. Of course, if it was our choice it would have been a lot more than that but it is an operational guideline, and it adds up to a fair amount of land if there are several CMTs together. And some interesting things, some surprising things, have shown up as we've been looking for these sites. Just recently, we were looking for some half-way between here and Juskatla, and some yellow-cedar gathering sites that are up on top of that big hill by

Alliford Bay and over on the backside of Charlotte, up past the top of the hill. And still I think it's a tentative agreement and there's still no real security for them. They could change the policy and we'd have to fight with them all over again. But part of the reason it came about was through court cases we had to launch. But it's the only example, if you're using an academic reason for it, it's the only example of living archeological sites. If we wanted to we could actually date back to the exact day that somebody put a hole into a tree or the exact day when they stripped the bark off.

There was a helicopter landing pad up on top of this hill behind Alliford Bay, not a big patch but almost the size of this room; we found about six bark-stripped trees. Two of them we dated; one was stripped 250 years ago and the other about 100 years ago. And the trees weren't very big and yet they were about 900 years old. And all of that would have been logged off.

This is why I was quite perturbed by the introduction of this symposium about the big problem of deer. I wouldn't hesitate to say that deer are a problem but there's also cedar on these Islands of all different ages. But you drive up toward Masset and you see them cutting little poles [like that] and then out around Lawnhill they're cutting stands that average [about that] and there's been nothing done in planning to try and protect representative stands of different age classes. The notion of planting trees for cultural purposes is almost a moot point when they're being planted on fibre farms. You know, if our people wanted to sit and wait for 500 years for those trees to grow, I think our culture would be long forgotten by the time those trees came to size.

Some other ideas that came out of the Heritage Branch is that they thought that really what is important at these sites is the information; it's the archeological stuff that's important. They were quite willing to come up and count rings and give us an idea of when this site was used and basically give it back to us in a little folder that we could stick on the shelf. We just told them that we're not interested in that. And the Heritage Branch has been like that consistently, not just with the forest but with the land. The first priority has been how can we get the information that we need in order that development can proceed.

So anyway, what I have over there [referring to map] is some of the sites that we know about. Some of them are canoe-building sites, or cedar-stripping sites. I guess it wouldn't be right to say that those forests that still survive with the cultural activities in evidence are exactly the same as they were. But basically it's the same trees that were there when the old people were out walking around looking for cedar, and the same trees that were there when the weavers went out looking for different qualities and selecting the pieces that they wanted. It's quite a feeling, and I don't think it's the same feeling for someone who's out there engineering, and these CMTs are just nothing but a nuisance to them. But to our own people, going out there is like being in the same surroundings and enjoying the same kind of experience, smells, and sounds that the old people had experienced.

I'm not good at making speeches so I'll save some of it. I'm good when people start arguing with me; that's how I stand up best. So, I'll leave it at that. Thank you.

Speaking about Cedar

Christian White
Artist
Old Massett, Haida Gwaii

Michael Nicoll Yahgulanaas: Our next speaker is Kilthgulaans from the Yahgulanaas clan in Massett, also known as Christian White. He is a carver who is establishing an impressive track record of wonderful pieces.

My name is Christian White. I'm from Old Massett Reserve. I'm speaking on behalf of my father Morris White, also known as Chief Edenshaw. He's descended from a great line of chiefs and a great line of woodworkers. One of the things that the Haida people have always done is work with wood. Besides the woodwork, we're also a seafolk; we're also a seasonal people. Each season there is a different time to do things. That's how we live—we live with the seasons.

During the early part of the century, when we started becoming more modern, the Haida people from Masset returned to boat-building. During that time we became fishermen, and fished all along the whole coast, which we had already travelled for centuries in dugout canoes, some reaching up to 80 feet long and carved out of logs from 500–800-year-old cedars.

My grandfather was quite a man. He was one of the first to start boat-building in Massett. Our people have always depended on that since they had to come back, to come together. The people of Massett and the people of Skidegate come from many different villages. All the dots you see on that map, they represent only some of the areas they utilized. They had many winter and also summer villages. And in each of these places they went out and used the materials off the land.

They used a great diversity of materials: every shape and size of cedar and spruce; the bark from the yellow-cedars. They'd probably be about a foot in diameter. They'd take a little strip about 5 inches wide or so and cut it along the bottom and they'd strip it high up into the trees. That inner bark would be used for making clothing. They had many uses for the materials and every size of tree they used.

On the bigger cedars they'd make a plank out of the bark of up to 10 feet long and maybe up to 2 feet wide. This would be off a 6-foot diameter tree. These bark pieces could be used to provide a quick shelter, and would be used for trading purposes. They would take them over to the mainland to the eulachon fishery that was going on the Skeena and Nass rivers. They'd trade the bark for eulachon oil. The bark could also be used as roofing on a house, and was quite portable, rather than carrying around heavy planks. They needed quite a diverse size of timber.

For the big pieces, like the totem poles and the canoes, they needed a certain type of tree. If the trees were aged they'd probably be between 500 and 700 years old; they'd be prime straight-growth cedar with very few knots up to 60 feet, tall and not too much of a taper.

There's not many of these trees left on the Islands. They're getting harder and harder to get at. They're in smaller and smaller pockets. But we know that the companies are making plenty off them and they seem to be able to get the timber out. But our people have a hard time to get material to work on. In my village of Massett, over the past 10 years or so, we've gotten maybe a dozen logs to work on. There are millions of dollars of logs going by our village and there's probably less than a handful of people working in the logging industry. So, you can see, that it's really starting to bother us quite a bit.

And we know that even if there were even a few pockets of trees left, and the mature stands were saved right now, that within a 100 years there might not be anything the right size and shape that is needed. So we're quite worried about having different-age stands, as Guujaaw mentioned.

There was quite a fleet of boats built in Massett during the '30s, '40s, and '50s. But the government and the fish companies got smart at managing the fisheries. They timed things right and next thing you know the Haida people had lost all their fleet of boats.

There's another thing that concerns us: the tree farm licence principle or the timber supply area. What bothers us is I don't think there's any way to really settle who owns the land and we haven't really been compensated. Almost anyone with a chainsaw gets out more timber than we do as Haida people. We get out maybe some cedar bark and some spruce roots. Back in the 1960s, my grandfather had a sawmill and he was running that for a couple of years, cutting wood for building and house material. And during the 1960s, all of a sudden he was not allowed to cut trees. He used to own a seine boat and do the hand-logging. So he had to turn to beachcombing, but that didn't last long.

Over the past few years I've been working on canoes and cedar totem poles. I want to be able to train some of the younger generation into working on the material. But it's quite hard for the individual carver to get material. We have to pay the stumpage fees, we have to pay the transportation. But how do you pay when you don't have the natural resources or it's almost illegal to get this?

I think the cedar planting has to continue. It's already started. But there has to be a lot of things that have to be figured out ahead of time because of introduced species.

We already know that hemlock is quite a prolific tree. You see them growing so thick. But cedars need a special environment. All I hope for now is that the people here today can figure out a way to convince the government that we need that biodiversity of the different aged stands and the different uses found from it: the bark and medicinal purposes. The Haida don't look at the trees as just money. We look at them as part of our freedom, and we'd like this to continue.

Speaking about Weaving Cedar

April Churchill-Davis
Artist
Old Massett, Haida Gwaii

Michael Nicoll Yahgulanaas: The next speaker on the list is from the Git-tens family from the upper Massett Inlet area who brings quite a pedigree in terms of involvement of her mother and grandmother in the gathering, preparation, and production of materials from bark and roots: roots from the spruce and bark from the cedar. It's quite an amazing technology. I was fortunate, in my younger years, to follow Selina Peratrovich through the forests: a 90-year-old woman out collecting bark. April Churchill has followed in her grandmother's footsteps and here she is to talk about that.

[Speaks in Haida]

Good people, I am happy to be speaking with you.

I am a Massett Haida. I belong to the Eagle people, the Eagle side, and I belong to the family of Git-tens. Alfred Adams is my grandfather; Selina Harris Adams, my grandmother; Delores Churchill, my mom. I'm known as Hiihliikingang, also known as April.

Some years ago, Claude Davidson was in Ketchikan at a ceremony and he stood up to talk. He started out by saying: "The Haida people don't talk about themselves in public. That is not how we do it. People will know who you are."

