4 THE ENVIRONMENT OF HAIDA GWAII

4.1 About the Islands

Haida Gwaii is an archipelago of more than 200 islands located between Vancouver Island and southeast Alaska, 50–130 km off the northern mainland coast of British Columbia (Figure 1.1). The archipelago is scimitar shaped, and extends 250 km from north to south. Together, Graham and Moresby Islands constitute 90% of the nearly 1 million hectares that comprise the archipelago. These two main islands are narrowly separated by Skidegate Inlet and Skidegate Channel. Other large islands in the archipelago include Louise, Lyell, and Burnaby Islands off the east coast of Moresby Island, and Kunghit Island to the south of Moresby Island.

The landscape of the islands is extremely varied: it ranges from broad sand beaches and dunes on the east coast to the rocky, surf-battered west coast, and from muskeg lowlands on Graham Island to the rugged, strongly eroded Queen Charlotte Ranges of Moresby Island. The prevailing tranquil environment of Haida Gwaii is at times interrupted by dramatic natural processes—fierce storms, high-energy surf, floods, landslides, earthquakes, and windthrow—events that substantially modify the landscape and the ecosystems of the islands. In many ways, the archipelago is a microcosm of coastal British Columbia, but it has its own distinctive, and in some respects unique, natural and cultural heritage.

The lands and waters of Haida Gwaii support a rich cultural heritage. Archaeological evidence indicates continuous human presence by the Haida and their ancestors dating back 10 000–13 000 years. Today, seven main communities are located on the east and north coasts of Graham Island and on the northeast tip of Moresby Island. Tourism, forestry, and fishing are the main economic drivers. About 4500 people of varied ancestry, almost half of them Haida, currently live on Haida Gwaii.

Approximately 52% of Haida Gwaii's land base is currently within protected areas, including heritage sites and conservancies, Gwaii Haanas National Park Reserve and Haida Heritage Site, Naikoon Provincial Park, and the Vladimir J. Krajina Ecological Reserve.

4.2 Climate[6]

Haida Gwaii's climate is driven by the archipelago's proximity to the Pacific Ocean (all of the archipelago lies within 40 km of tidewater), its separation from the continent, and the combination of physiography and movement of moist air masses off the Pacific Ocean. The ocean moderates air temperatures on the islands throughout the year. Moreover, the mainland Coast Mountains and Hecate Strait provide protection and separation from cold winter and hot summer continental air masses, which only rarely reach the islands.

The prevailing flow of the jet stream from the open Pacific Ocean toward the east is responsible for most of the air masses that move over Haida Gwaii. Throughout the late spring and summer (mid May to mid September), the North Pacific High Pressure System creates relatively dry, occasionally sunny conditions over the islands. As the North Pacific High begins moving south in September, it is replaced by the Aleutian Low, which engenders the cloudy skies, heavy precipitation, and strong winds that are typical during autumn and winter.

These conditions create a cool temperate, humid to perhumid, oceanic type of climate. The mean annual temperature of tidewater stations is 7–8°C, and the ranges in daily, seasonal, and annual air temperature are all narrow. Fall and early winter are mild and very wet. Winter is cool but rarely cold, and rainy, with more snow at higher elevations. Snowpack along the coast is usually ephemeral, but more snow falls at

6 This discussion draws on data that were summarized for the reference period 1961–1990 (Table 5.2) and which were generated using Climate WNA (www.genetics.forestry.ubc.ca/cfcg/ClimateWNA/ClimateWNA.html), except for 1961–1990 temperature or precipitation normals from specific stations, which were acquired from Environment Canada records (http://climate.weather.gc.ca/ [2013]), particularly mean annual precipitation values referenced in Section 4.2.2. ClimateWNA extracts and downscales PRISM monthly data (Daly et al. 2002) and calculates seasonal and annual climate variables for specific locations based on latitude, longitude, and elevation. Initial development of the PRISM climate surfaces incorporated point data from climate stations, including stations on Haida Gwaii (Cape St. James, Sandspit, Tlell, Sewell Inlet, Tasu Sound, Masset CFS, Masset, Port Clements, Sewall Masset Inlet, and Langara). All stations are located in the CWHvh3 or CWHwh1 low-elevation variants. See Chapter 5 and Table 5.2 for summaries of climate in relation to biogeoclimatic units of Haida Gwaii.

higher elevations (especially above 600 m) and in the interior of the larger islands. Summer is cool and moist but with periodic warm, dry spells, especially on the leeward east coast. Summer cloud cover is very common, and fog occurs frequently.

4.2.1 Temperature

Mean annual temperature is fairly consistent at lower elevations due to the moderating effect of the ocean. It averages 7–8°C at low elevations everywhere, and declines with increasing elevation. Estimated mean annual temperature is slightly higher than 6°C for montane areas and slightly lower than 6°C for the subalpine.

Degree-days are the cumulative annual total of Celsius degrees that the mean daily temperature is above or below a certain threshold. Two common thresholds used are growing degree-days (>5°C) and chilling degree-days (<0°C). The average number of growing degree-days is greatest at low elevations throughout Haida Gwaii (i.e., 1340–1400), and declines to 1162 in montane areas and 1066 in the subalpine. The number of chilling degree-days is lowest at lower elevations (about 164) and increases with elevation (>230 for montane and >260 for subalpine areas). The frost-free period ranges from about 100 days in northern, higher elevations to more than 300 days at Cape St. James, which has one of the longest known frost-free periods in Canada (Williams 1968). Although the frost-free period and growing season on Haida Gwaii are long, the number of growing degree-days is low compared to southern and less oceanic parts of the British Columbia coast. Thus, the number of effective growing degree-days (Coligado 1981) is relatively even lower.

4.2.2 Precipitation

The Queen Charlotte Mountains cast a rain shadow on eastern Graham and Moresby Islands, which results in a decrease in annual precipitation from more than 3000 mm on some of the low-elevation windward slopes to <1500 mm on the eastern lowlands. Mean annual precipitation (MAP) from the east to the west side of the islands ranges from 1042 mm to 7445 mm (see Table 5.2).

The orographic effect of the Queen Charlotte Mountains creates a large disparity in precipitation between windward and leeward sides of the islands. The mountains force the wet air that moves in from the Pacific

Ocean to rise, cool, and deposit moisture as rain or snow on the western slopes. Most of the eastern, leeward side of the islands is in a moderate rain shadow. Where there are breaks in the mountain barrier, such as Skidegate Channel and the low pass between Newcombe and Sewell Inlets, moist air can penetrate and intensify precipitation at eastern localities. The northern and southern tips of the archipelago (Langara Island and Cape St. James) are scarcely influenced by orographic lifting or rain shadow effects; therefore, the amount of precipitation they receive is intermediate between the windward west (e.g., Tasu Sound) and leeward east (e.g., Tlell) sides of the archipelago.

Eastern Haida Gwaii is the driest region of the islands. Tlell and Sandspit have MAP of 1216 mm and 1359 mm, respectively (Environment Canada 2013[7]), and represent the drier, rain shadow extreme of eastern Haida Gwaii. The west side is much wetter, with MAP in excess of 3000 mm. There are two active weather stations in wetter (windward) areas—on Langara Island in the north and Cape St. James in the south—which report 1874 mm and 1542 mm MAP, respectively (Environment Canada 2013). However, neither station is influenced by the orographic effects that prevail throughout most of western Haida Gwaii. The Tasu weather station, with a west coast location strongly affected by orographic lifting, recorded MAP of 4218 mm over the period 1951–1980. MAP generally increases with elevation. In montane areas, MAP is >2500 mm; in the subalpine, it is more than 4000 mm. Precipitation strongly influences the distribution of biogeoclimatic units (see Chapter 5).

There are also strong seasonal differences in precipitation. Summer weather and climate are dominated by the North Pacific High, which results in northwesterly winds and less precipitation, compared with other seasons. Mean precipitation in the driest month (July) is only about 20% of that in the wettest month (October). The Aleutian Low dominates the winter weather and brings frequent strong southeasterly winds and heavy rains. The orographic effect is thus most pronounced during the wettest months.

Very little snow falls at coastal localities on Haida Gwaii, and it usually melts within a few days. Mean annual snowfall at lower elevations

[7] Climate normals for 1961–1990 were acquired from http://climate.weather.gc.ca/

ranges from 152 cm on the east side to 260 cm in wetter (west side) areas. Snowfall in the interior of the islands and at higher elevations is estimated at more than 300 cm annually for montane areas and more than 600 cm for the subalpine. Williams (1968) estimated that at elevations of 300–600 m, snowfall of 100–120 cm per month could occur in some winters, and the resulting snowpack would be deep and long lasting. Williams (1968) also stated that most winter precipitation falls as snow above 600 m in the subalpine/alpine zone.

4.2.3 Wind

Frequent strong winds are an important element of climate on Haida Gwaii. Regional winds are controlled by pressure gradients and storms associated with the Aleutian Low and the North Pacific High. As the Aleutian Low develops and intensifies in the fall, it produces a counter-clockwise circulation of surface winds during fall and winter storms. By spring, the Aleutian Low dissipates and the North Pacific High develops, which results in less cloud cover, less precipitation, and westerly winds during summer (Walker 2006). Wind speed averages 19 km/h at Sandspit and 31 km/h at Cape St. James. Wind speeds are higher during the fall and winter. Higher sustained wind speeds and gusts may be of greater ecological importance compared with average speeds, particularly when individual trees and stands are uprooted or snapped off. For example, the maximum recorded "gust speed" at Sandspit Airport is 164 km/h.

4.3 Physiography

The Haida Gwaii archipelago can be subdivided into three physiographic regions (Sutherland Brown 1968; Holland 1976): the Queen Charlotte Ranges, which form the rugged, mountainous southwestern region; the Skidegate Plateau, a partially dissected peneplain of the northwest–central region; and the Queen Charlotte Lowland—plains and low hills of the northeastern region (Figure 4.1). The following description of physiography is adapted from Sutherland Brown (1968).

The Queen Charlotte Ranges is the most mountainous of the three regions, with the highest peak (Mount Moresby) at 1148 m. These ranges extend from Rennell Sound on Graham Island to Cape St. James at the southern tip of Haida Gwaii. There are three groups of high peaks. The

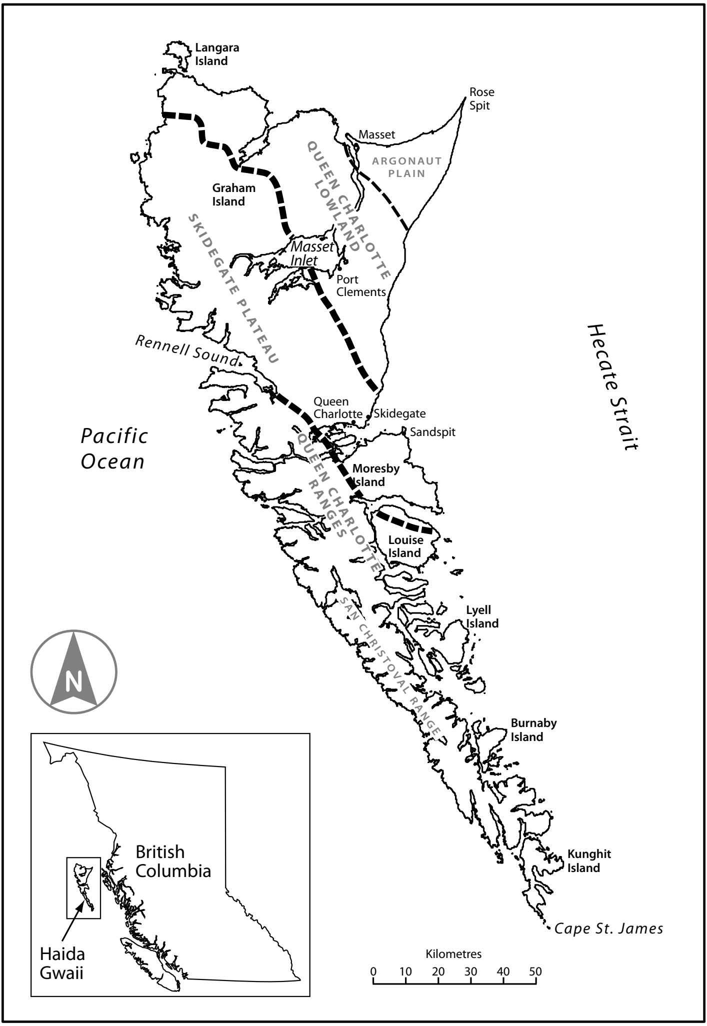


FIGURE 4.1 *Physiographic regions of Haida Gwaii (following Holland 1976).*

San Christoval Range extends linearly from Tasu Sound to Gowgaia Bay. A second group of high peaks occurs in a triangular area defined by Security Inlet in the north, Kootenay Inlet in the south, and Vertical Point on the east coast. The third group of high peaks, on southwestern Graham Island, extends from Kano Inlet to Skidegate Channel to Kagan Bay. The Queen Charlotte Ranges are extremely rugged, and include many cirques that were produced by intense alpine glaciation during the later stages of the Pleistocene. Cirques can be seen at a wide range of elevations, with some cirque basins near sea level along the west coast. Mountains up to 900 m elevation commonly have steep slopes with rounded summits; these were overridden by ice during the height of the Pleistocene glaciation. In contrast, mountains over 900 m elevation have steep, sharp, often Matterhorn-shaped peaks. This suggests that the maximum of the last continental glaciation did not extend above 900 m elevation on Haida Gwaii. The open Pacific coast is an abrupt, straight scarp that has been produced by the Queen Charlotte Fault. The ocean rapidly deepens to abyssal depths because there essentially is no offshore continental shelf flanking the west coast of Haida Gwaii.

