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Bulkley Valley Centre for Natural Resources Research & Management

Landscape and Stand Scale Structure and Dynamics, and Conservation Ranking of Skeena River Floodplain Forests

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Executive Summary

Riparian forests are important for maintenance of biodiversity and ecosystem function. The Skeena River is the largest temperate river in the world without major dams, and has an expansive lower floodplain that is mostly unmodified by agricultural and urban development. However, logging during the 20th century has resulted in changes in forest cover on the floodplain. Highly productive coniferous stands that were logged have largely regenerated to deciduous-dominated forest.

Ecosystems of the area are classified into three types based on flooding dynamics and resulting vegetation: low, middle, and high bench. These ecosystems form a dynamic gradient and successional sequence that is influenced by the flooding regime.

The Sitka spruce-dominated high bench floodplain ecological community is now Red-listed by the BC Conservation Data Centre, as a result of developmental impacts. The black cottonwood-dominated middle bench floodplain ecological community, well represented in young to old stands on the lower Skeena, is Blue-listed (Conservation Data Centre 2004). Opportunity to manage the lower Skeena for conservation and commercial timber production while respecting its important fisheries, recreational and other values remains. Finding the appropriate balance between extractive and non-extractive uses in this unique landscape presents challenges for forest managers.

This project examined structure and dynamics of floodplain ecosystems at the landscape and stand scale, and ranked forested ecosystems for their conservation value. The aim was to provide direction to conservation and management of floodplain ecosystems.

At the landscape scale, Terrestrial Ecosystem Mapping (TEM), using air photos from 1947 and 1994/2003, provided baseline and current condition information on the state of floodplain forests. Comparisons and overlay procedures using Geographic Information Systems (GIS) showed that conifer-dominated stands have declined by 77% and that there has been a corresponding increase in young deciduous-dominated stands. These changes are evenly distributed across the floodplain.

Erosional processes are active with an average erosion rate on high and middle bench ecological communities of 5.8 metres (m) per year. Overall deposition rates are roughly in balance with the erosion rates, as the total area in low, middle and high bench has remained relatively stable over the study period. However, there is a loss of area in high and middle bench and a gain of area in low bench. Erosion contributes large amounts of wood to the river each year, with an average yearly input of 22,120 m^3 or 280 m^3/kilometre (km).

At the stand scale, we sampled primary Sitka spruce stands, primary deciduous stands, and secondary (post-logging) deciduous stands, and measured or described soils, stand structure, stand dynamics, regeneration, gaps, coarse woody debris (CWD), and vegetation composition and structure. Despite the difference in their ages, primary deciduous stands (mean age = 82 years (yr)) and secondary deciduous stands (mean age = 46 yr) had similar wood volumes (491 and 480 m^3/hectare (ha) respectively), while the primary Sitka spruce stands (mean age >250 yr) had much higher volumes (908 m^3/ha). The volume of CWD was uniformly low in all three stands types (118 m^3/ha). Conifer regeneration occurred almost entirely on CWD or stumps in the harvested stands.

The primary Sitka spruce stands were distinct from younger deciduous stands not only in tree species composition but also in their structural and species diversity. The Sitka spruce stands had significantly higher structural diversity and more canopy gaps, especially medium and large developmental (tree fall) gaps, than deciduous stands. They also had greater species richness and diversity in all vegetation layers. The secondary deciduous stands had greater species richness than the primary deciduous stands, likely due to existence of remnants of the pre-harvest plant community.

Results of this study indicate the need for, and the challenges of, a management plan for the study area that allows for forest harvesting while maintaining representative ecosystems. The harvesting–induced change from old growth to young deciduous-dominated seral stages currently exceeds the guidelines recommended in the BC Forest Practices Code Biodiversity Guidebook by a large margin (BC Ministry of Forests 1995a). Recruitment of old growth and conifer-dominated stands must be a high planning priority.

Large conifers play a crucial role in ecological integrity of the study area. Alive or standing as snags, large conifers provide perching, denning and nesting sites for wildlife, and serve as substrate for arboreal lichens. Dead and down, they provide slowly decomposing CWD for conifer establishment.

Large, slowly decomposing conifer logs also play a key role in logjam stability and back channel dynamics, providing fish and wildlife habitat and influencing erosion and deposition patterns. Small diameter and deciduous logs do not replace the large conifers in these functional roles. Existing conifers must therefore be maintained during harvesting, and management plans must include strategies for recruiting additional conifers. This objective can be achieved partly through placement of wildlife tree patches and riparian reserves on conifer patches. Retention and recruitment of old black cottonwood and red alder trees is also important for maintenance of biodiversity and wildlife habitat.