The introduction that I gave to you of myself—knowledgeable people would know who I was. I wouldn't have to explain who Alfred Adams was, that he was Kyanuusalii people, that he established the Native Brotherhood. I wouldn't have to explain that my mom's brother Gaalaa was village chief of Massett. I wouldn't have to explain our responsibility to the people of Kana-sa-lee, my grandfather's family; people would understand the ancestral war that we had. But, as usual, what happens is I'm going to have to make an adjustment because to speak of weaving and not to speak of myself and my family would be an impossibility. And, as always, since I've been small we've been adjusting to school systems and I'll make an adjustment so that my Western brothers and sisters are able to understand the things I have to say.

Nowadays we hear a word being said a lot about First Nations activities. It's called "revival" and I'm certain it applies to some things we do. But a more appropriate word would be "revealing" for we have never really lost these things. We are just a very clever people. When laws were against us for memorializing our people through feasts and raising memorial sculptures we moved into the church and started doing what was acceptable, moving our head stones, conducting a dinner. We've always been here and we've always been doing what we've been doing. We've always had those treasured people with us who had the knowledge who acted as a thread to those people, to our ancestors and the wisdom they had. Today, the laws allow us to reveal who we are.

Selina Peratrovich Adams was my grandmother. Above all things, as a young woman, she wanted to go to school. But her grandmother said to her: "No, you won't go to school. You take a look around in the village and you look what's happening. All these young people going to school, they're coming back, and they're no good for the village."

Selina wanted school so badly but she didn't go. Instead she was trained to be Haida. She took that responsibility as the torch-bearer of knowledge very seriously and passed things down to her family. I learned to weave from Selina and it took years and years and years to learn. I started when I was 5 or 6 years old, harvesting out in the woods with her. I didn't take a 30-hour unit that taught technical skills. Spiritual, scientific, technical, historical knowledge all through the years intertwined—just like the roots of the forest—to create a Haida weaver.

Often times, I become really offended when I'm reading what other people write about us, people from other cultures, when they write in the past tense. Because we're not only past but we're today, we're tomorrow, and we're thousands and thousands of years of tomorrows.

There's a concept that needed to be understood and I'd like you to take the time to think about it. You heard that I said that I belong to the Eagle people and I belong to the family of Git-tens. I did not say the Git-tens family is mine. I am one of the women known as a "woman of Ain." When we refer to ourselves, we're the Women of Ain. We are not the women who own Ain. We are part of a whole, a full picture.

I wanted to bring up one little thing up: the logging that is going up in Ain, there isn't anyone who came and consulted with the women of Ain. Every weaver knows that the tree is our sister. No one came and asked us: "women of Ain, what do you want done with your sister." They just went up and started logging our sisters away.

"And you shall have dominion over this earth," is not a concept that belongs to us. We do not have dominion over the earth. We have a small place in the whole structure of the universe. We are part of each other. When we have dominion we can do anything that we want. But when we're equal to and on equal footing with all living things then we have to be responsible and we have to take care of each other.

The bark, the roots, the flesh on the fish is not our right. Each of these things that are given to us are gifts from living spirits. And anyone who has gone harvesting for bark has experienced speaking to and feeling the spirit of the tree. It's not a made-up fairy tale thing. It is a real thing. We speak to the tree and it speaks to us. Harvesting is a spiritual responsibility. It is an annual event that reminds us that we hold a responsibility to all things that live.

Like the eagles, which are coming down off the mountains and hanging around Massett right now because their tree homes are being shipped out on these logging barges, I'm bewildered and I'm scared. One of my family's places for digging spruce roots has become what is known today as "teachers' row." A few years ago, one of the new owners asked me to please leave their property.

Another place that we got our roots was made into an environmental park. And I was told that we're not supposed to take anything out of that environmental park. Somewhere, someone forgot that for thousands of years we have been part of that ecosystem.

I'm bewildered because where am I supposed to get spruce roots? How do I meet my spiritual obligation to the spruce? The Culturally Modified Trees (CMTs)—I think that's what you call it—that's a wonderful project. It's important that we preserve these places. But it's a little late. There isn't anyone in this room who doesn't know that our lands have already been logged. Those places that are accessible to us have already been logged. Now, where do I go to meet my spiritual, my ancient spiritual obligation to the cedar? Where do I go to get my bark?

A couple of days ago I talked to my sister Evelyn. She works in Raven's Tail and Chilcat weaving. When you work in mountain goat hair—fur—you need yellow-cedar bark to spin inside your yarn. She's currently residing in Washington State where they've issued permits. Wise people have identified a designated spot where native American people can go to get their bark. She started early in the morning, got in the car, drove, drove, drove, miles and miles, up a logging road that was barely passable, up into the mountains—only to come to where the designated trees were twisted and gnarled and begging not to be touched. She came home without any bark.

To me, every time I hear "permit" and "designated area," the only thing it says to me is that again another thing is being taken from my great-great-great-grandchildren.

We used to have the biggest—in both Alaska and on this side—fishing fleet. Find out how many people owned boats in the village of Massett. "Permits" mean no longer do I get to practice those things that have been passed to me for thousands of years.

We need to remember that the cedar have provided for the people that lived here—us, me—for thousands of years. For vast populations, everything that we needed came from there: our clothing, our baskets, our boxes, our house, our transportation. And there was a vast population here. And yet, when the first European guests arrived on these islands, they found lush forest. They found a people who knew how to keep the forest in good health, who understood that 5 years or 10 years was not a "long-term plan."

When I come back—whether it be 100 years from now or 500 years from now—I am asking you please, if you are going to be making these kinds of decisions, leave standing forest for me, leave healthy sisters for me. As long as this society believes that it has dominion over the earth, then we can rape and plunder, and that's what is happening on these islands right now.

There's somebody who is thinking we should put a sign up on the Charlottes saying: "Welcome to the Charlottes: where there used to be trees and there used to be fish." It's not funny; it's very sad. If each of you who are going into positions where you are going to be making decisions, or sitting in negotiation places, if you could stop and take the time to experience those trees, to feel them, it will make things so much better. You won't be able to allow people to just go in and crash them down.

Now I'll tell you what I think you thought I was really going to talk about. The reason I didn't want to just give you this technical information is because if you just hear technical stuff, I'm really afraid you are going to stick me on top of a mountain, like my sister Evelyn.

And after hearing me talk I'm not going to answer you and tell you what I do. But do you really believe that when I walk into these eco-parks where I have always dug roots that I won't leave with roots? Do you think if you send me to the top of a mountain where the trees are gnarled that that will be the only place I will go? I have an obligation. You make a perfectly lovely, kind, law-abiding person not abide the law.

Anyway, what we need when we go harvesting are tall trees. And when we go in we actually do listen for the tree to talk to us. We don't harvest trees less than about this size—about 30 cm in diameter. When you go in and find a CMT, you never touch a CMT. Any tree that's already given a gift we don't touch. Those smaller trees, we leave them for the next generation. All of my children, my nieces and nephews, they need this resource. Their children will need this resource. If a tree is crooked you don't touch the tree. You can get greedy out there but that tree is not going to perform for you. The baskets will be ugly. You're doing this in cooperation. So, we don't touch trees where the bark is moving in this direction. We only go for the trees that are very straight. We take a strip about 6 inches wide. And, on occasion, like yesterday when I was collecting, a tree will tell you that you can take a bit more.

You actually feel it, you actually hear it. I was working and I looked over to see what it was talking about and there was about that much more, but it went all the way to the top and there wasn't one knot in it. We're very conservative. Also, when we go into the forest we look to see if the other trees look healthy because we're not out to kill trees. It's important to us that the spirit of that tree is allowed to carry on. We speak to the trees; we thank the trees.

It takes quite a long time to do weaving. You have to thin the bark down and then you have to split it down into the little tiny threads. It takes hours and hours and hours. We teach non-native people to weave, but in the last 20 years there's been only one non-native who kept it up. It's a lot of work and you have to actually have a feeling of love for it.

Now I teach in schools, which means there may be 30 kids. On the Islands last month we taught about 70 people to weave. I don't go to the trees for that bark; there are enough logging sort yards around that you can go down and pull bark off the logs for that kind of thing. But I don't want to be relegated to going down or people telling me to go down to the sort yard to get bark. As I said before, I have a spiritual obligation.