The Skidegate Plateau extends down to sea level along part of both the west and east coasts, and from Pivot Mountain on Graham Island in the north to Skedans Bay on Louise Island in the south. Most of the plateau is about 600 m in elevation; it slopes down to about 300 m where it adjoins the Queen Charlotte Lowland, and reaches almost 800 m between Port Chanal and Tartu Inlet. The plateau is fairly well dissected, but the intervening, flat-topped ridges are a characteristic feature. Glaciation has broadened the valleys and rounded the edges of the plateau surface. The Skidegate Plateau is the most heavily timbered physiographic unit, and therefore the most important for forestry.

The Queen Charlotte Lowland encompasses most of the northeastern half of Graham Island and a small portion of Moresby Island around Sandspit. Most of the Lowland is below 160 m elevation. The Argonaut Plain, a subunit of the Lowland, is a large glacial outwash plain that lies northeast of a line drawn from Masset to Cape Ball. Both the Lowland and the Argonaut Plain are mostly poorly drained and are covered extensively with wetlands and scrubby forests. A remarkable feature of the Queen Charlotte Lowland is the wide sand beach along Graham Island's east and north coastline, which extends nearly continuously for more than 100 km from Tlell to Masset. The transport of granular materials by wave action (longshore drift) has formed prominent sand spits—Rose Spit on Graham Island and another at Sandspit on Moresby Island. Strong winds during dry summer weather have produced sand dunes, which commonly extend inland a few hundred metres behind the present-day beaches (Sanborn and Massicotte 2010).

4.4 Geology

The present landscape of Haida Gwaii is mainly a product of tectonic uplift and subsequent glacial, fluvial, and colluvial erosion and deposition. The islands were formed 20 million years ago when the Farallon Plate began to slide under the North American continent. This collision of tectonic plates led to the formation of a range of rugged mountains that rises from the ocean floor and stretches from Vancouver Island to southeast Alaska, including Haida Gwaii. The archipelago has been further shaped by other physical forces, including volcanic activity, erosion, sedimentation, and glaciations. Many prominent landforms, including fjords, U-shaped valleys, and cirques, are products of several glaciations; other landforms, such as floodplains, river terraces, fans, cones, and elevated wave-cut scarps formed during postglacial time (Barrie et al. 2006).

4.4.1 Bedrock geology

Bedrock exerts a major influence on ecosystem development and distribution, particularly in the perhumid hypermaritime. The nature of bedrock strongly influences site characteristics, including the extent of outcrop, the steepness and complexity of slopes, the physical (texture, coarse fragments) and chemical–nutritional nature of weathered materials and soils, and the type and frequency of mass wasting.

Haida Gwaii is part of the western Insular Belt system of the Canadian Cordillera. This system is comprised largely of volcanic and sedimentary rock, together with intrusions of granitic rock (Southerland Brown 1968; Holland 1976). The geology tends to be more complex to the south and uniform to the north. Sedimentary rocks of the Skonun Formation dominate the northeastern portion of Graham Island, where they are almost entirely mantled by thick deposits of sands and gravels, whereas volcanic rocks of the Masset formation dominate western Graham Island. Moresby Island is particularly diverse, with a complex assemblage of volcanic, sedimentary, and igneous rocks (Sutherland Brown and Yorath 1989).

Lewis (1982) and Lewis and Kehm (2007) group bedrock formations into several ecologically significant groups based on dominant lithology (Table 4.1). Volcanic rocks that include rhyolite, andesite, and basalt are placed into two groups: "hard" and "soft" categories. The hard volcanics are typified by the thick, massive basalts of the Karmutsen Formation, which is most extensive in the Queen Charlotte Ranges of Moresby Island. Although these volcanics can be rich in nutrient bases, the rock is very resistant to weathering, produces limited surficial material, and releases nutrient elements slowly. The softer volcanics, mainly of the Masset Formation, which are widespread and occur mostly north of Rennell Sound and the Yakoun Formation, have been extensively fractured and chemically weathered. The productive forests of the Skidegate Plateau and Queen Charlotte Ranges are underlain mainly by the soft volcanics that weather much more readily than the hard volcanics.

Sedimentary rocks underlie most deep surficial deposits (glacial and marine) on the Queen Charlotte Lowland. Minor areas of sedimentary rocks occur on the Skidegate Plateau and Queen Charlotte Ranges. Where limestone occurs, it is associated with distinctive flora and productive forest, often growing on shallow soils. Intrusive bedrock is restricted largely to the Queen Charlotte Ranges, where it and the hard volcanics tend to support low-productivity forest and sloping bogs. Granitic plutons intrude the core of the Queen Charlotte Ranges and appear as batholiths south of Rennell Sound and along the southwest coast of Moresby Island.

Of special interest on Haida Gwaii are karst landscapes formed from the soluble limestones of the Kunga Group of sedimentary rocks (Sutherland Brown and Yorath 1989). These rocks underlie 26 000 ha of Haida Gwaii (Griffiths and Ramsey 2009). In these karst areas, slightly acidic subterranean drainages enlarge cracks and fractures in the bedrock, creating a variety of characteristic landforms, such as sinkholes, arches, and caves. Karst landscapes require special management because above-ground activities such as logging or road building can alter drainage and damage karst (Gillieson 1996). In 2006, Haida Gwaii became the first Forest District in British Columbia to legally protect most karst features during forestry operations.

4.4.2 Surficial geology

Surficial material includes all deposits of unconsolidated mineral or organic materials that overlie bedrock (Soil Classification Working Group 1998). Surficial deposits form the parent materials of soils, and thus help define the physical, chemical, and biological nature of ecosystems. Surficial materials have been transported, deposited, and modified over time by glaciation, gravity, water, wind, living organisms, and other natural or anthropogenic disturbances. Where these materials are <1 m thick, they are termed veneers; blankets are thicker than 1 m. Most Haida Gwaii forests occur on morainal, colluvial, and upland organic deposits. Fluvial materials are localized along rivers and streams, and aeolian materials are localized behind sand beaches. Marine and lacustrine materials (including glaciomarine and glaciolacustrine) and non-transported, residually weathered bedrock (saprolite) are localized on Haida Gwaii (Barrie et al. 2006).

Morainal deposits On Haida Gwaii, surficial material that was transported and subsequently deposited by glacier ice (also called glacial till) is widespread on hillslopes and plateau surfaces but is less extensive on ridges and hilltops. Till blankets are much less widespread than on the British Columbia mainland (inland of the outer coast), where more uniform blankets commonly occur over large areas. The nature of the morainal deposit (texture, compaction, coarse fragment content) varies considerably depending on its origin and subsequent weathering. Although a small but noticeable component of till is transported a considerable distance (erratics), the bulk of the till is relatively local; consequently, its character is strongly influenced by the underlying bedrock.

Colluvial deposits Colluvial deposits result from the downslope movement of materials under the influence of gravity. Colluvium occurs mostly as veneers on steep, upper to mid slopes, and as much thicker blankets on lower slopes and toe slopes where fan, cone, or apron

TABLE 4.1 *Bedrock formation groups based on dominant lithology (modified from Lewis and Kehm 2007)*

Bedrock group	Formations	Rock types: Major	Rock types: Minor	Structure	Acidity	Nutrient supply	Texture	Weathering	Rock outcrop	Permeability	Ecological implications [a]: Wet lee side (CWHwh) trends	Ecological implications [a]: Very wet windward side (CWHvh) trends
'Hard' volcanics	Karmutsen Tow Hill Sills Migmatite Plutons Unnamed diabase	Basalt (flows, pillow lavas)	Breccia Tuff Volcanic sandstone Limestone Migmatite Diabase	massive	less acidic	intermediate	silty	medium	common	low	Extensive matrix zonal forest (Hw, Ss, Cw) with component of rock outcrop associations	Extensive cedar-dominated (Cw, Yc) forest, shore pine common, productive HwSs forest restricted to steep slopes
'Soft' volcanics	Masset Yakoun Ramsay I Gust I Undivided volcanics Unnamed marine sedi-mentary and volcanics	Basalt Andesite Rhyolite Agglomerate Tuff Volcanic sandstone	Siltstone Shale	fractured	less acidic	good	silty	medium–rapid	rare	medium	Overwhelmingly zonal matrix forest (Hw, Ss, Cw); no rock outcrop	High proportion of HwSs productive forest similar to zonal, east-side forests
Granitics (Plutons)	San Christoval Kano Chaatl Inlet Burnaby I Unnamed orthogneiss	Diorite Granodiorite	Granite Gneiss	massive	more acidic	poor	sandy	slow	abundant	low	Complex of zonal forest and rock outcrop associations	Extensive blanket bog and bog woodlands; productive forest very limited

Fine clastic sedimentary	Haida Bearskin Bay Sandilands Peril Hotspring I Tarundl Slatechuk Skidegate (?)	Siltstone Shale	Sandstone	bedded	less acidic	good	silty–clayey	rapid	rare	medium–low	Complex of zonal forest and richer associations	
Coarse clastic sedimentary	Haida Honna Moresby Group White Point Beds	Sandstone Conglomerate Arkose	Siltstone	bedded	less acidic	intermediate	sandy	medium	common	medium	Complex of zonal forest and rock outcrop associations (linear ridges)	
Calcareous clastic sedimentary and meta-sedimentary	Kunga – Member 2 Maude Longarm	Argillite Shale Siltstone Greywacke	Sandstone	bedded	calcareous	good	silty	rapid	rare	medium	Predominantly richer associations; outcrops essentially absent	Predominantly richer associations with productive forest (HwSs); steep slopes commonly unstable with gullies and slides; bogs absent
Carbonate sedimentary	Kunga – Member 1 Sadler Limestone	Limestone	Marble Calcareous sedimentary rock	massive	calcareous	good	silty	medium	abundant	high	Distinctive limestone associations, including species not/rarely seen elsewhere; extensive bedrock outcrops and Folisolic soils	Productive forest (Cw, Ss, Hw) and distinctive limestone associations and species; strong contrast with adjacent bedrock types; bogs absent
Thick surficial	Quaternary Sediments	Consistent blankets of morainal, glaciofluvial, and other surficial materials		N/A [b]	less acidic	variable	variable	rapid	nil	variable	The effects of bedrock are masked by the thick cover of unconsolidated materials	

[a] Cw=western redcedar; Yc=yellow-cedar; Hw=western hemlock; Ss=Sitka spruce.

[b] N/A: Not applicable.

landforms occur. The process of colluvial deposition is active; these materials are loose and non-cohesive compared to morainal deposits, and are well-drained and well-aerated. If the colluvium is derived from bedrock, it is gravelly, rubbly, or even blocky with few fine particles. Colluvium derived from morainal materials has properties that reflect those of the till from which it was derived; it is referred to as "colluviated morainal," as in this report.

Fluvial or alluvial deposits Materials that are transported and deposited by streams and rivers are termed fluvial or alluvial. Fluvial materials differ in texture and coarse fragment content depending on the sedimentation environment. Exposed fluvial profiles invariably display layers of different textures, which indicate a deposition history of fluctuating flows, velocities, gradient, and sediment origin.

Fluvial material is most common in or near present-day riparian systems. Fluvial material that was deposited from glacial meltwater streams during the last glacial period is termed glaciofluvial. Thick glaciofluvial blankets underlie the Argonaut Plain, less extensive areas of the Queen Charlotte Lowland, and localized areas within some of the larger valleys (e.g., Skidegate and Mosquito Lakes).

Aeolian deposits Aeolian materials are transported and deposited by wind, and include both dune sands and silty loess. Dune sands are non-cohesive, well- to rapidly drained deposits that are very sensitive to disturbance. Dune sands may be active or inactive depending on the degree of colonization and stabilization by plants. Dunes are most extensive behind the beaches on northeast Graham Island, but small areas of dunes also occur behind smaller sand beaches. Silty loess does not occur on Haida Gwaii.

Marine and lacustrine deposits Marine and lacustrine materials include silts and/or clays that have settled out of suspension in quiet waters (in oceans or lakes, respectively) or accumulated as coarser beach materials (sand or gravel) along shorelines. Due to isostatic rebound since the last glaciation, glaciomarine materials occur inland and at elevations above present-day sea level along the British Columbia coast. These materials appear to be very limited on Haida Gwaii.

Only the coarser beach deposits are well known on Haida Gwaii; they are extensive and occur as a series of curvilinear ridges and swales that are parallel (or sub-parallel) to the coastline on the Argonaut Plain and on the beach plain behind the community of Sandspit. The strongly contrasting, well-drained sandy beach ridges and poorly drained intervening depressions produce a distinctive vegetation pattern of productive forest and open or wooded wetlands.

Organic deposits Organic surficial materials, which by definition contain at least 30% organic material by weight, result from vegetation residues that accumulate faster than they decay. A cool and moist climate must prevail for this process to occur. Regional climate is the overriding factor that controls the accumulation of organic matter, but other factors such as disturbance regimes (windthrow, colluvial action), microclimate, and local edaphic conditions (e.g., drainage) are also important.

Organic deposits include both upland and wetland forms. Folic materials accumulate from forest litter under freely drained conditions on upland sites. Wetland organic materials, including both peat and organo-mineral muck, accumulate in poorly drained conditions where the absence or scarcity of oxygen greatly restricts decomposition. This occurs in bogs, fens, swamps, and marshes.

On the Queen Charlotte Lowland, most organic materials occur as peat in the extensive poorly drained bogs and fens. On the Skidegate Plateau and in the Queen Charlotte Ranges, wetland organics occur in poorly drained basins and depressions, and on flats and toe slopes. Upland organic deposits also occur locally throughout the Skidegate Plateau and Queen Charlotte Ranges, commonly on ridges and knolls, as well as on mid to upper, moderate to steep slopes.

Bedrock Outcrops of rock covered by <10 cm of mineral or organic soil are considered to be bedrock. Bedrock is also considered to be "nonsoil," although on Haida Gwaii, the cool, moist climate allows almost all such substrates to support some rooted vegetation. Within forested areas, bedrock outcrops are not extensive since all but the steepest rock is usually covered by a layer of upland (folic) organic material.

4.5 Soils

Soils provide the medium for plant growth and, in combination with climate, the inherent nature of a soil is the primary determinant of the ecosystems described in this guide (see Appendix 12 for descriptions of common Haida Gwaii soils). Key soil properties that affect the nature and distribution of forest ecosystems include rooting depth, acidity, nutrient supply, site stability, and water holding capacity. In the hypermaritime climate, it is more often the ability of a soil to shed excess soil water rather than store soil water that promotes higher forest productivity.

4.5.1 Zonal soils

The term "zonal site" refers to an average, moderately well-drained, mid-slope site that most directly reflects the influence of the regional climate, and that consequently can develop climatic climax or zonal ecosystems. The zonal soils that develop on zonal Haida Gwaii sites are mainly the product of two soil-forming processes: podzolization and humification.

Podzolization, which is engendered by the cool, wet Haida Gwaii climate, is characterized by the intense weathering of parent materials and the strong leaching of bases under the acidic conditions associated with coniferous forest and ericaceous vegetation. In freely drained mineral surficial materials (typically morainal and colluvial), these processes produce a range of Podzol soils that have the following attributes in common:

a) development of thick, orange to dark reddish-brown podzolic Bf or Bfh horizons that are enriched with iron, aluminum, and organic compounds but are depleted of bases/cations;
b) formation of strongly leached, greyish, upper mineral horizons (Ae) in parent materials containing quartz; and
c) development of acidic, continually moist, surface organic horizons (LFH, humus, or forest floor) that are commonly 10–30 cm thick, are classified as a Humimor or Resimor Humus Form, and contain the bulk of available nutrients.

Over sloping bedrock or mineral soils, zonal vegetation can also be supported by upland organic soils that result from humification over prolonged periods. Thick accumulations of forest floor on zonal sites on Haida Gwaii result from the influence of climate on decomposition (of acidic, nutrient-poor litter, mostly from conifers and bryophytes), the resulting humification, and the lack of stand-replacing fires. This is particularly important in the hypermaritime climate but is much less a factor in the drier east-side climate. Organic soils called Typic Folisols are characterized by >40 cm thick LFH horizons over mineral soils, or at least 10 cm thick over bedrock. In Folisols, roots are almost entirely restricted to the surface organic horizons; consequently, ecosystem nutrient cycling may be influenced very little by underlying mineral soil horizons.

Over time, thick accumulations of organic material on zonal sites can cause a negative feedback whereby drainage is impeded, especially if *Sphagnum* mosses occupy the forest floor. Cemented horizons can also develop in the strongly leached mineral profile, which further restricts drainage. In both cases, tree roots are increasingly limited to upper aerobic organic horizons, and stand productivity is reduced due to increasingly limited reserves of available nitrogen and phosphorus. Strong disturbances, such as windfall and mass movements, can counteract humification if they result in the mixing of organic and mineral soil horizons, disruption of cemented horizons, and creation of complex micro-topography. The resulting improved drainage and aeration, accelerated decomposition, and greater nutrient availability allows more productive forests to re-establish (Green 1989; Banner et al. 2005; Alaback et al. 2013).

4.5.2 Other common soil types

Soil development on azonal sites is influenced primarily by drainage, which is in turn controlled by parent materials, topography, and development of soil cementation. Soils of drier, well-drained ecosystems on ridge crests and steep, upper slopes are usually Folisols or shallow Podzols that developed directly over bedrock or in shallow colluvial or morainal materials. Humus forms are Humimors and Hemimors. Bedrock type can greatly influence soil development, fertility, and species composition and vigour on such sites. Folisols overlying limestone bedrock are noticeably more productive than other bedrock types. This is a consequence of rapid internal drainage through karst features and lower soil acidity/higher calcium (Ca) concentrations that results from the ongoing weathering of carbonates.

Moist to wet, highly productive forest ecosystems develop on well-aerated sites with abundant water, nutrients, and active nutrient cycling and decomposition. Such sites include active alluvial landforms, fans, and lower colluvial or colluviated morainal slopes. Active geomorphic processes, including repeated fluvial/alluvial erosion and deposition, and soil mixing from colluvial action and windthrow, also characterize many of the more productive forest ecosystems. Typical soils on active fluvial landforms are Brunisols and Regosols with Mormoder and Mullmoder humus forms. Podzols with Humimors characterize older, inactive fluvial landforms. Gleyed Ferro-Humic Podzols, Dystric Brunisols, and Folisols with Humimor, Hydromor, and Mormoder humus forms support moist, rich ecosystems on colluvial and colluviated morainal deposits.

Poorly drained Gleysols and Organic soils (Mesisols, Humisols) support wet, low- to medium-productivity scrub and swamp forests on flat or depressional terrain, where a high water table results in poor soil aeration and shallow rooting. Cemented soil horizons often occur in these poorly drained soils (Sanborn and Massicotte 2010). Lower productivity is associated with stagnant water regimes where there is little or no lateral water flow through the soil.

Wetlands with soils that are saturated to or near the ground surface for most of the year are commonplace on Haida Gwaii, especially on the Queen Charlotte Lowland and the hypermaritime west coast. All of the major wetland classes described in Chapter 7—bogs, fens, swamps, and marshes—can be found on the Lowland, whereas blanket/slope bogs characterize the hypermaritime. Mesisols 40–200 cm thick, usually dominated by sphagnic peat, dominate in the bogs. Bog soils are very acidic and scarcely influenced by seepage from surrounding mineral terrain/soils, though the shallowest sloping bogs on the west coast undoubtedly experience some mineral seepage. It appears that most fen soils are Mesisols and Humisols that consist of non-sphagnic (usually sedge) peat. Gleysols and Terric subgoups of Organic soils are more typical of swamps and marshes. The fens, swamps, and marshes are all less acidic and have a higher nutrient availability than the bogs.

4.5.3 Nutrient analysis of forest soils

Accelerated weathering and aging of soils in oceanic climates can lead to deficiencies in phosphorus, which can eventually supersede nitrogen as the regulator of biological activity (Wardle et al. 2004). Chemical analysis indicates that soils of Haida Gwaii are low in available phosphorus (P) and high in organic matter, iron (Fe), and aluminum (Al) (Sanborn and Massicotte 2010) compared to soils from central and eastern Vancouver Island. Soils that develop on hard igneous bedrock are particularly nutrient-poor because of slow-weathering and low concentrations of P, potassium (K), magnesium (Mg), and Ca. Volcanic bedrock and limestone have more of these essential elements and are more easily weathered; consequently, they support more productive forests (Heilman and Gass 1974; Kranabetter and Banner 2000). Inorganic P concentrations are commonly low in acidic Podzols because P ions react with Fe and Al to form insoluble compounds (Preston and Trofymow 2000). In many coastal ecosystems, soil organic P concentrations and carbon:phosphorus ratios can be better indicators of nutrient status than nitrogen levels (Kranabetter et al. 2005). Nitrogen availability is closely linked to P status of soils. Foliar analysis has also suggested secondary deficiencies of K or Mg in coastal soils, depending on tree species and site type (Kranabetter et al. 2003).

4.6 Vegetation

The plants of Haida Gwaii are of great scientific interest. In addition to common, widespread, coastal, boreal, and montane species, the flora contains taxa at or near the southern or northern limit of their ranges, and others that have disjunct populations on the islands. Still others are relics of a northward migration that preceded or occurred during the post-glacial, warm, dry, Hypsithermal period. A group of endemic taxa forms a major part of the biological evidence for a Pleistocene glacial refugium on the islands (Ogilvie 1989; Schofield 1989).

The plant cover of Haida Gwaii is a tapestry of forests and non-forested wetlands, from maritime to high-elevation communities (Calder and Taylor 1968; Pojar and Broadhead 1984; Banner et al. 1989; Golumbia 2007; Pojar 2008a). Vascular plant geography is covered thoroughly in Calder and Taylor (1968), Taylor (1989), and Cheney et al. (2007). Bryology on Haida Gwaii is summarized by Schofield (1989) and Golumbia and Bartier (2004). Brodo (1995) provides preliminary information about the lichens. Stein and Gerrath (1969) conducted an exploratory survey of freshwater algae of Haida Gwaii. Kroeger et al. (2012) provide a treatment of mushrooms on the islands.

4.6.1 Forested vegetation

Haida Gwaii's forests are overwhelmingly comprised of conifers, which are well suited to the prevailing cool, wet climate and cool, wet, acidic and nutrient-poor soils. Western hemlock, western redcedar, and Sitka spruce dominate the closed coniferous forest at lower elevations, while mountain hemlock and yellow-cedar gain importance at higher montane to subalpine elevations. Prior to the logging of the last century, the lower-elevation coniferous forests were mostly old; now there is a much greater range of successional stages. Yellow-cedar and mountain hemlock, along with shore pine (*Pinus contorta* var. *contorta*), join western hemlock, western redcedar, and Sitka spruce in lower-elevation, often boggy hypermaritime forests. Lower subalpine forests of closed mountain hemlock and yellow-cedar give way to increasingly open, park-like stands at higher elevations, above which the forest is replaced by treeless alpine.

Deciduous forests are very localized on the islands. Seral stands of the sole deciduous tree species, red alder (there is a single occurrence of black cottonwood [*Populus trichocarpa*] at Yakoun Lake), are best developed on river floodplains and low terraces, but they also occupy recent landslides and fan deposits, and occur in some logged-over areas and along many road rights-of-way. Alder woods also occur along some sea beaches and on lake margins.

Ericaceous species dominate the shrub layer on all but the richest sites at most elevations. In the submontane and montane, this includes blueberries/huckleberries (*Vaccinium* spp.) and salal (*Gaultheria shallon*); increasingly in the subalpine and alpine, heathers become dominant. Ferns and herbs no longer provide much cover due to the browsing of introduced deer; mosses provide a nearly continuous cover on the forest floor.

Chapter 6 provides a detailed classification and description of the forested ecosystems of Haida Gwaii.

4.6.2 Non-forest vegetation

Wetlands Wetland communities are among the most conspicuous features of Haida Gwaii vegetation (see Banner et al. 1988). The wetland classes that are widely recognized by ecologists and are generally familiar to many people are bog, fen, marsh, swamp, and shallow waters (MacKenzie and Moran 2004).

Flat and raised bogs, which are supported by the most acidic wetland soils, cover extensive areas of the Queen Charlotte Lowland. Slope or blanket bogs are especially widespread on the windward Queen Charlotte Ranges, where in some areas they are more or less continuous from sea level to alpine. Bogs are typified by a considerable diversity of forms and species, including stunted, shrubby conifers, evergreen-leaved shrubs, several graminoids, and *Sphagnum* peat-mosses, along with numerous ponds, rills, and streams.

Fens also have peaty soils but are somewhat less acid and more nutrient-rich than bogs, and their vegetation is dominated by graminoids, deciduous shrubs, or patchworks of graminoids and shrubs. Marshes are also relatively nutrient-rich, and they occur on mineral sediments and support strictly herbaceous vegetation that is emergent from standing water. Sedge marshes are the most common marshes on Haida Gwaii. Fens and marshes are localized along flowing water and lake margins and are rarely extensive, with the notable exception of an area known as the "Pontoons" at the head of the Tlell River.

Swamps are wooded or forested wetlands, rich in minerals and nutrients, but with moving rather than stagnant water and mucky soils that are sufficiently aerated to support tall shrubs and trees. Conifer swamps are common on Haida Gwaii but are usually localized and do not dominate the landscape as do bogs. Dominant tree species are western redcedar and Sitka spruce, usually with a sub-canopy of western hemlock; the forest sometimes includes red alder, with yellow-cedar at higher elevations. Skunk cabbage (*Lysichiton americanus*) is a characteristic understorey species of swamps, as are the snake liverwort (*Conocephalum conicum*) and selected sphagnum species suited to less acid substrates.