Speaking about Responsibility

Lavina White
Elder
Old Massett, Haida Gwaii

Michael Nicoll Yahgulanaas: Our next speaker is a Nonni, which translates into English roughly as "grandmother," but it carries with it much more significance than the translation would suggest—as in your mother's mother, your father's mother. It brings along with it certain degrees of responsibility and status within the community. Lavina White is a member of the Yahgulanaas family from Old Massett, who comes with a reputation of not only local and national activism but international activism over the last quarter century.

Thank you very much.

I wasn't expecting to be able to speak to you today so I didn't become too concerned about what I was going to talk about. But today when I was speaking to you I made up my mind that I would come and talk to you about some things that we think are essential to what you're doing right now.

My name is Tthow-hegwelgh but I'm known as Lavina White, the imposed name that I got. I come from the house of Yahgulanaas, my lineage comes through the Yahgulanaas and, on my father's side, Yahxtswas. Henry White was my father and chief Charles Edenshaw, Staastas, that's my grandfather. And so when I asked my mother why I got the name that was given to me she said it only means one thing: "The sound of many copper shields is one that carries a lot of responsibility." Tthow-hegwelgh is "the sound of many copper shields."

So I was brought up from the cradle to know what my responsibilities are and it is something I can never walk away from. And part of my responsibility has been to try to work towards the betterment of things for our people even when they don't want it. And to try and stop the onslaught that has taken place in this country. I also work on the environment and I work on peace and I worked on the child-care changes for our people for one whole year. For the colonial mindset doesn't take only trees, it also takes children.

And part of my responsibility, as I see it, is to inform people like yourselves, because I know there are industry people here and I know there are government people. So I intend to speak on things that maybe you won't be very happy to hear, but I think logging is at an end on this island. I think the logging companies have to go. The genocide policies of this country are still in place, still active, alive and well.

So, when you talk about cedar you are talking about a people that are cedar people. You are talking about a people that are salmon people. That is the backbone of our culture. Cedar meant many things to us. My grandmother, I think, was maybe one of the best basket people that has ever been on the island. My grandfather was also an artist, well known throughout the world. And they instilled in us a spiritual respect that we have to have for our land and our environment.

As a consequence, I have grown up being very angry at the destruction that we see around us. It is very difficult for our elders to see this. I used to visit all the old people from down here and up in Massett. The pain they felt when they saw their lands being destroyed came to mind today when I listened to the academia talking about cedar.

The forest can't be treated like a garden. You can't play God. Science, had it worked with the Earth people, might have been fine. For we, the indigenous people, are the Earth People. Had we worked together, maybe things would have gone differently. But the colonial mindset put us in a category of people that were worthless. We have our own science. There are two paradigms in this country and both conflict with the other.

That's one of the things I wanted to talk to you about today. I am old enough to remember what it was like to be free. To be able to go to the river when we know it was right. Now we're being told when to go and how long we can stay. We're trespassers in our own forests. We're squatters on our own land. And the ones that came and squatted are the ones who tell us what we can do. Maybe you don't like that statement but that's the way it is. We're squatters on our own land. They tell us that the land that we live on doesn't belong to us. I find that unacceptable.

The freedom I knew as a child I can never forget and I can never let go. I intend to live long enough—if it takes to 200 years, I will live that long—to regain the control of our lands, our lives, and our resources. The destruction of our forest is genocide and I don't care what else you call it, that's what it is. The policies that exist to control all of our resources is genocide. And yet, Canada is signatory at the world level against genocide. In fact, the laws in this country on our side ignore that too.

So I have to believe that when we're talking, we're not talking partnership, because we find no honour, anywhere. We were a people that shared. The strongest philosophy that we have is of sharing. And, despite all that has been done to us, it's still the strongest philosophy that we have. That comes with every native group on this side of the world. Indigenous people on this side of the world—and I don't care which nation you're talking about—we are nations with different nations much as you Europeans, but the people that came here did not want to recognize that.

I gave up my Canadian citizenship a while ago. There were nine Haidas that gave up their Canadian citizenship. There were some young fellows that were on the board of directors that decided they were going to give up their citizenship. When I came to the board of directors meeting they informed me that was what they were thinking about but they weren't quite sure if they should, and I said, "Put my name down." So we notified the Canadian government that we had given up our citizenship—our imposed Canadian citizenship. And they told us that we'd have to find us a country. And I said, "No, we have a country." Our Nation is the Haida Nation. I didn't follow it up after that. I don't know if we had any more of a response from them; I'd have to talk with Guujaaw and Miles and all those that were involved at that time.

But you all had a choice. Those that came had a choice of whether they wanted to become a Canadian citizen or not. We didn't have that choice. I don't vote. I don't accept the system that was imposed on us. I don't accept them cutting all our trees down like they have. And you can't plant trees after there's just rocks left. I'd like to get a contract with the government, not give all the money that's been given to the companies that have destroyed our forests. The list of names and the list of dollars that the companies got for destroying our forests—I can't believe that we have a system like that and you put up with it—you taxpayers. We're always hearing about that, taxpayers are paying people large dollars to renew the forests that took hundreds of hundreds of years to grow. We're an ancient people; we've been here since the beginning of time and our land was intact. We used it to build our homes, to build our boats. We used all of our resources, but in a sustainable manner.

Deer Management to Protect Forest Vegetation —A British Perspective

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Introduction

Following centuries of depletion and neglect, the forest cover of Britain has been increasing during the 20th century at a rate of up to 2% per year (Locke 1987; Peterken 1996). Concurrently, deer populations also increased, being largely confined to the Scottish Highlands in the early 19th century (Ritchie 1920), but now occurring over most of Britain (Corbet and Harris 1991). As a result, problems with deer damage have grown over the last few decades and methods of dealing with them are relatively modern.

Today, approximately 70% of British forests are coniferous—much of this consists of large, comparatively new plantations of introduced species: Sitka (*Picea sitchensis*) and Norway spruce (*P. abies*), larch (*Larix* spp.), lodgepole pine (*Pinus contorta*), and Corsican pine (*P. nigra* var. *maritima*). The remaining area includes various types of broadleaved woodland, most of which occurs in smaller blocks (Locke 1987). Although there is now no primeval woodland left, there is still a significant amount of ancient woodland (13% of total area), which was established before 1600 and now has a high conservation value. However, even most of this has been under some form of exploitation since then (Peterken 1996).

Deer Species

Altogether, six species of deer occur in the wild in Britain. Red (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) are native species and still the most numerous and widespread. Fallow deer (*Dama dama*) were introduced during the 11th century (or beforehand); sika (*Cerrus nippon*), muntjac (*Muntiacus reevesi*), and Chinese water deer (*Hydropotes inermis*) were introduced in the l9th and 20th centuries. The distribution of each species is somewhat patchy. However, upland forests usually contain red and roe deer and sometimes sika as well, whereas lowland forests contain either roe, fallow, or muntjac, and sometimes also sika or red deer in various combinations. All species are generally thought to have increased in range and/or numbers in recent years (Ratcliffe 1987a; Gill 1990; Chapman et al. 1994b). This tendency will result in more species inhabiting each forest, increasing the potential for competition and complicating the interactions between the deer. Large predators have been eliminated from Britain, and, with a mild climate, shooting is seen as the only means of controlling populations or preventing excessive natural mortality through starvation.

The Impact of Deer on Forest Vegetation

The most widespread form of damage caused by all deer species is browsing on young trees. Browsing can increase mortality rates, particularly in the first year after planting, as well as retard the growth of survivors (reviewed in Gill 1992b), both of which substantially increase establishment costs. The removal of the leading shoot also causes poor stem form and multi-trunking in many conifers (Welch et al. 1992). Early experience with restocking revealed that survival after browsing could be increased by using better-quality planting stock and handling techniques. Multi-leadering is now suspected to be the most serious consequence of browsing damage in Sitka spruce stands. More information is needed, however, on the long-term effects of browsing on other species to accurately assess the costs of deer damage.

In semi-natural woodlands, regeneration is often severely restricted by deer browsing. Putman et al. (1989) found that an area protected from fallow deer had a density of 6440 saplings/ha after 14 years, in contrast to only 20/ha in an adjacent heavily browsed area. However, regeneration of the less palatable species is often successful if the initial density of seedlings is high (Gill 1992b).