Maritime communities Maritime terrestrial vegetation occurs on a variety of tidelands and uplands between the forest and the sea. Calder and Taylor (1968) describe the vegetation that occupies a range of maritime communities, including sand and shingle beaches, rock and cliff habitats, and salt marshes. The authors also differentiate coastal sites strongly affected by salt spray.

High-elevation communities Heaths that have a high cover of dwarf evergreen shrubs (various mountain-heathers and crowberry [*Empetrum nigrum*]) dominate much of the alpine and the openings within the subalpine parkland mosaic of tree clumps and gaps. Herbaceous alpine meadows support a wide variety of grasses, sedges, and vigorous forbs. Although these meadows are less extensive than the heaths, their lush growth distinguishes the alpine of Haida Gwaii from that of the mainland Coast Ranges and mountains of Vancouver Island. Alpine areas underlain by limestone (e.g., Takakia Lake) are especially lush with an exceptional diversity of species. High-elevation rock outcrops, cliffs, boulder fields, talus slopes, wet runnels and gullies, and avalanche tracks have a discontinuous, sparse plant cover, but these rocky habitats support a diverse flora, which includes many of the rare vascular plant species of Haida Gwaii. True alpine vegetation occurs above 800 m elevation and is concentrated in three areas: southwestern Graham Island, north-central Moresby Island, and the San Christoval Range south of Tasu on Moresby Island.

Chapter 7 provides a detailed classification and description of many of the non-forested ecosystems of Haida Gwaii.

4.7 Disturbance and Change

4.7.1 Natural disturbance

Natural disturbances on Haida Gwaii include windthrow, mass movements, floods, snow avalanches, earthquakes (some followed by tsunamis), insects and disease, and, rarely, wildfire.

Wind is a major disturbance factor, but most windfall is endemic, which results in relatively small canopy gaps, often formed by the stem breakage of individual or a few trees. Larger-scale stand-replacing blowdown with root throw occurs sporadically and more often on specific, exposed, topographic positions, where it creates larger forest openings. Damaging winds generally come from the southeast and occur in the fall and winter. Catastrophic or stand-replacing storms probably occur every 100–200 years (Alaback et al. 2013), though smaller blowdown (<5 ha) may occur much more frequently.

Mass wasting and shifts in stream channels are dominant geomorphic processes on Haida Gwaii, especially in mountainous terrain, and will continue to be so (Gimbarzevsky 1988; Barrie et al. 2006). Mass movements include debris flows, debris torrents, slump earth-flows, rock falls, and rock slides. These movements are widespread on the islands, especially on steep hillslopes with thin veneers of mineral or organic soils. Tectonic activity and the prolonged rainfall events and wind of the hypermaritime environment contribute to the relatively high rates of instability. Although most mass movements are small, individual slides can affect relatively large areas, and the cumulative effect of numerous small slides over a large area can be substantial (Banner et al. 1989; Schwab 1998; Jagielko et al. 2012). The combination of shallow soils, frequent large rainstorms, and rugged topography also engenders periodic intense flooding events, which help define the structure and dynamics of stream systems on the islands.

Insects and disease fungi impacts on Haida Gwaii's forests have essentially remained at background levels since 1850—with some notable exceptions, including the recent outbreaks of blackheaded budworm (*Acleris gloverana*) and hemlock sawfly (*Neodiprion tsugae*) (Turnquist et al. 1998). Several outbreaks of green spruce aphid (*Elatobium abietinum*) have occurred since the insect was first recorded on Haida Gwaii in 1961 (Engelstoft and Bland 2002), which has resulted in the defoliation and sometimes mortality of Sitka spruce in riparian areas, especially along the east coast of Graham Island. Defoliating insects, needle diseases, dwarf mistletoe, root rots, and stem rots all play direct and indirect roles in disturbance dynamics. In particular, they can kill or weaken individual trees and precondition them to stem breakage and windthrow (Alaback et al. 2013).

Historically, natural fire has played only a minor role in the forest ecology of Haida Gwaii. Parminter (1983) reported that from 1940 to 1982, only four lightning-caused fires were recorded for the archipelago, none of which exceeded 0.1 ha. The history of older lightning-caused fires is poorly known. Pearson (1968) found evidence of "forest fires of note" in 1757 and 1857. Pearson's 1857 fire is the same Tlell fire reported by Dalzell (1973) (see Section 4.7.2). Prior to European settlement, most forests were evidently uneven-aged and not of fire origin, as is the case for most rainforests of coastal British Columbia (Daniels and Gray 2006).

The low frequency of large-scale, stand-destroying disturbances has, on productive sites, resulted in extensive old-growth forests that are characterized by large trees, substantial accumulations of biomass and coarse woody debris, and a diversity of associated habitats (Pojar and MacKinnon 1994; Lertzman et al. 1997; Alaback et al. 2013).

4.7.2 Anthropogenic disturbance

Paleobotanical studies indicate that Haida Gwaii's forests "have existed in essentially their present form for the last 5500 years or so, with the only significant natural change since then being the increased importance of red cedar during the past three millennia" (Mathewes 1989). Most of the apparent human-caused change in Haida Gwaii's forests occurred after 1850. During the pre-1850 period, when only the Haida occupied the islands, human impacts on terrestrial ecosystems were likely comparatively minor. Selective single-tree harvesting of western redcedar by the Haida likely mimicked the natural gap dynamics of the coastal forest. However, the Haida's occupation of the islands for at least 10 000 years, with populations perhaps as high as 20 000 (Fedje and Mathewes 2005), undoubtedly had an impact on native vegetation in and around villages, on shorelines and tidelands, and on selected species that were used as food, as medicine, or in technology (e.g., western redcedar, western yew [*Taxus brevifolia*], Sitka spruce). It has been suggested that forests dominated by western redcedar along the Yakoun River (and elsewhere) may reflect centuries of Haida management.

The role and extent of fires set by Aboriginal peoples on Haida Gwaii remains uncertain. However, reports of burning by Aboriginal peoples along Skidegate Inlet (Turner 1999) suggest that burning was practised, especially near villages and in drier eastern areas, where charcoal in soil profiles and forest age class structure suggest a history of burning.

There are several large areas of human-caused fires on Haida Gwaii. Dalzell (1973) reported that a large fire burned from Miller Creek to Masset around 1840. (Different sources report that this fire occurred in different years.) It is unclear how that fire started, but the thrifty second-growth forest of western hemlock, western redcedar, Sitka spruce, and shore pine that followed is very different from the original old-growth redcedar–hemlock stands. Some fires, especially along the east coast, were probably related to land-clearing by settlers. Others were probably escaped slash fires that burned after logging in the 1940s and 1950s, including a large intense fire that burned nearly 5000 ha around Skidegate Lake. Stand-replacing fire could have been more frequent than previously believed in the CWHwh1 in the Queen Charlotte Lowland (N. Reynolds, forestry consultant, pers. comm., Mar., 2013).

European settlement on Haida Gwaii started around 1860, with sporadic homesteading and townsite development related to whaling, fishing and processing, mining, logging and sawmilling, and cattle ranching. These developments and settlements have remained rather small but locally have had a substantial "ecological footprint." Industrial logging commenced in the early 1900s, intensified during the two World Wars, expanded and became increasingly mechanized in the 1950s and 1960s, peaked in 1985, and continues to the present, but at lower rates of harvesting.

Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) were introduced to the islands in the early 1900s. In the absence of large predators, the deer greatly increased in numbers and spread throughout the islands by the 1960s. Their browsing severely impacted the vegetation of Haida Gwaii (see "Impacts of introduced species," below).

Impacts of logging

The most dramatic changes to forests during the last century have resulted from logging, including early clearing, firewood cutting, hand-logging, and A-framing, and later, extensive clearcutting. Logging can have serious environmental impacts on hydrology, fish and wildlife populations, slope stability, and visual quality. For the most part, however, the plant species composition of Haida Gwaii's forests has not changed permanently or significantly (at the landscape scale) due to logging. After the initial cutting, the forests quickly regrew, and secondary succession involved mainly the same tree and understorey plant species as those found in the old-growth forests, but in different proportions. The most dramatic changes to species composition and abundance has been in the epiphytic (communities on tree trunks and branches) bryophyte and lichen communities, which take much longer to re-establish after logging than do terrestrial plant communities (Lesica et al 1991; Price and Hochachka 2001; Banner and LePage 2008). Following the few large, relatively intense post-logging slash fires of the 1940s and 1950s, regeneration to conifers was similar to unburnt clearcuts except that there was a much higher proportion of Sitka spruce. There are localized exceptions where pioneering red alder occupied disturbed areas with exposed mineral soil or parent materials, similar to the primary succession that occurred on bare surfaces (Smith et al. 1986).

Some early ground-based logging, where creeks were used as skid roads (e.g., Two Mountain Creek), destabilized channels and fluvial deposits, and caused considerable erosion and the initiation of seres dominated by red alder and deciduous shrubs. Conventional clearcut logging since the 1940s, particularly because of its attendant road development, has triggered landslides and exacerbated floods, and the network of roads themselves results in long-term loss of forest habitat. Many slopes of the Queen Charlotte Ranges and the Skidegate Plateau are only marginally stable; logging such slopes can significantly accelerate rates of mass wasting and modify fluvial structure and processes downstream (Hogan 1986; Banner et al. 1989; Schwab 1998; Baird et al. 2012). Aside from road development and the creation of slide tracks, logging on Haida Gwaii (and more generally in coastal British Columbia) usually does not expose much mineral substrate.

The main ecological impact of logging has been the change in age-class distribution of forests over the landscape. Large areas, especially in the heavily timbered Skidegate Plateau, have been converted from almost entirely old forest (250+ years, sometimes 500+ years) to early and mid seral stages. Young forests are very different from old growth—structurally, functionally, and as habitat for other organisms (Lertzman et al. 1997; Carey 1998). Forests with varied species composition and a wide range of age classes are important for maintaining biodiversity. However, elements of biodiversity associated with old or late successional forests are very significant in the rainforest landscapes of Haida Gwaii. Conversion of old-growth forests to managed, young production forests on a 60- to 80-year rotation has major impacts on late successional elements, such as specialist canopy invertebrates and epiphytic and epixylic bryophytes and lichens.

The 2007 Haida Gwaii Strategic Land Use Agreement and 2010 Haida Gwaii Land Use Objectives Order mandate implementation of ecosystem-based management (EBM) on Haida Gwaii. Current EBM initiatives emphasize old-growth ecosystem representation and higher conservation targets for rare old-growth forest types. The goals of EBM emphasize the maintenance of healthy ecosystems and healthy human communities.

Impacts of introduced species

Introduced Sitka black-tailed deer occur on all the major islands of Haida Gwaii. Browsing by these deer has drastically altered the composition and structure of forest vegetation on Haida Gwaii, and has greatly reduced or virtually eliminated preferred forage species in many areas (Pojar and Banner 1984; Pojar 2008a and b). Many Haida Gwaii forests are now dominated by only a canopy of trees and a ground cover of mosses; shrubs, ferns, and herbs have been reduced to a fraction of their historical cover. Deer browsing has seriously depleted and sometimes eliminated western redcedar regeneration in many old forests and on logged-over sites (Martin and Daufresne 1999). Yellow-cedar has also suffered, especially in montane forests, but has not been as severely reduced overall as redcedar. Deer have affected Sitka spruce much less, but it is locally heavily browsed (Vila et al. 2001; Vila and Martin 2008), and the regrowth of spruce is delayed. Browsing has affected western hemlock the least overall.

There has been a dramatic reduction in the shrub and herb layers in most of Haida Gwaii's forests. Deer have heavily browsed huckleberry and blueberry, false azalea (*Menziesia ferruginea*), salal, and salmonberry, among other shrubs. The near-removal of the shrub layer is particularly significant for shrub-nesting birds (Stockton 2008). Reduced forage due to deer browsing has also caused declines in populations of grouse, which depend on the same plant species for food. This has important implications for the endangered Northern Goshawk (*Accipiter gentilis laingi*) because grouse are an important prey item for this species. Deer have also depleted ferns and other typical coastal forbs, such as skunk cabbage, twistedstalks (*Streptopus amplexifolius* and *S. lanceolatus*), and five-leaved bramble (*Rubus pedatus*). On the few islands or islets where introduced deer do not occur, or where exclosures have been established, growth or regrowth of shrubs, ferns, and herbs is lush.

Other mammals that have been introduced to Haida Gwaii include rats (*Rattus norvegicus* and *R. rattus*), red squirrel (*Tamiasciurus hudsonicus*), raccoon (*Procyon lotor*), common muskrat (*Ondatra zibethica*), American beaver (*Castor canadensis*), and Rocky Mountain elk (*Cervus elaphus nelsoni*). All of these species are at least local agents of ecological change. Rats, raccoons, and squirrels cause the most significant negative impacts, especially on ground-nesting birds.

Although there are more than 100 species of introduced vascular plants on Haida Gwaii (Calder and Taylor 1968; Engelstoft and Bland 2002), most of them are ruderal species and have not made significant inroads on native vegetation. To successfully invade most Haida Gwaii ecosystems, a plant must be shade-tolerant. Most weeds are not; therefore, they do well in open, disturbed habitats, such as roadsides, clearings, gravel pits, fields, and pastures. Introduced invasive plants on Haida Gwaii include Scotch broom (*Cytisus scoparius*), gorse (*Ulex europaeus*), Canada thistle (*Cirsium arvense*), marsh thistle (*C. palustre*), and several knotweeds (notably *Persicaria wallichii* and *Fallopia japonica*). Broom has probably had the greatest negative effect on native vegetation so far, having invaded several communities at Tlell, including open spruce forest as well as stabilized dune habitats.