The larger deer species (red, sika, and, to a lesser extent, fallow) also cause significant amounts of damage to thicket-sized and pole-sized trees by removing bark. Bark loss sometimes results in stem breakage (particularly in pines) but the most common consequence is the stain and decay that develops in the main stem following fungal attack of the wound (Pawsey and Gladman 1965; Gregory 1986).

In addition to the damage inflicted on forest trees, there is increasing concern for the effect that deer have on woodland vegetation and fauna. Deer browsing typically results in increases in some species: for example, bracken (*Pteridium aquilinum*), grasses, mosses, foxglove (*Digitalis purpurea*), and ragwort (*Senecio jacobea*); and decreases in others: for example, Bramble (*Rubus fruticosus*), honeysuckle (*Lonicera periclymenum*), ivy (*Hedera helix*), wild rose (*Rosa canina*), holly (*Ilex aquifolium*), gorse (*Ulex* spp.), and heather (*Calluna vulgaris*). To a large extent, these changes mirror the diets of the deer (Putman et al. 1989; author's data).

Since deer focus much of their feeding on herbs, shrubs, and grasses, these plants are able to recover quickly from the relatively little grazing they receive. Deer are likely to tip the balance of competition in favour of grasses and often decrease the diversity of the ground flora. Furthermore, in some areas, nationally rare plants such as the oxlip (*Primula elatior*) are known to be depleted by deer browsing (Rackham 1975; Chapman et al. 1994a). The vegetation changes brought about by deer are also likely to affect fauna (Gill et al. 1995). Decreases in the abundance of many invertebrate groups, small mammals, and birds are known to occur (Putman et al. 1989; Baines et al. 1994; R. Fuller, pers. comm.).

Relationship between Damage and Deer Numbers

The severity of most forms of damage is widely recognized to increase with population density. This has been clearly demonstrated in many studies (Gill 1992a), but is most apparent where deer numbers have been manipulated directly (e.g., Beaumont et al. 1995), since damage can vary considerably between sites. Differences in palatability between tree species, as well as the effects of habitat or feeding selection or other behaviour are known to influence the amount of damage occurring at any one site (McIntyre 1975; De Jong et al. 1995). Since some of these factors are unquantifiable, it is difficult to give general prescriptions for any one area, although available evidence suggests that densities need to be in the range of 4–25 deer/km^2 to keep damage within acceptable limits (Gill et al. 1995).

In the absence of predation or culling, the density-dependent effects on recruitment or adult survival will not prevent densities rising above the level at which damage or some other unwanted impact becomes significant. In areas with little or no deer control, red deer may achieve densities as high as 40/km^2, and roe deer often exceed 75/km^2 (Ratcliffe 1984; Gill 1994; Gill et al., in press). More information is needed on the amount of damage occurring at different densities and sites to help provide appropriate targets for deer management.

Deer Population Management—An Outline of the Legal Structure in Britain

Taken purely from the viewpoint of the landowner, Britain has the most liberal shooting regulations of any country in Europe or North America. The landowner has the right to decide how many (if any) deer are to be shot in any one season. Thus, culls may be set without having to negotiate with government agencies, or having to consider the interests of hunters or the public in general, as is the case in much of Europe and North America (Gill 1990). In Scotland (but not the rest of the U.K.), it is a legal requirement simply to report the numbers of deer shot to a government agency, the Deer Commission (DC).

The fact that the landowner owns the right to shoot does not of course mean that they are the only individuals who shoot deer. Many of the larger landowners (the Forestry Commission, major forest companies, and owners of large shooting estates) typically employ stalkers (referred to as rangers or ghillies) to shoot deer. However, the majority of stalkers in Britain are amateurs who buy or lease the shooting rights from the owner on a seasonal or daily basis.

Although wild deer are not “owned” by anyone, once they are shot, the landowner may sell the venison or hide from the carcass. The costs of any culling operation may be offset, at least in part, by the income received from the sale of venison and the fees paid by stalkers (Table 1).

This legal framework provides landowners considerable freedom to attempt to manipulate deer populations as the need is perceived. Typically, forest or woodland owners try to limit damage by maintaining a heavy culling pressure. Sport-shooting leases often protect female deer to keep up the numbers of males. These leases include primarily moorland habitats where damage to trees or crops is immaterial. Between these two extremes there are many owners (usually smaller landowners) with ambivalent attitudes towards deer control, as well as a handful in direct opposition to any form of culling.

Current legislation on shooting seasons and firearms in the U.K. is based on humanitarian considerations but also reflects the needs of landowners wishing to prevent damage, as well as the interests of stalkers. The shooting seasons vary between deer species and sex, and between England and Scotland. In general, for female deer the open seasons occur between weaning and late pregnancy (3.75–5 months long) and for males when the antlers are not in velvet (4–9 months). In Scotland, out-of-season shooting as well as night shooting is permitted, but only if necessary to prevent damage to trees or crops. The Deer Commission also has the power (though rarely used) to impose a cull in response to complaints from neighbouring landowners.

Deer Control in Forests

Some form of census is normally carried out to estimate population numbers, to provide a basis for setting cull targets. Traditional methods based on direct counts are now known to yield under estimates in woodland habitats (Andersen 1953; Ratcliffe 1987b). This has resulted in high deer population densities developing in some areas as a result of cull targets being set too low (Ratcliffe 1987b). Currently, a census based on counts from vantage points or of fecal pellets is encouraged, although other methods, such as thermal imaging, as well as improvements in fecal pellet counts, are being investigated.

An appropriate cull is normally based on the census figure and an estimate of the number of recruits likely to be produced before the next shooting season. Population models are increasingly being used as an aid to predicting the effect of different culls (Buckland et al. 1995; Mayle, in press). Fertility rates in red, sika, and roe deer populations are known to vary between forest areas (Ratcliffe 1987b; Ratcliffe and Mayle 1992) and the inclusion of these factors helps to make models more site-specific.

The objective of deer control is to reduce deer numbers in anticipation of damage to trees. However, deer may be culled for other reasons; for example, to maintain herd health or reduce traffic accidents, or for conservation objectives. Complete elimination of deer is rarely attempted and would be impossible in anything other than small, isolated woodlands.

Culling is usually done with a high-velocity rifle equipped with a telescopic sight (legal minimum .243 calibre; .222 calibre for roe deer in Scotland) taken either from a high seat or by stalking on foot. It is illegal to pursue or shoot deer directly from a vehicle or aircraft, although it is common practice to use an off-road vehicle to retrieve a carcass once shot. Deer are taken either with a neck or heart shot, for both humane reasons as well as to preserve the value of the carcass. Increasingly, attention is being given to improvements in carcass handling and preparation. Wildlife rangers are now trained to inspect deer carcasses for a wide range of parasites and diseases, and reject them if considered unfit for human consumption (Adams and Dannat 1989).

Methods of Tree Protection Fencing

Fencing is widely used in British forests to protect against deer during the establishment phase. Currently, the most widely used specification consists of a wire mesh supported on spring steel straining wires, with treated posts at 10–14 m intervals (Pepper 1992). Fences require regular maintenance to prevent break-in. Successful exclusion becomes increasingly difficult with age, with boundary length, during heavy snow falls, after storms, and over rough terrain. Attempts to enclose very large areas (a few hundred hectares) usually result in deer becoming established inside. Trials are in progress to find specifications for electric fencing that effectively deters deer as well as meets British health and safety restrictions (limited to a 5-joule energizer).

Tree guards and growth tubes have been found to provide good protection for individual trees against deer and other mammals. Tubes also have the benefit of stimulating growth in some tree species, although they can cause poor stem form in others (Potter 1991). Where a tube is not desirable, guards made of rigid polyethylene netting give good protection (Pepper et al. 1985), provided they are tall enough for the deer species in that locality. Heights of 1.2 m are normally adequate for roe and muntjac deer, but 1.8 m is required for red, sika, or fallow.

Since tree guards cost in the region of $2.12–$3.39 each, there is little economy of scale for large plantations. Fencing is normally considered more economic for areas greater than 2–5 hectares, although this depends on the shape of the site and tree stocking density.

Chemical Repellents

A considerable number of repellents have been marketed in recent years purporting to offer protection against browsing by deer and rabbits. These have included chemicals that either make the plant unpalatable or mimic the odour of predators. However, out of more than 50 chemicals tested so far (Pepper 1978; H. Pepper, pers. comm.), the results are generally disappointing. Most offer only short-term or partial protection, and some are phytotoxic if used in sufficient quantities to deter browsing. Only one, Aaprotect®, has so far been found to give consistently good results, but even this offers protection for conifers for one winter only. A fundamental limitation with most repellents is that new foliage remains unprotected unless the repellent is re-applied after every growing season.

Alternative Feeding

In spite of being a common practice in central Europe, supplementary food is not normally provided as part of deer management in British forests. It is difficult to provide a food source that is eaten in preference to trees all year round, and there is a possibility that feeding would stimulate recruitment into the deer population, thereby making the problem worse.

Discussion

The choice of protection method (or methods) adopted in Britain depends to some extent on local circumstances. Reliance solely on fencing or tree guards is never recommended, since the risk of a fence being breached, or of tree guards being damaged, increases if deer are not culled. Furthermore, excessive use of fencing can force deer to use other areas, causing more damage elsewhere, and tree guards do not protect other vegetation. Since most (in some cases, all) of the costs of culling are covered by venison sales, the recommended approach is to reduce the deer population until damage becomes insignificant. However, some reliance on other protection methods is often required, for a number of reasons. Firstly, it is not always possible to achieve sufficient reduction by culling (e.g., in urban areas, where it can be unsafe), or where culling is countered by substantial immigration from elsewhere (McIntosh et al. 1995). Secondly, the most palatable tree species may still require protection if planted in small openings heavily used by deer. Finally, deer population reductions to low density can be difficult to effect by culling. Where necessary for forest management, a cull is applied, and additional protection, in the form of guards or fencing, is used if needed on the most vulnerable trees or stands.

One of the major problems in deer management in Britain is the difficulty of reconciling differences of intent between landowners. Landowners with a major interest in stalking complain if “too many” deer are shot by a woodland neighbour. Equally, woodland owners, especially of small blocks, are unable to prevent damage by deer that may move onto their land for short periods. This problem has been approached, with some success, by establishing deer management groups, which are formed under the guidance of the Deer Commission in Scotland and the Deer Initiative (a group of government and non-government organizations created to improve deer management) in England. However, even within such a group it can be difficult to formulate a concerted control policy, with the result that some properties need to be fenced, even if this means barring a migration route or enclosing deer completely.

Recently, two alternatives to culling and physical barriers have been discussed as means of deer control. These include the re-introduction of the wolf and the use of immuno-contraception. The principal obstacle to re-introducing wolves or other large predators into Britain is the enormous free-ranging sheep population, which would suffer heavy predation. Most trials of immuno-contraception have focused so far mainly on white-tailed deer and feral horses (Turner et al. 1992; Garrott 1995), and the potential range of behavioural and physiological side-effects have yet to be fully explored. Furthermore, contraceptives requiring manual delivery would be costly and impractical for free-ranging forest deer populations, many of which would remain unseen and untreated, and hence the main objective of population reduction would not be achieved (Garrott 1995). A method of automatic or oral delivery may have the potential for being more practical, although it would probably require both the response as well as any side effects to be largely dose-independent.

Apart from methods of deer control, research into the chemical and genetic basis of palatability may yield new methods of limiting damage to trees. The full range of secondary chemical compounds produced by plants, their genetic basis, and their influence on diet choice still remain to be explored in greater depth. This line of research offers potential for developing browse-resistant varieties or chemical repellents for trees, although not the surrounding vegetation. However, as a general means of protecting forest vegetation, culling remains the most viable and cost-effective option in the U.K.

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Table 1 *Estimated costs of re-stocking and deer control (Forestry Commission 1991–1992)*

Forest area 896 000 hectares
Area planted 11 300 hectares

	$ (Million)	$ / hectare
Expenditures:		
Planting and site preparation	22.7	2008
Rangers (salaries+equipment)	2.5	229
Fencing	6.1	551
Revenue:		
Venison sales and stalking lets*	2.5	235
Net costs:	28.8	2553
Losses:		
Estimated additional losses due to browsing and bark stripping in unfenced areas	?	?

Figures calculated on total forest area, approximately 15% of which does not contain deer.
*1989–1990

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Introduced Species and their Impacts on the Forest Ecosystem of Haida Gwaii

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Introduction

Big trees, few mammals—Old-growth forests with their giant conifers are—or were—the most striking natural wonder of Haida Gwaii as well as a considerable source of wealth.

To the contemporary visitor their remnants look magnificent and have a friendly open understory. To earlier people, however, the understory looked quite different. "There was no soil to be seen. Above the beach it was all luxuriant growth; the earth was so full of vitality, that every seed which blew across her surface germinated and burst. The growing things jumbled themselves together into a dense thicket; so tensely earnest were things about growing in Skedans that everything linked with everything else… Just one roof still squatted there among the bushes… We broke through the growth above our heads to reach the house." (Emily Carr 1871–1945, in Carr 1986).

These forests do not teem with large charismatic animals. The indigenous terrestrial mammalian fauna has only eight species, one of which became extinct this century (Table 1). Interestingly, five of these eight species are carnivores or insectivores. There is no large native forest herbivore or browser.

Newcomers—Another striking feature of the fauna of these forests is the large number of mammals introduced by humans in the course of the 20th century. There are at least eight major introduced mammals (Table 1) (McTaggart-Cowan 1989). Some of these remain locally distributed. Others, such as the black-tailed deer (*Odocoileus hemionus*) and the red squirrel (*Tamiasciurus hudsonicus*) have become widespread. These two literally fill the forest with new ecological "actors," namely a large browser and a large rodent, that were entirely missing from the forest ecosystem.

Introduced species, biological diversity, and economic losses—There has been an awareness for centuries of the problems posed by alien species. But it is only recently that these problems have gained more widespread recognition. Many biologists today consider the impact of introduced species as one of the major planetary changes caused by humans. Alien species have wiped out entire faunas and floras, especially on islands. Hawaii, for example, has lost more than half of its indigenous birds and 10% of its native plants, and more than 30% of the remaining species are listed as endangered (Murphy 1996).

The economic losses due to introduced species can be staggering. For the United States only, according to a 1993 report by the U.S. Congress Office of Technology Assessment (OTA), it is estimated that about 80 of the 4500 non-indigenous species that have established significant populations in the United States caused losses of $97 billion between 1906 and 1990. Estimates of future losses induced by the 15 potentially high-impact species are as high as $135 billion (Murphy 1996).

In such a context it is legitimate to wonder about the biological and economic consequences of species introduction on Haida Gwaii.

In this paper we will investigate the changes that have occurred in the forests of Haida Gwaii as a result of their colonization by the black-tailed deer and the red squirrel.

Three questions arise: (1) What are the ecological changes caused by these species? (2) What are the short- and long-term consequences of these changes on the processes at work in these forests? (3) Can we mitigate these impacts if we have the will to do so?

We will address the first two of these questions. The third question will no doubt arise again and again each time the issue of deer, squirrels, and forests on Haida Gwaii is raised. To most, the answer may look straightforward: the challenge is too big. But experience elsewhere, as in New Zealand, has taught us that with good background knowledge, determination, and resilience, results can be obtained that go beyond initial expectations.

Materials and Methods

The new actors

The black-tailed deer was introduced at the beginning of this century to provide venison for the local community (Foster 1989). Due to its good dispersal ability and to its good reproductive potential, the deer colonized all but the smallest, most isolated offshore islands (Martin et al. 1995; Martin, unpubl.) and achieved high population densities in most places.

The red squirrel was introduced in the 1940s to help the people gathering the cones of Sitka spruce (*Picea sitchensis*) (Foster 1989). The squirrel has a checkerboard distribution and squirrel-infested islands lie adjacent to squirrel-free islands (Martin, unpubl.). Usually considered a gentle vegetarian, the squirrel is in fact an efficient raider of songbird nests, preying on both eggs and nestlings (Burt and Grossenheimer 1976).

Deer and plants

Sampling localities—In 1993 and 1994 we surveyed islands that cover the entire range of island area found within Juan Perez Sound and Laskeek Bay, on the east coast of Moresby Island: Lost Island (5.3 ha), Tar Island (6 ha), Low Island (9.6 ha), Agglomerate Island (20 ha), East Limestone Island (48 ha), Reef Island (250 ha), Ramsay Island (4557 ha), and two areas on the large main islands: the De la Beche Inlet area on Moresby Island and an area near Haswell Point on Louise Island. With the exception of East Limestone Island, the Moresby Island sites, and Louise Island, the islands were selected so as to be isolated enough from the main island of Moresby to limit the study to deer populations that are resident populations rather than individuals commuting on a short-term basis between several islands. Deer are absent from Tar, Lost, and Low islands. Based on our direct knowledge of the habitat conditions on most of the islands in the area (Martin et al. 1995), we consider the sample as ecologically representative.