The more recently introduced wall lettuce (*Lactuca muralis*) and English ivy (*Hedera helix*) are shade-tolerant exceptions to the ruderal rule. Both are local on the islands to date (neither is reported in Calder and Taylor 1968), but they have been very successful in invading forests of southwestern British Columbia.

It is difficult to predict which species will eventually become serious invasives. The potentially most dangerous species are shade-tolerant shrubs or herbs that are unpalatable to deer and have good dispersal mechanisms. Such species could rapidly take over the deer-depleted and often nearly vacant understorey strata of Haida Gwaii's forests (Pojar 2008b).

For an excellent general reference on the effects of introduced species on Haida Gwaii, see Gaston et al. (2008).

Climate change

British Columbia will experience biome shifts due to climate change, including species losses, gains, and reassembly in altered communities; changes in hydrology and fish habitat; increased frequency of extreme events; and increased impacts from invasive species (Spittlehouse 2008; Pojar 2010; Wang et al. 2012). Haida Gwaii will likely experience continuing changes on the land, in the water, and across all levels of biological organization (genes, species, ecosystems) and the interactions among them. The effects of this pervasive human-induced change could eventually eclipse impacts from all other anthropogenic disturbances.

Scenarios of climate change for the north coast project a continuing warming trend during this century, probably accompanied by increasing precipitation. This could take the form of warmer seasons generally, wetter falls and winters (with decreasing snowfall and diminished snowpack), and perhaps slightly drier summers (Walker 2006). Projections of temperature changes, however, have greater certainty than projections of precipitation changes. The uncertainty is compounded on Haida Gwaii by the area's complex topography and pronounced ecological gradients.

As a consequence of these climatic trends, water temperatures in Haida Gwaii's rivers and lakes are expected to increase, and complex changes in the amount and timing of streamflows will likely occur. Impacts from storms, floods, erosion (including landslides), and forest pests will probably increase. Sea level on the north coast is conservatively projected to rise 0.5 m by 2100 (Bornhold 2008), which could have considerable impacts on shorelines, generally, and on the low-lying Argonaut Plain, in particular.

"Climate envelopes" (the spatial extent of suitable climatic conditions) of ecological zones and species are shifting. Alpine ecosystems will decline if the distribution of subalpine forests shifts upslope. The distinctive alpine zone and its endemic and disjunct species are at risk, although the cool windy hypermaritime climate could help alpine-like environments persist longer than projected by models. Climate change is already driving changes in processes (disturbance regimes, hydrological regimes) and in ecosystem structure, function, and distribution. A good example of this is yellow-cedar decline in southeast Alaska and north coastal British Columbia (Hennon et al. 2012).

Future ecological conditions are complex and difficult to predict because they reflect the combined effects of changing climate, land use and resource use activities, and invasive species, all in the face of a limited data and knowledge base.

Three biogeoclimatic zones occur on Haida Gwaii. The Coastal Western Hemlock (CWH) zone dominates the islands: it occurs from sea level to subalpine elevations (500–600 m) throughout the Skidegate Plateau, Queen Charlotte Lowland, and Queen Charlotte Ranges. The Mountain Hemlock (MH) zone occurs at subalpine elevations in the Queen Charlotte Ranges and Skidegate Plateau, and the Coastal Mountain-heather Alpine (CMA) zone is restricted to the highest mountains above 800–900 m elevation, mostly in the Queen Charlotte Ranges. Figure 5.1 shows the distribution of the biogeoclimatic units of Haida Gwaii. Figure 5.2 illustrates the geographic and elevational distribution of biogeoclimatic units along six east–west transects from northern to southern Haida Gwaii.

This chapter describes the general features of these three zones and their subzones/variants on Haida Gwaii. Tables 5.1, 5.2, and 5.3 provide comparative summaries of the environmental, climatic, and vegetation characteristics, respectively, of these biogeoclimatic units on Haida Gwaii. Chapter 6 further defines the distinguishing characteristics and presents a distribution map of each biogeoclimatic unit, at the beginning of each set of site series descriptions.

5.1 Coastal Western Hemlock Zone

The Coastal Western Hemlock zone (CWH) occurs at low to middle elevations, mostly west of the Coast Mountains, along the entire British Columbia coast, and into both Alaska and Washington/Oregon. The zone covers much of Vancouver Island, Haida Gwaii, and windward flanks of the Coast Mountains (Meidinger and Pojar 1991). Characteristic floristic features of zonal ecosystems in the CWH zone in British Columbia are the prominence of western hemlock, the presence of a sparse herb layer, and the predominance of several moss species (especially step moss [*Hylocomium splendens*] and lanky moss). Of the ten CWH subzones that occur provincially, two occur on Haida Gwaii—the Very Wet Hypermaritime subzone (CWHvh) and the Wet Hypermaritime subzone (CWHwh), the latter of which is endemic to Haida Gwaii.

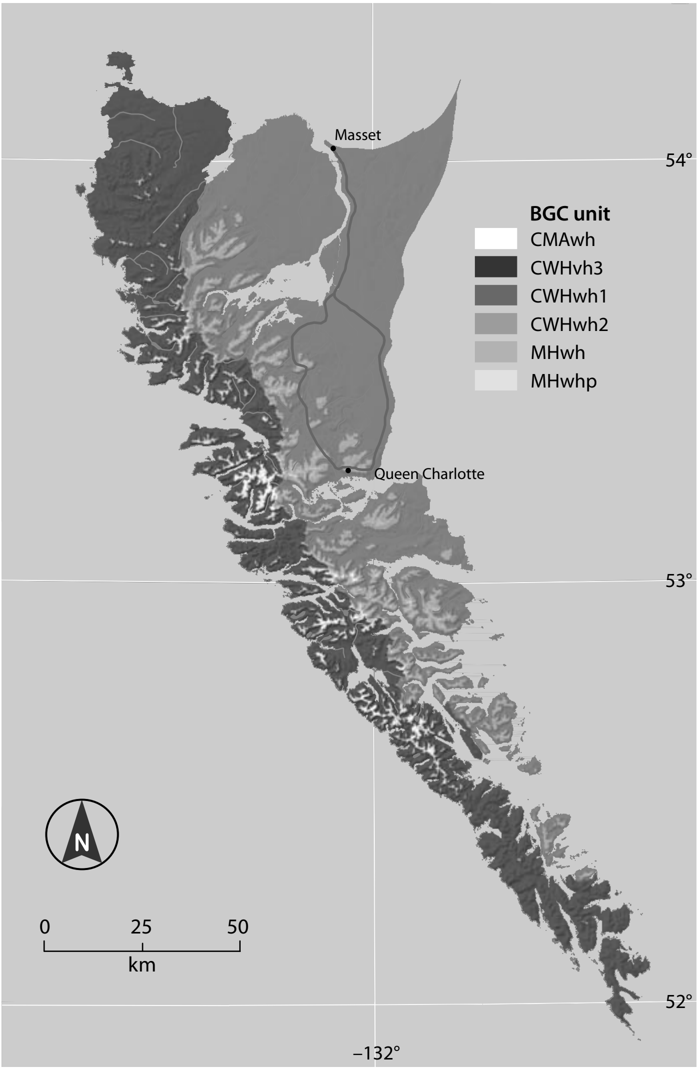
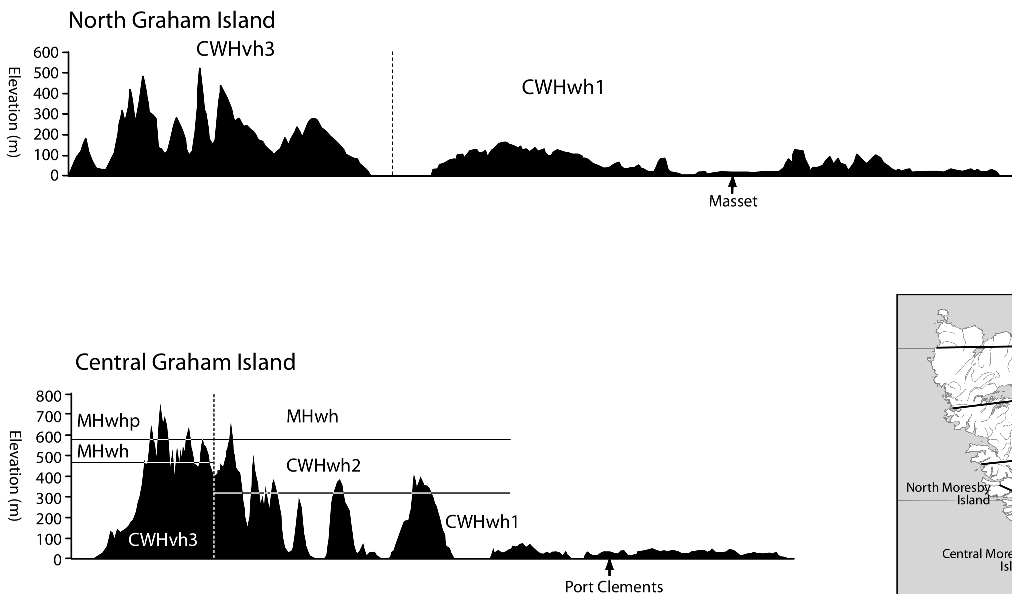


FIGURE 5.1 *Distribution of biogeoclimatic units of Haida Gwaii.*



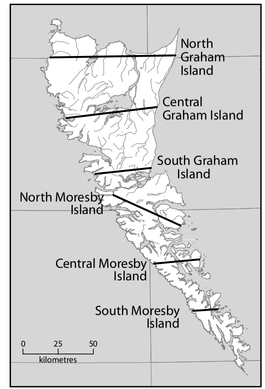


FIGURE 5.2 *Biogeoclimatic cross-sections of Haida Gwaii.*

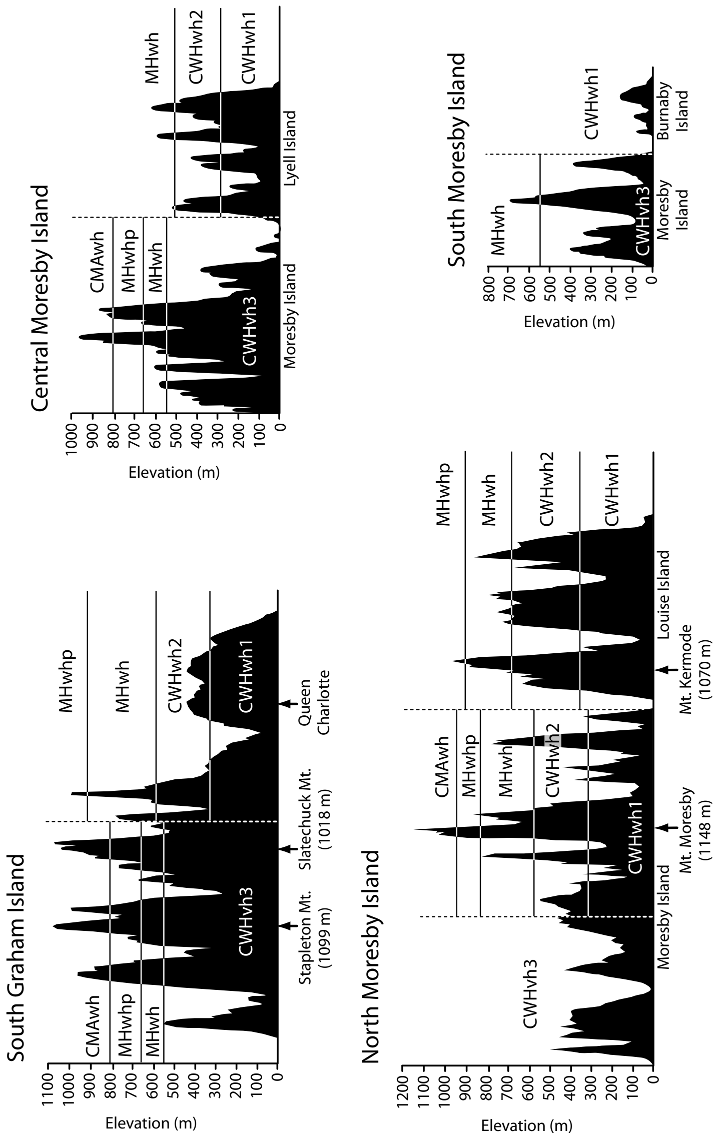

South Graham Island
Elevation (m)
CMAwh
MHwhp
MHwh
CWHvh3
MHwhp
MHwh
CWHwh2
CWHwh1
Stapleton Mt. (1099 m)
Slatechuck Mt. (1018 m)
Queen Charlotte
Central Moresby Island
Elevation (m)
CMAwh
MHwhp
MHwh
CWHvh3
MHwh
CWHwh2
CWHwh1
Moresby Island
Lyell Island
North Moresby Island
Elevation (m)
CWHvh3
CMAwh
MHwhp
MHwh
CWHwh2
CWHwh1
MHwhp
MHwh
CWHwh2
CWHwh1
Moresby Island
Mt. Moresby (1148 m)
Mt. Kermode (1070 m)
Louise Island
South Moresby Island
Elevation (m)
MHwh
CWHvh3
CWHwh1
Moresby Island
Burnaby Island

TABLE 5.1 *Summary of the biogeoclimatic (BGC) units of Haida Gwaii* [a]

BGC unit; zone/subzone/variant abbreviation	**CWHvh3**	**CWHwh1**	**CWHwh2**	**MHwh**	**CMAwh**
Full name of BGC unit	Coastal Western Hemlock zone, Very Wet Hypermaritime subzone, Haida Gwaii variant	Coastal Western Hemlock zone, Wet Hypermaritime subzone, Submontane variant	Coastal Western Hemlock zone, Wet Hypermaritime subzone, Montane variant	Mountain Hemlock zone, Wet Hypermaritime subzone	Coastal Mountain-heather Alpine zone, Wet Hypermaritime subzone
Extent [b]	402 034 ha or 40% of Haida Gwaii land area	491 015 ha or 49% of Haida Gwaii land area	69 373ha or 7% of Haida Gwaii land area	39 672 ha or 4% of Haida Gwaii land area	2 887 ha or 0.3% of Haida Gwaii land area
Distribution/ elevational range	Low to mid elevations (0 to ±550 m) on W and S Haida Gwaii; NW Skidegate Plateau, W and S Q.C. [c] Ranges	Lower elevations (0 to ±350 m) on E Haida Gwaii; leeward side of the mountains; Q.C. Lowland, NE and S Skidegate Plateau, E Q.C. Ranges	Mid (montane) elevations (±350 m to ±600 m) on E Haida Gwaii ; leeward side of the mountains; Q. C. Lowland, NE and S Skidegate Plateau, E Q.C. Ranges	High (subalpine) elevations in the Q.C. Ranges and Skidegate Plateau (500+ to ± 800 m above the CWHvh3; ±600 to ±900 m above the CWHwh2); upper 100 to 150 m is parkland (MHwhp)	Highest (alpine) elevations above the MHwhp (above ± 800 m in the west and above ±900 m in the east); mostly in the Q.C. Ranges
Climate	Cool, wetter than most of the CWHwh1; little snow and ephemeral snowpack; very cloudy, foggy, windy; "hyperoceanic"	Cool, moderately wet summers; scattered dry spells; cool, wet fall and winter; light snowpack; cloudy, foggy, windy	Cooler, wetter than the CWHwh1; more snowfall, more persistent snowpack; cloudy, foggy, windy	Cooler and wetter than the CWH; short, cool, wet summers; cold, wet winters; much more snowfall and more persistent snowpack than the CWH; very cloudy, foggy, windy	Cool, wet, short summers; cold, snowy winters; wet, long-lasting snowpack; extreme exposure to high winds and cool, humid air; "oceanic alpine"

BGC unit; zone/subzone/variant abbreviation	CWHvh3	CWHwh1	CWHwh2	MHwh	CMAwh
Tree species [a]	Cw, Yc, Hw (Plc, Hm) on zonal sites; Plc, Yc, and Hm very common on wet, boggy sites; Ss restricted to freely drained sites; Dr on disturbed sites	Hw, Cw, Ss on zonal sites; Plc on very wet and dry sites; Yc (and Hm) on some poorly drained sites; Dr on disturbed sites	Hw, Yc (Ss, Cw, Hm) on zonal sites; Yc and Hm more common on wet sites; Dr less common than in the CWHwh1	Hm, Yc, (Hw) on zonal sites; Ss and Cw much less common and less productive than in the CWH	Trees lacking except for minor krummholz of mostly Hm
Zonal association	Western redcedar – Western hemlock – Salal – Deer fern	Western hemlock – Sitka spruce – Lanky moss	Western hemlock – Sitka spruce – Lanky moss	Mountain hemlock – Sitka spruce – Blueberry	Alaskan and White mountain-heathers – Tufted hairgrass
Distinguishing vegetation characteristics. *Note that introduced deer have dramatically reduced forest understoreys, which are usually very sparse and moss-dominated; thus, vascular plant species listed may have only very scattered occurrences. In assessing sites, reliance should not be placed on any one characteristic but rather a combination of characteristics that suggest the most appropriate BGC classification.*	-Occurrence of Yc, Plc, and Hm in zonal forests (with Hw and Cw); scrubby nature of zonal forests -dominance of salal in zonal understoreys -productive HwCwSs forests restricted to well-drained, steep slopes and fluvial landforms -occurrence of blanket bogs and bog woodlands on slopes -greater abundance of epiphytic bryophytes, especially common scissor-leaf liverwort	-Zonal forests comprised of productive Hw, Cw, Ss mixes— Yc, Hm, and Plc restricted to wet sites -dominance of red huckleberry and feathermosses in zonal understoreys -salal restricted to edaphic sites	-Common occurrence of Yc and lesser abundance of Cw and Ss on zonal sites; scattered occurrence of Hm on zonal sites -greater general abundance (compared with CWHwh1) of oval-leaved blueberry, spleenwort-leaved goldthread, small twistedstalk, alpine fir-moss, heron's-bill moss, and yellow-ladle liverwort (zonal and azonal sites) -general scarcity of salal, sword fern, false lily-of-the-valley, salmonberry, and Oregon beaked-moss -greater abundance of Indian hellebore on wet sites	-Dominance of Hm over Hw and Yc over Cw in zonal forests; forests are more open and trees have tapered form -at upper elevations, parkland, (MHwhp) with tree islands and Hm krummholz/elfinwood, dominates -even greater expression of understorey vegetation trends mentioned for the CWHwh2 -minor occurrence of pipecleaner moss -scattered occurrence of subalpine species such as mountain-heathers, partridge-foot -greater abundance of epiphytic lichens	-Non-forested communities dominated by Alaskan, white, yellow, and club-moss mountain-heathers and a variety of other alpine/subalpine species

Continued on next page

TABLE 5.1 *(Continued)*

BGC unit; zone/subzone/variant abbreviation	CWHvh3	CWHwh1	CWHwh2	MHwh	CMAwh
Landforms [a]	Ov and LFH/ Rock and Mv; Cv, F, marine beaches	M, C, F, (LFH/R), (O – peat on Q.C. Lowland), (GF), (sand dunes, marine beaches)	Compared with the CWHwh1, shallower surficial deposits – Cv, Mv, LFH/R; slope-washed sediments derived from M; F less common; steeper terrain than the CWHwh1	LFH/R, Cv, steep upper slopes to ridge crests	Mostly steep terrain with LFH, Ov, Cv /R
Zonal soils [a]	FHP, HFP, FO (G, H, M) with Mor humus forms averaging 30+ cm deep; gleyed soils common	HFP, FHP (FO) with Mor humus forms averaging 20 cm deep	FHP, HFP, FO with Mor humus forms averaging 25 cm deep; soils sometimes gleyed	FHP, FO, HFP (G) with compact Mor humus forms averaging 30+ cm deep; gleyed soils common	R, FO, (FHP), non-soil

[a] Codes used in the table are described in Section 3.2.2. Brackets indicate that the attribute (tree species, landform, or soil type) is of relatively minor occurrence in that BGC unit.

[b] Data source: Hectares BC (www.hectaresbc.org/app/habc/HaBC.html) accessed February 10, 2012.
Note area based on BEC v.8, excludes fresh water from land area.

[c] Q.C.: Queen Charlotte.

TABLE 5.2 *Selected climate variables (1961–1990 normals [a]) for forested biogeoclimatic units of Haida Gwaii*

Climate characteristics		CWHvh3	CWHwh1	CWHwh2	MHwh
Annual precipitation	Mean	3156	1948	2536	4111
(mm)	SD [b]	1009	642	662	1012
	Range	1434–6933	1042–5458	1344–6592	1503–7445
Mean growing-season	Mean	779	477	592	931
precipitation (mm)	SD	246	156	181	289
(May–September)	Range	268–1852	212–1299	244–1644	272–2037
Annual snowfall (cm)	Mean	260	152	331	626
	SD	186	93	157	275
	Range	28–1383	42–991	45–1195	62–1858
Annual temperature (°C)	Mean	7.2	7.4	6.2	5.8
	SD	1.1	0.7	0.9	0.9
	Range	4.0–10.0	5.1–9.2	3.7–9.0	3.6–9.0
Mean warmest month	Mean	13.5	14.0	13.1	12.7
temperature (°C)	SD	1.0	0.9	0.9	0.9
	Range	10.5–16.3	11.4–16.4	10.6–16.0	10.0–15.9
Mean coldest month	Mean	1.8	1.6	0.3	0.1
temperature (°C)	SD	2.2	2.0	2.0	2.0
	Range	-6.7–6.9	-5.6–5.5	-7.4–5.5	-7.4–5.8
Chilling degree-days	Mean	164	164	236	261
(degree-days below 0°C)	SD	69	51	76	84
	Range	50–491	70–364	71–553	68–551
Growing degree-days	Mean	1337	1392	1162	1066
(degree-days above 5°C)	SD	217	154	168	161
	Range	779–1974	932–1774	740–1740	710–1707
Number of frost-free days	Mean	281	277	246	238
	SD	29	19	24	27
	Range	187–345	212–324	174–323	169–331
Frost-free period (days)	Mean	203	193	162	155
	SD	37	22	24	25
	Range	113–319	127–258	103–258	96–277
Extreme min. temperature	Mean	-18.8	-20.0	-22.6	-23.0
over 30 years (°C)	SD	2.7	1.5	1.8	2.2
	Range	-25.5 to -13.0	-23.1 to -16.6	-26.4 to -16.8	-27.1 to -15.6
Extreme max. temperature	Mean	30.5	31.1	30.6	30.3
over 30 years (°C)	SD	0.6	0.3	0.4	0.5
	Range	29.1–32.2	30.3–31.9	29.8–31.9	29.2–31.2
Hargreaves climatic	Mean	15	51	38	15
moisture deficit (mm)	SD	18	36	29	20
	Range	0–101	0–142	0–121	0–115

[a] Climate normals for the period 1961–1990 were generated from 60 random points for each biogeoclimatic unit using ClimateWNA (www.genetics.forestry.ubc.ca/cfcg/ClimateWNA/ClimateWNA.html).

[b] SD: standard deviation.

TABLE 5.3 *Vegetation summary table comparing zonal sites for forested biogeoclimatic units on Haida Gwaii*[a]

Stratum	Subzone/variant:	CWHvh3	CWHwh1	CWHwh2	MHwh	
	Number of plots:	131	114	80	33	
Tree layer	*Tsuga heterophylla*	■■■■	■■■■■	■■■■■	□□□□	western hemlock
	Picea sitchensis	□□□	■■■■	□□□	□□□	Sitka spruce
	Thuja plicata	■■■■■	■■■■■	□□□□		western redcedar
	Chamaecyparis nootkatensis	□□□□□		■■■■	□□□□□	yellow-cedar
	Tsuga mertensiana			**	■■■■■	mountain hemlock
Shrub layer	*Thuja plicata*	■■■	**	**		western redcedar
	Tsuga heterophylla	■■■■	■■■■■	■■■■	■■■	western hemlock
Regen	*Chamaecyparis nootkatensis*	□□		**	**	yellow-cedar
	Tsuga mertensiana				□□□	mountain hemlock
Shrubs	*Gaultheria shallon*	■■■■■	**			salal
	Vaccinium parvifolium	■■	■■■	□□	■■	red huckleberry
	Menziesia ferruginea	■■	□□	□□	*	false azalea
	Vaccinium alaskaense	**	**	□□	□□□	Alaska blueberry
	Vaccinium ovalifolium		*	**	□□□	oval-leaved blueberry
Herb layer	*Maianthemum dilatatum*	□□	*			false lily-of-the-valley
	Blechnum spicant	■■	■■	■■	■■	deer fern
	Listera spp.[b]	■■	■■	■■	■■	twayblades[b]
	Coptis aspleniifolia			■■	■■	spleenwort-leaved goldthread
	Huperzia haleakalae	**		□	*	alpine fir-moss
	Moneses uniflora		*	□	□	single delight
	Streptopus spp.[b]	*	*	■■	■■	twistedstalks[b]
	Rubus pedatus				□	five-leaved bramble
	Veratrum viride				□□	Indian hellebore

Stratum	Subzone/variant:	CWHvh3	CWHwh1	CWHwh2	MHwh	
	Number of plots:	131	114	80	33	
Moss layer	*Hylocomium splendens*	■■■■	■■■■■	■■■■	□□□	step moss
	Rhytidiadelphus loreus	■■■■■	■■■■■	■■■■■	■■■■■	lanky moss
	"leafy mosses"[b]	■■■	■■■	□□□	□□□	leafy mosses [b]
	Plagiothecium undulatum	□□	■■	□□	□□	flat moss
	Eurhynchium oreganum	■■■	■■■	**		Oregon beaked-moss
	Dicranum spp.	□□	*	■■■	■■■	heron's-bill mosses
	Scapania bolanderi	***	□□	■■■■	■■■■	yellow-ladle liverwort
	Rytidiopsis robusta				****	pipecleaner moss

[a] Table symbology denotes plant species constancy and percent cover as follows:
Constancy: ▬▬ >70% □□ >50–70% * 25–50%
Mean cover: ■■■■■ >18% ■■■■ >8–18% ■■■ >3–8% ■■ ≥ 0.5–3% ■ <0.5%

[b] See Table 6.1 for included species.