Impacts on shrubs—We focused on the two commonest shrubs, salal (*Gaultheria shallon*) and huckleberry (*Vaccinium* spp.). Plants were divided into two categories: well-developed shrubs (height ≥ 0.5 m, with several stems or main branches) and shoots (height < 0.5 m, with only one stem).

Well-developed shrubs were sampled along transects within 10 m to the left or to the right. When shrub cover was very dense, only one or two individuals were studied at regular intervals (10–20 m) in order to avoid biases due to locality. When shrub cover was low (individual shrubs spread out across the landscape) all individuals found along the transect were sampled. We measured shrub size (distance between shrub base and shrub top), the height above ground at the base of the shrub for the individuals that did not grow on the ground (e.g., growing on a stump or downed log), the type of support on which the shrub was growing, the height from the ground at which foliage was present on the stems and branches (foliage and buds were the target of deer), and, finally, the amount of browsing that the shrub suffered, scored from 0 (no browsing) to 5 (very heavy browsing). Minimal sample size per species and per island was fixed at 30.

Shoots were sampled in a similar way to shrubs. All shoots were accessible to deer and were found growing on the ground or on other growing supports. For each shoot we recorded the impact of browsing by deer. It was assessed by counting the number of times the shoot had been clipped by deer (deer, having no upper incisors, will rip off the tip of the shoot, leaving a jagged edge). If one assumes that each spring the plant grows a new shoot, the number of clipped shoots per individual can be an estimate of the number of years this individual was trying to get "started." Sample size per island was at least 30 shoots per species.

Differences in the browsing patterns were tested by the Cholmogorov Smirnov test.

Impact on tree regeneration—The impact of deer on tree seedlings (young trees between 0.1 and 0.5 m high) was also quantified. There were three target species: Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and redcedar (*Thuja plicata*).

Seedlings were identified along transects and scored from 0 (no browsing) to 4 (shape very significantly affected by browsing). Seedlings were usually found in small patches of regeneration. In these cases, 10 individuals were sampled and additional individuals were searched for at a distance of at least 25 m away, in order to limit locality effects. Sampling of a given species stopped on an island when the 100 individuals had been examined.

Deer impact on the ecology of the understory—We studied more than 150 vegetation plots of 40 m^2 each on Reef, East Limestone, Low, Lost, and South Low islands. In each plot we estimated the cover of each plant species in two layers: the ground and bush layer (<1.5 m) and the understory (1.5–6 m).

We also estimated the level of stress due to browsing for each plant species present in the plot (the percentage of the plant sample obviously stressed by browsing).

Deer and birds

The profound changes in the vegetation caused by deer must have effects that go beyond the vegetation. The lack of stems, foliage, and flowers in the understory must reduce the abundance of insects and their diversity. To estimate this effect, we censused the number of bird species and the number of individuals per bird species on deer-free Low Island and compared it to data from an equal area on deer-infested Reef Island.

Squirrels and birds

In order to estimate the impact of squirrels on the breeding of small forest birds, we placed wicker nests baited with two quail eggs along three 1-km-long transects on a squirrel-free (Ramsay) and a squirrel-infested (East Limestone) island. One nest was placed on the ground and one above the ground (between 0.5 and 2.0 m height, usually in a small tree or shrub) every 50 m along the transects in order to mimic both ground-nesting and shrub-nesting birds. The interior of the nests was lined with moss. Nests were checked every 3 or 4 days until day 15.

The results of these experiments were analyzed by the Mayfield method for estimating nest survival rates (Mayfield 1961, 1975). Equality of nest survival estimators was tested according to the method proposed by Hensler and Nichols (1981).

Predation rate was also compared between conifer- and alder-dominated habitats on East Limestone Island, and squirrel abundance was monitored by censusing squirrels along transects set up in both habitats.

Results

Conspicuous changes

Pojar and coworkers (Pojar et al. 1980; Pojar and Banner 1984), in their pioneering study on the impacts of deer on the forests of Haida Gwaii (see also Pojar, these proceedings), described the major changes in vegetation structure caused by deer on the islands.

Shrubs are destroyed by overbrowsing (Photograph 1, Plate 1). As a result, shrubs tend to be more and more restricted to inaccessible sites, such as stumps (Photograph 2, Plate 1), snags, and rock faces.

Individual shrubs on deer-infested islands tend to be devoid of foliage below 1.5 m above the ground (Photograph 3, Plate 1), and all the new stems that sprout from the base of the shrubs are pruned by the deer, limiting the capacity of shrubs to rejuvenate themselves (Photograph 4, Plate 1).

Tree seedlings are often so heavily browsed that they acquire a cushion shape (Photograph 5, Plate 1). Ultimately, some will manage to escape and resume normal growth (Photograph 6, Plate 1).

Differences in vegetation cover between deer-free and deer-infested islands

Vegetation cover on deer-infested islands differs dramatically from that on deer-free islands (Table 2):

- the cover of salal, huckleberry, and ferns is reduced to a tiny fraction, compared to that on deer-free islands;
- the other shrubs usually found in the understory are completely missing from the samples on deer-infested islands (they are statistically extinct), whereas they are common and widespread on deer-free islands;
- conversely, the cover of young spruce and hemlock is increased in the shrub layer on deer-infested islands; and
- redcedar is missing in the shrub layer on the deer-infested islands.

The role of island area

As illustrated for salal in Figure 1, signs of browsing are non-existent on the small islands with no resident deer population. They peak on the large offshore islands. Browsing impact is intermediate on the large main islands. The pattern is similar for the other shrubs and for the other variables sampled, such as the height at which foliage grows from the ground, or the proportion of shrubs growing on deer-safe sites. The average number of clips observed for shrub shoots (Figure 2) also shows the same pattern. These patterns are statistically significant.

For tree seedlings (Figure 3), the impact of deer is also highest on the large offshore islands. Note that for redcedar, no seedlings were found on any of the islands, despite the presence of mature trees on most of them.

Deer impact on the ecology of the understory

The impacts of deer go beyond the static and visual modification of the vegetation landscape.

The age and size structure of shrubs and ferns is dramatically altered on deer-infested islands (Figure 4). For example, we found salal individuals of all sizes and ages in the absence of deer, but only large old individuals on deer-infested islands. Only insignificant numbers of juveniles were observed.

For huckleberry also, we observed shrubs of all size and age classes in the samples from deer-free islands; whereas, on deer-infested islands, we observed only very old, heavily browsed veterans side by side with tiny seedlings, or heavily browsed “bonsai” of unknown age.

Ferns account for a significant proportion of the ground cover on deer-free islands (Table 2) where we found mostly large adult individuals and only very few juveniles (Figure 4). Conversely, on deer-infested islands, more than 90% of the ferns encountered were tiny juveniles and there were few adults, all heavily browsed.

On deer-infested islands, the stress level estimated for salal and huckleberry is nearly 100% (100 and 89%, respectively) (Table 3). For the other plants, stress levels are also high.

Deer and birds

Population densities of bird species that forage or breed in shrubs, such as Rufous Hummingbird (*Selasphorus rufus*), Swainson’s Thrush (*Catharus ustulatus*), Orange-crowned Warbler (*Vermivora celata*), Fox Sparrow (*Passerella iliaca*), and Song Sparrow (*Melospiza melodia*) were 3–7 times lower on deer-infested islands than on deer-free islands (Table 4).

Squirrels and eggs

Predation rates of artificial nests on squirrel-infested East Limestone Island are several orders of magnitude larger than on squirrel-free Ramsay Island (Figure 5).

On East Limestone Island, predation rates are significantly higher in the spruce/hemlock habitat than in the habitat dominated by alder (Figure 6), and so are squirrel densities (Table 5). All the differences are statistically significant.

Discussion

The understory on deer-infested islands differs dramatically from the understory on deer-free islands. On deer-infested islands (Plate 2, left) the understory is open below 1.5 m from the ground, tree seedlings are heavily browsed, and shrub and fern biomass is significantly reduced. On deer-free islands (Plate 2, right) the understory is lush with a dense shrub and fern layer.

These preliminary results confirm that browsing by deer has caused profound changes in the structure of the vegetation. They also indicate that the arrival of the deer has dramatically altered the ecological processes at work in these forests:

- deer have depleted the biological diversity of the understory by eliminating many shrub species;
- deer have drastically reduced the foliage and woody biomass in the shrub layer, thereby reducing the quantity of these resources available in the food chain;
- browsing by deer has significantly altered the size and age distribution of surviving shrubs and ferns;
- little or no recruitment of juveniles, together with over-browsing of aging individuals, will lead to increasing impoverishment of the shrub layer in the short term; and
- the abundance of shrub-nesting or shrub-foraging birds is significantly reduced on deer-infested islands. (The results given in Table 4 have been confirmed by more anecdotal observations from other islands and by the results of the extensive land-bird surveys presented in Martin et al. 1995.)

Although severe on all deer-infested islands, the impact of deer varies with island size and is highest on large offshore islands with permanent deer populations. The reason for this is not clear yet. Possible reasons may be: (1) reluctance by young deer to disperse away from the most isolated islands with permanent deer populations, causing higher local densities (fence effect of Krebs et al. 1969; Crowell 1983), (2) lack of summer range on these islands compared to large main islands, which have high-elevation zones with good summer habitat for deer, resulting in lower overall pressure on the low-elevation zone, and/or (3) milder and drier weather conditions on eastern offshore islands, leading to better winter survival. These speculations will require new data for clarification.

In any case, our results suggest that the presence of deer has virtually eliminated most of the ecological function of the understory. Most of the standing shrub biomass has already been eliminated over large tracts of forest. The continuing overbrowsing of the aging shrub individuals that survive on deer-infested islands will likely produce relict populations made of "living dead."

When tree regeneration is considered, our anecdotal observations suggest that the presence of deer in old-growth forests strongly limits or suppresses the regeneration of redcedar. On the other hand, and more surprisingly, the cover of spruce and hemlock seedlings in the shrub layer is highest on deer-infested islands. This could be due to less competition for light and nutrients because of the elimination of the shrub cover or, more directly and exclusively, to the fact that browsing of seedlings by deer prevents them from growing, leading to an accumulation of small stunted spruce and hemlock in the shrub layer. These two interpretations are not mutually exclusive. How deer-induced changes in seedling stress and juvenile cover translate into adult tree recruitment is not clear yet. However, some of our unpublished results tend to indicate that increased spruce and hemlock recruitment could be a feature of deer-infested islands. Such questions will be solved only with additional data, as will the question of the consequences of the removal of the dense shrub layer on litter composition, soil stability, and the invasion of the understory by non-indigenous plants.

Beyond their potential impact on the long-term presence and abundance of cedar on the Islands, deer have already depleted many of the resources that the understory traditionally provided to people (e.g., materials, food, and medicine) and to the indigenous animals (e.g., food and nest sites for birds). Finally, when squirrels are present, they are a potential source of additional stress on breeding birds. Photographs of predation events obtained by automatic cameras monitoring artificial nests baited with quail eggs (Martin 1995), as well as the correlation between squirrel density and nest predation rate, indicate that squirrels are indeed the culprits on East Limestone Island. How far these results reflect predation patterns on real nests remains unknown, as does most of the impact squirrels have on the ecology of forests of Haida Gwaii.

In conclusion, it seems inevitable to say that the forests of Haida Gwaii are dramatically altered and impoverished by the presence of deer, and that this process of degradation is worsening with time.

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Table 1 *List of indigenous and most common introduced mammals on Haida Gwaii*

Indigenous terrestrial mammals	Introduced terrestrial mammals
dusky shrew	black-tailed deer
black bear	wapiti
marten	red deer[b]
Haida weasel	red squirrel
river otter	Canadian beaver
deer mouse (*P. maniculatus*)	roof rat
deer mouse (*P. sitkensis*)	muskrat
Dawson caribou[a]	raccoon

a = extinct
b = introduced c. 1920, extirpated c. 1944

Table 2 *Impact of deer browsing on plant cover (%) in the understory*

	Plant	Deer-free islands	Deer-infested islands
Shrubs and ferns	salal	43	<1
	red huckleberry	9	1
	sword fern	14	<1
Young trees	sitka spruce (juveniles)	1	15
	hemlock (juveniles)	<1	8
	redcedar (juveniles)	<1	0

Table 3 *Estimated amount of stress due to deer browsing in the 0–1.5 m layer (%)*

	Plant	Deer-free islands	Deer-infested islands
Shrubs and ferns	salal	0	100
	red huckleberry	0	89
	sword fern	0	18*
Young trees	Sitka spruce	0	60
	western hemlock	0	72
	redcedar	-	-

* = conservative value.

Table 4 *Comparison of bird abundance (number of pairs) on a deer-free island and on a similar area from a deer-infested island*

	Low Island—Deer free 9 ha	Reef Island—Deer infested 9-ha reference area
Rufous Hummingbird	5	2
Swainson's Thrush	3	1
Orange-crowned Warbler	5	2
Fox Sparrow	5	2
Song Sparrow	7	1

Table 5 *Index of squirrel abundance in spruce-dominated and alder-dominated habitat on East Limestone Island*

Squirrel abundance in conifer-dominated forests	Squirrel abundance in alder-dominated forests
two contacts/100 m	one contact/100 m

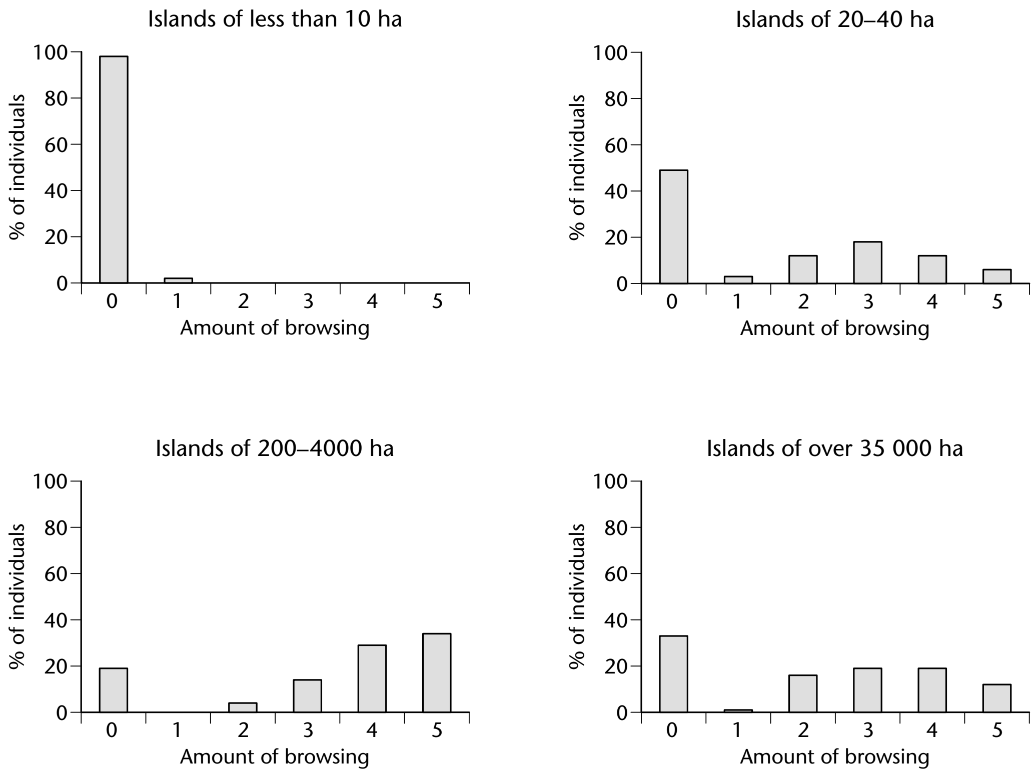

Figure 1 *Impact of deer browsing on salal in relation to island area. (0 = no browsing, 5 = very heavy browsing.)*