5.1.1 CWHvh, Very Wet Hypermaritime subzone

The CWHvh occurs on the outer coast of British Columbia from western and northern Vancouver Island and the adjacent mainland north to southeast Alaska, including the west coast of Haida Gwaii (Meidinger and Pojar 1991). Three variants are currently recognized—two on the mainland and adjacent coastal islands (CWHvh1 – Southern variant and CWHvh2 – Central variant) and one restricted to Haida Gwaii (CWHvh3 – Haida Gwaii variant).

5.1.1.1 CWHvh3, Haida Gwaii variant

Location and distribution: The CWHvh3 is restricted to Haida Gwaii: it occurs on the western (windward) portions and across the southern tip of the archipelago, south of Huston Inlet (Figures 5.1 and 5.2). It occupies the outer and exposed coastal areas on the westernmost Skidegate Plateau and Queen Charlotte Ranges, from sea level to 500–550 m elevation. This variant transitions to the CWHwh to the east and to the subalpine MHwh at higher elevations. The CWHvh3 covers 402 034 ha or 40% of Haida Gwaii's total land area.

Climate: The "hyperoceanic" climate of the CWHvh3 is wetter than most of the CWHwh (>4000 mm mean annual precipitation on the outer west coast vs. ± 1200 mm on the east coast). Summers are mild, wet, and humid, and rarely have dry spells; falls and winters are cool and very wet. Near sea level there is very little snowfall and only an ephemeral snowpack, but at mid to high elevations, a more consistent snowpack occurs. Clouds and fog are very common, and relative humidity is high throughout the year. Section 4.2 provides additional information on the climate of Haida Gwaii; Table 5.2 presents a summary of climate data for each of the biogeoclimatic variants.

Vegetation: Climatic climax forests on zonal sites consist of low-productivity mixtures of western redcedar and yellow-cedar, western and mountain hemlock, and shore pine. These occur on moderate to gentle slopes, which in the CWHwh would support productive western hemlock – western redcedar – Sitka spruce forests.

Understorey vegetation on zonal sites generally has a significant salal component, depending on deer browsing impacts. Alaska and oval-leaved blueberry and false azalea are also typical shrubs. Herbaceous composition is often sparse, but deer fern (*Blechnum spicant*), twayblades (*Listera cordata* and *L. caurina*), and false lily-of-the-valley (*Maianthemum dilatatum*) consistently occur. Lanky moss, step moss, and Oregon beaked-moss (*Eurhynchium oreganum*) dominate the moss layer; yellow-ladle liverwort (*Scapania bolanderi*), leafy mosses (*Rhizomnium, Plagiomnium*, and *Mnium* spp.), and patches of common green peat-moss (*Sphagnum girgensohnii*) are also typical.

Productive forests in the CWHvh are restricted mainly to steep colluvial slopes and alluvial valley bottoms, where rapid surface drainage is maintained. The occurrence of yellow-cedar, mountain hemlock, and shore pine in zonal ecosystems from sea level to montane elevations, together with the scrubby nature of these zonal forests, are the major features distinguishing the CWHvh3 from the CWHwh. The occurrence (dominance) of salal on zonal sites is also distinctive.

Much of the landscape in the CWHvh3 is covered with scrub forest and blanket bog. On the west coast, open bogs and bog woodland can occur on slopes up to 60%. This is in contrast to the CWHwh, where bogs are restricted to flat or depressional areas in the landscape, and thus result primarily from topographic rather than climatic factors.

Soils: Zonal soil-forming processes in the CWHvh3 are dominated by the continuous gradual buildup of organic matter at the ground surface. Zonal soils are characterized by thick (commonly 20–40+ cm), wet surface organic layers (LFH; mainly H) over a wide variety of mineral soils (Podzols, Gleysols, Brunisols) or bedrock. Peaty organic soils (Mesisols, Humisols) have also been sampled on some sites with "zonal" vegetation.

Freely drained Podzols are much more restricted in occurrence in the CWHvh3 than in the CWHwh. They occur on steeper colluvial (and colluviated morainal) slopes that support productive forests of western hemlock, Sitka spruce, and western redcedar. Such sites are considered to be submesic in the CWHvh3. A history of natural disturbance (colluvial and windthrow) helps keep such sites productive in this hypermaritime environment by combating the accumulation of deep, stable, surface organic horizons that are associated with declining forest productivity.

Productive fluvial forest ecosystems occur along larger streams (e.g., Riley, Gregory, and Bonanza Creeks), where moist but freely drained

Regosols, Brunisols, and Podzols that are subject to subsurface aerated seepage yield nutrient-rich conditions for forest growth. This is in contrast to the wet but poorly aerated soils (Gleysols) of the swamp forests on some gentle slopes and depressions, and the very common bog forests, bog woodlands, and open blanket bogs, where peaty organic soils prevail. Some steeply sloping bogs on the west coast, however, have very little peat accumulation.

5.1.2 CWHwh, Wet Hypermaritime subzone

The CWHwh is a lowland to montane subzone that occurs only on Haida Gwaii. It extends from sea level to 550–600 m elevation on the drier, leeward (eastern) side of the archipelago. This subzone contains most of the productive forests on the islands; it is distinguished from mainland subzones of the CWH by the absence of amabilis fir (*Abies amabilis*) (or any true firs) and Douglas-fir (*Pseudotsuga menziesii*), and by the widespread occurrence of Sitka spruce in a broad range of habitats, including climatic climax or zonal forests.

The CWHwh covers all of the Queen Charlotte Lowland (except the northwestern tip) and the eastern flanks of the Skidegate Plateau and Queen Charlotte Ranges on Graham Island, northern Moresby Island, and the adjacent islands. South of Tangil Peninsula, the CWHwh is restricted mainly to the smaller east coast islands (Lyell, Burnaby) and the extreme eastern edge of Moresby Island. It does not extend much further south than Jedway. The CWHwh grades into the CWHvh3 to the west and on the southern tip of Moresby Island. At elevations above 550–600 m, the CWHwh is replaced by the Mountain Hemlock zone. Two variants of the CWHwh are recognized—the CWHwh1, Submontane (lower-elevation) variant and the CWHwh2, Montane (higher-elevation) variant (see Tables 5.1–5.3).

5.1.2.1 CWHwh1, Submontane variant

Location and distribution: The Submontane variant of the CWHwh extends from sea level to approximately 350 m elevation on the Queen Charlotte Lowland, eastern Skidegate Plateau, and eastern edge of the Queen Charlotte Ranges (Figures 5.1 and 5.2). This variant includes most of the land area within the CWHwh on eastern Graham Island, northeastern Moresby Island, and the many smaller islands (Lyell, Burnaby, and Louise) and islets on the east coast, north of Skincuttle Inlet. The CWHwh1 covers 491 015 ha or 49% of Haida Gwaii's total land area.

Climate: The climate of the CWHwh1 is characterized by mild, wet winters with little snowfall and cool, moist summers (Table 5.2). The warmest, driest, most equable climate in the subzone occurs in this variant along the east coast of Haida Gwaii.

The rain shadow cast by the Queen Charlotte Mountains causes precipitation to decrease from west to east within the CWHwh1. Decreases in temperature and increases in total precipitation and snowfall are associated with increasing elevation (toward the CWHwh2). Soil moisture deficits during the growing season are rare in the CWHwh1, although they may occur during dry, warm spells, especially on shedding sites on the east coast. Section 4.2 provides a further discussion of the climate of Haida Gwaii.

Vegetation: Major tree species in the CWHwh1 are western hemlock, western redcedar, and Sitka spruce. Yellow-cedar, shore pine, red alder, mountain hemlock, and western yew are minor species. Tree species composition in zonal stands is variable, and depends largely on long-term successional factors. Western hemlock–dominated stands are considered to be successionally less advanced (though still old growth) and tend to characterize areas with a history of windthrow disturbance. Openings in the canopy due to disturbance such as small-scale mass movements also favour Sitka spruce regeneration. Sitka spruce is usually much less abundant than western hemlock in climax stands; however, scattered, large spruce protruding above the main canopy are typical. An increasing dominance of western redcedar over western hemlock is believed to be associated with successionally more advanced stands that have developed over several centuries in the absence of larger-scale disturbance.

Understorey vegetation in zonal ecosystems is sparse to poorly developed, largely because of depletion due to deer browsing. Regeneration of western hemlock dominates the shrub layers. Common shrub species are Alaska and oval-leaved blueberry, red huckleberry (*Vaccinium parvifolium*), and false azalea.

The herb layer is usually sparse; typical species are deer fern, twayblades, false lily-of-the-valley, and spiny wood fern (*Dryopteris expansa*). On the forest floor, a well-developed carpet of mosses, predominantly lanky moss, step moss, leafy mosses, and Oregon beaked-moss, is typical.

Yellow-cedar is restricted to poorly drained scrub forests in the CWHwh1. Mountain hemlock and shore pine also occur sporadically in these habitats. In some very dry, rocky habitats on the east coast, shore pine may occur with western redcedar and western hemlock.

Wetlands are a common feature of the Queen Charlotte Lowland and occur locally elsewhere throughout the CWHwh1. Raised *Sphagnum* bogs with scrubby shore pine are the most widespread wetland type. Swamps of western redcedar, Sitka spruce, and western hemlock are common but localized in the CWHwh1. Minor areas of non-forested fens and marshes occur mainly on the Queen Charlotte Lowland.

Soils: The zonal ecosystem in the CWHwh1 occurs most commonly on morainal and colluvial blankets and veneers. Dominant soils on these landforms are moderately well- to imperfectly drained Humo-Ferric and Ferro-Humic Podzols. Climatic climax forests also occur on Folisols that consist of LFH accumulations directly over bedrock. An important characteristic of both the mineral soils and the Folisols is the accumulation of acidic Mor humus. Humus depth commonly ranges from 10 to 25 cm, and most of the fine and medium roots are confined to these surface organic layers. Mineral soil textures range from silt loam to sandy loam, and skeletal soils (>35% coarse fragments) occur, especially in the colluvial materials.

The soils of dry, well-drained ecosystems (uncommon in the CWHwh1) are Folisols and shallow Podzols. These occur on upper slopes, crests, and rocky ridgetops on the east coast of Moresby Island and adjacent smaller islands. The spruce–moss forests of sandy beach/dune deposits are also well to rapidly drained.

On middle to toe colluvial slopes that receive abundant seepage, Orthic and Gleyed Podzols and, less commonly, Gleysols support productive forest ecosystems. Alluvial landforms support some of the most productive forest ecosystems in the CWHwh1. Soils of young, recently active alluvial landforms are Brunisols with thin (<10 cm) Moder (and

Mull) humus forms. More mature Brunisols and Podzols with Mor and Moder humus forms are associated with the older, inactive alluvium.

Poorly drained Gleysols, Humisols, and Mesisols are typical of wet scrub forests and swamps. The wettest ecosystems in the CWHwh1 are non-forested wetlands. Mesisols characterize the bogs, fen soils are Mesisols and Humisols, and marsh soils are usually peaty Gleysols.

5.1.2.2 CWHwh2, Montane variant

Location and distribution: The CWHwh2 occurs above the CWHwh1 throughout the eastern Skidegate Plateau and eastern Queen Charlotte Ranges (Figures 5.1 and 5.2). The elevational limits of the CWHwh2 vary depending on location. In the eastern part of the CWHwh, the Montane variant generally occurs between 350 and 600 m. Towards the CWH-vh3, and in some of the long valleys that drain the mountains to the west (e.g., Mamin, Blackwater, and Deena Rivers), the lower elevational boundary of the CWHwh2 appears to extend down to about 300 m. The CWHwh2 covers 69 373 ha or 7% of Haida Gwaii's total land area.

Climate: The Montane variant of the CWHwh is both cooler and wetter than the Submontane variant, and has greater snowfall and longer snowpack duration. Low cloud and fog, especially during the growing season, probably influence this variant more than the Submontane variant. Whereas moisture deficits may occur on some sites in the CWHwh1, they are rare in the CWHwh2. There are no long-term climate station data for the climate at upper elevations on Haida Gwaii, but Table 5.2 presents modelled attributes and trends.

Vegetation: Major tree species in the CWHwh2 are western hemlock, yellow-cedar, western redcedar, and Sitka spruce. Mountain hemlock, shore pine, red alder, and western yew are minor species.

As in the Submontane variant, tree species composition in zonal ecosystems is variable. A component of yellow-cedar is the major feature that distinguishes climatic climax forests of the Montane variant from those of the Submontane. Mature, all-aged stands are predominantly western hemlock with variable amounts of yellow-cedar, western redcedar, and Sitka spruce. However, younger, more even-aged, pure hemlock stands, which established after blowdown on exposed ridges and upper slopes, are common in this variant. In comparison to the CWHwh1, a slight decline in productivity of western hemlock and a lower abundance and productivity of western redcedar and Sitka spruce are evident in the CWHwh2. Mountain hemlock occurs only sporadically on zonal sites in the CWHwh2, but it occurs on a wider variety of sites than in the CWHwh1. It is most common in poorly drained scrub forests. Shore pine is less common in the CWHwh2 than in the CWHwh1, and is restricted to small pockets of sphagnum bog and some scrub forests.