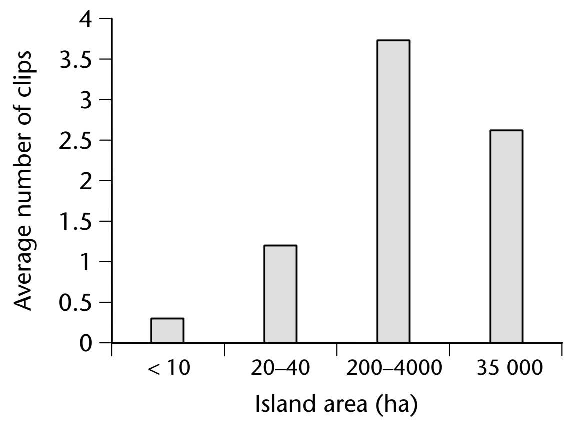

Figure 2 *Variation of the average number of clips observed per salal shoot in relation to island area.*

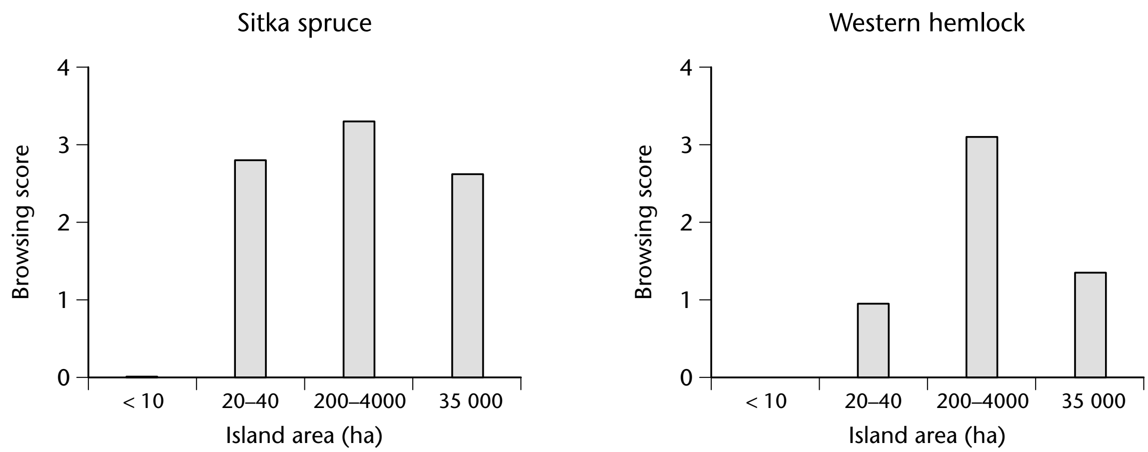

Figure 3 *Variation in the amount of deer browsing on tree seedlings in relation to island area. Note that no redcedar seedlings have been observed in the samples. (0 = no impact of browsing, 4 = very high impact.)*

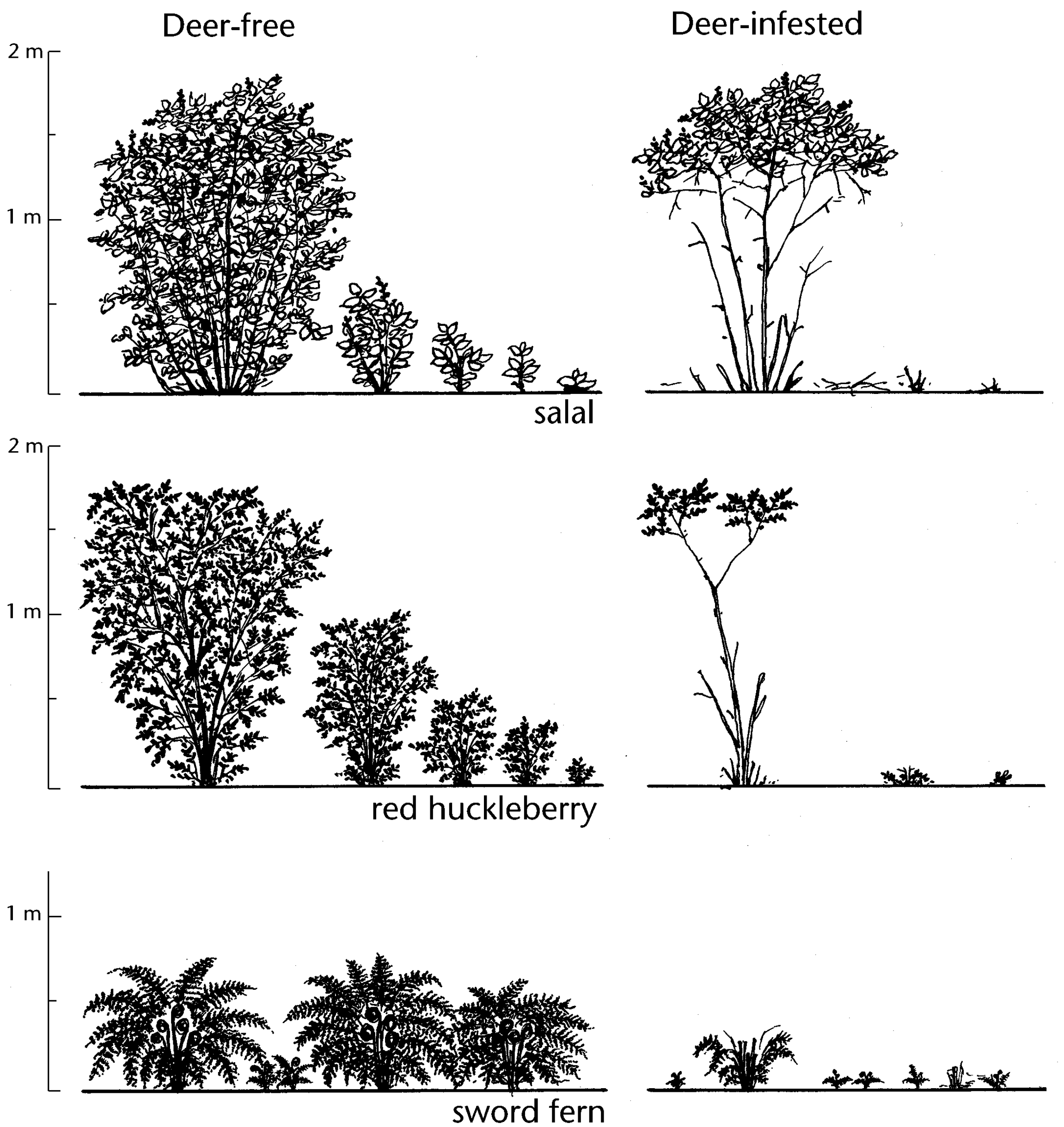

Figure 4 *Differences in plant size and plant age distribution between deer-free and deer-infested islands.*

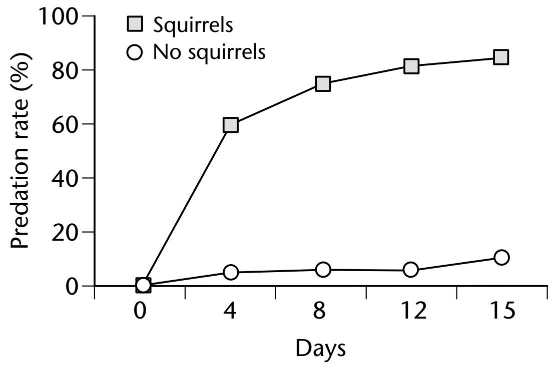

Figure 5 *Predation rate curve of artificial nests baited with quail eggs on an island with squirrels (East Limestone) and an island without squirrels (Ramsay).*

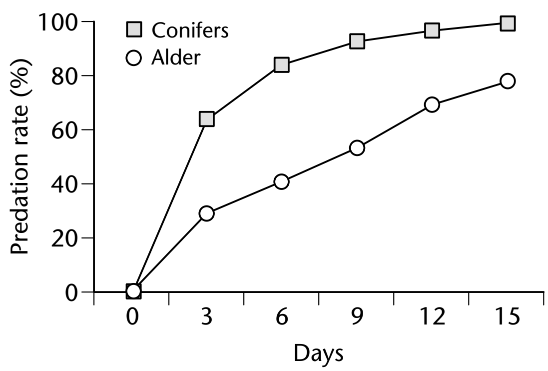

Figure 6 *Predation rate curve of artificial nests baited with quail eggs in conifer- and alder-dominated habitats on East Limestone Island.*