Deer browsing has dramatically influenced the understoreys in climatic climax stands in the CWHwh2. The sparse shrub layers consist mainly of western hemlock regeneration, but scattered regeneration of all the other tree species may also occur. Oval-leaved and Alaska blueberry, red huckleberry, and false azalea occur in varying amounts.

Herb layers consist of scattered twayblades, spleenwort-leaved goldthread (*Coptis aspleniifolia*), deer fern, rosy twistedstalk, small twistedstalk (*Streptopus streptopoides*), alpine fir-moss (*Huperzia haleakalae*), and running club-moss (*Lycopodium clavatum*). Yellow-ladle liverwort, flat-moss (*Plagiothecium undulatum*), leafy moss, heron's-bill mosses (*Dicranum* spp.), lanky moss, and step moss dominate the bryophyte layer on zonal CWHwh2 sites.

The dominance of yellow-ladle liverwort and heron's-bill mosses and the lesser dominance of step moss and lanky moss help distinguish CWHwh2 zonal ecosystems from those of the CWHwh1. Other understorey species that tend to be more common in the CWHwh2 than in the CWHwh1 are oval-leaved blueberry, spleenwort-leaved goldthread, small twistedstalk, alpine fir-moss, and Indian hellebore (*Veratrum viride,* mostly on wetter sites). However, none of these species are very consistent indicators of the CWHwh2 on their own; thus, site assessment and classification must include observations of overstorey and understorey composition, as well as elevation and other environmental factors. Aspect and cold air drainage, for example, can influence the elevational transition to CWHwh2.

A few understorey plant species are generally absent or less common in the CWHwh2 than in the CWHwh1. They include salal, sword fern (*Polystichum munitum*), false lily-of-the-valley, western yew, and salmonberry.

Soils: Soil characteristics on zonal sites in the CWHwh2 reflect the generally shallower surficial deposits, the increased dominance of colluvial and organic (LFH) veneers, and the wetter (and cooler) climate at montane elevations on Haida Gwaii.

Zonal ecosystems extend from steep upper colluvial slopes and ridgetops, where the soils are moderately well drained, shallow to extremely shallow Podzols and Folisols, to gentler middle (rarely lower) slopes where deeper Podzols develop in morainal veneers. These soils may be gleyed or mottled. Mor humus forms, averaging 25 cm thick, are typical of zonal soils in the CWHwh2. Humus layers are, on average, slightly thicker in the Montane variant, but the difference in humus depth between the two CWHwh variants is not consistent.

On the few well- to rapidly drained sites observed in the CWHwh2, shallow to extremely shallow Podzols and Folisols occur. The vegetation even on these driest forested sites, however, is essentially zonal. Where seepage water is concentrated close to the soil surface on steep, shallow veneers over bedrock, Gleyed Podzols, Typic Folisols, and Gleysols support wet, productive forest ecosystems. On these steep slopes, wet surface horizons easily slide downslope when disturbed.

The Montane variant lacks the extensive fluvial deposits that occur along the lower reaches of the major rivers in the CWHwh1. A significant, though smaller-scale, erosion/sedimentation process is associated with morainal slopes in the CWHwh2. Initially, the morainal materials are eroded by overland water flow, and the resulting silty, slope-washed sediments accumulate downslope in depressions and behind logs that lie across the slope. These 5–20 m^2 "sediment basins" usually support large, wet carpets of liverworts (shiny liverwort [*Pellia neesiana*] and snake liverwort) and mosses (stiff-leaved haircap moss [*Polytrichastrum alpinum*] and crane's-bill moss [*Atrichum selwynii*]) within the montane forests. Poorly drained Gleysols, often with deep (20+ cm) organo-mineral surface Ah or Hi horizons, characterize these slope-washed morainal landforms. A similar erosion/sedimentation phenomenon has been described in the CWHvh3 (Wilford 1984).

In the CWHwh2, scrub forests of yellow-cedar, mountain hemlock, and western hemlock develop on poorly drained organic and morainal deposits where the soils are Mesisols, Humisols, and Gleysols.

5.2 Mountain Hemlock Zone

The Mountain Hemlock zone (MH) occurs at subalpine elevations above the CWH zone in the coastal mountains of British Columbia and extends north through southeast Alaska and south into Washington and Oregon (Meidinger and Pojar 1991). Provincially, mountain hemlock, amabilis fir, and yellow-cedar are the most common tree species in the zone, with subalpine fir (*Abies lasiocarpa*) increasing in abundance in eastern areas that are transitional to the Engelmann Spruce – Subalpine fir (ESSF) zone of interior British Columbia.

Two forested MH subzones were previously described in British Columbia (Meidinger and Pojar 1991; Banner et al. 1993; Green and Klinka 1994). Historically, the Wet Hypermaritime subzone (MHwh) included the mountains of the outer mainland coast and Haida Gwaii. A Moist Maritime subzone (MHmm) included the mainland central and north coast, inland of the MHwh, and the south coast and Vancouver Island mountains. As a result of recent BEC revisions, the MHwh is now restricted to Haida Gwaii, and the other mainland and adjacent areas that were previously mapped as MHwh are now being re-evaluated.

5.2.1 MHwh, Wet Hypermaritime subzone

Location and distribution: The MHwh occurs above the CWHwh2 and CWHvh3 (Figures 5.1 and 5.2). The boundary occurs at lower elevations in the west, above the CWHvh3 (500+ m), compared with the CWHwh2 (±600 m) to the east. This subalpine subzone is not extensive on Haida Gwaii. It is best developed on the Queen Charlotte Ranges but also occurs on the highest parts of the Skidegate Plateau. Most of the MHwh on Haida Gwaii is forested. Minor areas of the parkland subzone (MHwhp), where clumps of trees alternate with open subalpine heaths and meadows, occur in the upper 100–150 m elevational transition to treeless alpine tundra (CMAwh occurring above ±850 m elevation). The MHwh covers 39 672 ha or 4% of Haida Gwaii's total land area.

Climate: The climate of the MHwh is characterized by short, cool, wet summers and cold, wet winters with much more snowfall and longer snowpack duration than in the CWHwh or CWHvh. Low cloud and fog are very common, and many sites experience high winds. Table 5.2 presents modelled climate attributes for the MHwh.

Vegetation: Climatic climax (zonal) forests in the MHwh are usually open with relatively short, tapered trees. The dominance and better form and vigour of mountain hemlock over western hemlock in zonal ecosystems distinguishes this zone from the CWHwh2 and CWHvh3. Yellow-cedar is often a co-climax tree species with mountain hemlock. Although Sitka spruce and western redcedar occur up to timberline on Haida Gwaii, they are very minor species and have poorer form and vigour than at lower elevations in the CWHwh and vh.

Understorey vegetation communities share many of the same species as zonal CWHwh2 and vh3 sites (e.g., oval-leaved and Alaska blueberry, red huckleberry, spleenwort-leaved goldthread, twayblades, deer fern, and feathermosses), but many species tend to increase in abundance in the MHwh (e.g., oval-leaved blueberry, spleenwort-leaved goldthread, small twistedstalk, alpine fir-moss, Indian hellebore, yellow-ladle liverwort, heron's-bill mosses, and pipecleaner moss [*Rhytidiopsis robusta*]). Others become rare or absent in the MHwh (e.g., salal and Oregon beaked-moss).

The scattered occurrence of several subalpine to alpine species, such as Alaskan mountain-heather (*Harrimanella stelleriana*), white mountain-heather (*Cassiope mertensiana*), club-moss mountain-heather (*C. lycopodioides*), yellow mountain-heather (*Phyllodoce glanduliflora*), partridge-foot (*Luetkea pectinata*), Newcombe's butterweed (*Sinosenecio newcombei*), and Sitka valerian (*Valeriana sitchensis*), help distinguish the MH from the CWH on Haida Gwaii. Frog pelt lichen (*Peltigera polydactylon*) and epiphytic lichens, such as common witch's hair (*Alectoria sarmentosa*) and the large foliose lungwort lichens (*Lobaria linita*, *L. pulmonaria*), tend to be significantly more abundant in the MH zone than in the lower-elevation CWH subzones.

Non-forested ecosystems in the MHwh include the mountain-heather and herb meadows that occur in high-elevation parkland (MHwhp) near treeline, and extensive subalpine blanket bog communities, which have very similar species composition as those communities that extend down to sea level in the CWHvh3 on the west coast.

Soils: Forested ecosystems in the MHwh usually occur on steep upper bedrock or colluvial slopes. Imperfectly drained Folisols and shallow Gleyed Podzols, often with thick, compacted LFH horizons (Resimors), typify zonal soils. The driest, exposed sites tend to have Folisols over bedrock or fragmental shallow Podzols. Gleysols and peaty organic soils (Mesisols) are typical of poorly drained forested sites and boggy habitats, respectively.

5.3 Coastal Mountain-heather Alpine Zone

Treeline on Haida Gwaii appears to be influenced by both climatic and edaphic factors, especially bedrock type. Lewis (1982) states that treeline is highest in areas of calcareous (limestone) bedrock and lowest over the hard, resistant volcanic and igneous bedrock types. Other factors such as soil depth, steepness of slope, and aspect also influence the upper elevational limit of trees. The control of treeline by both climatic and edaphic factors makes it difficult to generalize about the elevational boundaries of the subalpine and alpine zones throughout the islands. On the exposed west coast of Moresby Island (CWHvh3), plant communities on rocky headlands, steep rugged slopes, and blanket bogs extend to near sea level and have similarities to described alpine or subalpine ecosystems.

5.3.1 CMAwh, Wet Hypermaritime subzone

Location and distribution: The CMA of Haida Gwaii is designated as the CMAwh subzone and is floristically and ecologically distinct from alpine ecosystems on the adjacent coastal mainland. However, ecosystems described for the Brooks Peninsula, Vancouver Island (Hebda and Haggarty 1997) and Alaska (Viereck et al 1992) have similarities to those described in this guide. The CMAwh covers 2887 ha or 0.3% of Haida Gwaii's total land area. It occurs at the highest elevations (above ±800 m in the west; above ±900 m in the east) above the MHwhp, mostly in the Queen Charlotte Ranges (Figures 5.1 and 5.2).

Climate: A true alpine climate, with low growing-season temperatures, wide temperature extremes, and short frost-free periods, does not occur on Haida Gwaii. The development of alpine or alpine-like vegetation at the highest elevations is determined largely by an "oceanic–alpine" type of climate with heavy precipitation, deep, wet, and long-lasting snowpack, and extreme exposure to high winds and cool, humid air.

Vegetation: Herb meadows, alpine heath, and rocky steeplands comprise the three broad types of alpine ecosystems on Haida Gwaii. Herb meadows extend from subalpine to alpine and are dominated by grasses, sedges, and herbs. Some typical species are crowberry, tufted hairgrass (*Deschampsia cespitosa* ssp. *beringensis*), arrow-leaved groundsel (*Senecio triangularis*), cow-parsnip (*Heracleum maximum*), subalpine daisy (*Erigeron peregrinus*), Indian hellebore, Pacific reedgrass (*Calamagrostis nutkaensis*), large-awned sedge (*Carex macrochaeta*), Jeffrey's shootingstar (*Dodecatheon jeffreyi*), and partridge-foot.

Alpine heaths are dominated by members of the heather family, namely Alaskan, white, club-moss, and yellow mountain-heathers; bog and dwarf blueberries (*Vaccinium uliginosum* and *V. caespitosum*); and crowberry. In addition, many species of the herb meadows also occur in the heaths. Woolly lousewort (*Pedicularis lanata*), alpine bistort (*Bistorta vivipara*), and mountain sagewort (*Artemisia norvegica*) are three herbaceous species that are more common at higher elevations.

Rocky steeplands, including talus slopes, rock outcrops, cliffs, and wet runnels, though sparsely vegetated, provide habitat for many of the endemic, rare, and disjunct species on Haida Gwaii. Rare plants are often located in these habitats, especially those over calcareous bedrock. Early descriptions of the vascular plant communities that are typical of these rocky habitats and other subalpine and alpine ecosystems are provided in Calder and Taylor (1968). Later studies of the high-elevation vascular plant communities (Roemer and Ogilvie 1983; Ogilvie 1994) added several interesting taxa to the known flora of Haida Gwaii. Chapter 7 presents the current classification and descriptions of alpine site units on Haida Gwaii.

Soils: Soils of Haida Gwaii's alpine ecosystems have been little studied. Limited reconnaissance indicates that Folisols, consisting of very thin and discontinuous veneers of humus over bedrock or coarse colluvium, characterize the alpine heath soils. Many soils, especially on rocky steeplands, would be termed "non-soil" because they consist of <10 cm of organic material over rock. The soils of herb meadows are usually the deepest and often have well-developed surface Ah horizons due to the decomposition of grass and herb roots. Regosols, Brunisols, and Podzols have been described in the herb meadows.