Acknowledgements

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1.0 Introduction

The Skeena River, in northwestern British Columbia, Canada, is the largest river without significant flow regulation in the temperate world (Dynesius and Nilsson 1994). Its lower floodplain remains largely unmodified by urban and agricultural development.

Riparian forests, particularly those associated with large rivers such as the Skeena, are important in maintaining biodiversity (Bayley 1995, Bunnell et al. 1999). Extensive clearcutting of riparian Sitka spruce forests occured in the 1950's and 1960's on the floodplain. Previously harvested areas now support second growth deciduous stands that are of harvestable size. The opportunity to manage for both commercial and conservation values now exists in the study area.

Because of extensive land development, damming, diking, and past harvesting, many floodplain ecological communities in British Columbia, including those on the lower Skeena River, are either Red- or Blue-listed by the Conservation Data Centre (CDC). Because natural processes still occur over most of the Skeena River floodplain, potential exists for restoration of Red- and Blue-listed old growth and conifer-dominated riparian forest ecosystems that may not be feasible on other river systems. Integration of endangered ecological community management and restoration with commercial forest harvesting requires detailed landscape and stand scale information.

The impetus for this project came from concerns about the status and extent of Red- and Blue-listed ecological communities on the Skeena floodplain, raised by staff in the BC Ministry of Environment in 2000. Furthermore, the Kalum Land and Resource Management Plan (LRMP) (BC Ministry of Sustainable Resource Management 2002a) directs resource managers to conserve vulnerable, rare, threatened, and endangered species and their habitat and ecological communities. Strategies listed to achieve this are to:

1. Identify and conserve vulnerable, rare, threatened and endangered habitats.
2. Determine where and to what degree Red- and Blue-listed species exist within the timber harvesting landbase.
3. Identify and manage critical habitats and ecosystems for vulnerable, rare, threatened and endangered wildlife species and ecological communities where resource development is planned.

The goal of this project is to provide baseline information for a comprehensive ecosystem management strategy for the Skeena River floodplain forests. This project has four components:

1. A review of the hydrology, geomorphology, and ecology of the Skeena River floodplain (de Groot 2005).
2. Landscape scale Terrestrial Ecosystem Mapping (TEM) using 1947, 1994 and 2003 aerial photography to determine floodplain dynamics and historical and present extent of Red- and Blue-listed ecological communities.
3. Stand scale comparison of forest structure at different successional stages.
4. Ranking of stands for conservation value.

Objectives are to:

1. Determine historical extent of floodplain ecosystems on the Skeena River.
2. Document landscape and forest dynamics and forest structure.
3. Make recommendations for conservation and restoration of listed ecological communities.

At the landscape scale, floodplain ecology information describes historical and present distribution and location of targeted communities, types and rates of geomorphic processes, and patterns of wildlife use.

Stand scale information provides additional detail regarding present condition, dynamics, structure, and diversity of floodplain plant and animal communities; and soils, gaps, tree regeneration and CWD.

Past forest harvesting on the floodplain was concentrated in old growth Sitka spruce[1] and western redcedar forests. Natural regeneration consisted predominantly of black cottonwood, with some red alder. On younger islands (typically less than 100 years old), unlogged forests are also dominated by black cottonwood and red alder. Both the primary (unlogged) and secondary (previously-logged) deciduous stands have a variable amount of conifer regeneration in the understory. Thus, while short-term harvesting will occur in deciduous stands, there may be opportunities to enhance the coniferous component of future stands.

The dynamic nature of the floodplain ecosystem presents important conservation challenges. While floodplain ecosystems may not change substantially in area over time, their locations shift constantly due to erosional and depositional processes. Low bench ecological communities, although not Red- or Blue-listed listed by the CDC, may eventually develop into listed middle and high bench ecological communities through primary successional processes. Managing the floodplain landscape to maintain representation of all bench types, including high benches in the desired old growth condition, requires long-term management planning to allow for recruitment of each successional stage (Burton 2000).

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[1] See Appendix 1 for Latin names of species used in the text.

2.0 Study Area Description

The Skeena River floodplain study area is downstream of Terrace, British Columbia. The study area encompasses parts of the Kalum and North Coast Forest Districts. The study area is 81.5 km long, with a mean width of 2.5 km, and a total area of 16,000 ha, of which 10,000 ha is vegetated, approximately 1,300 ha is gravel bar, and the remainder is river (Figure 1). The area in gravel bar and river will vary seasonally.

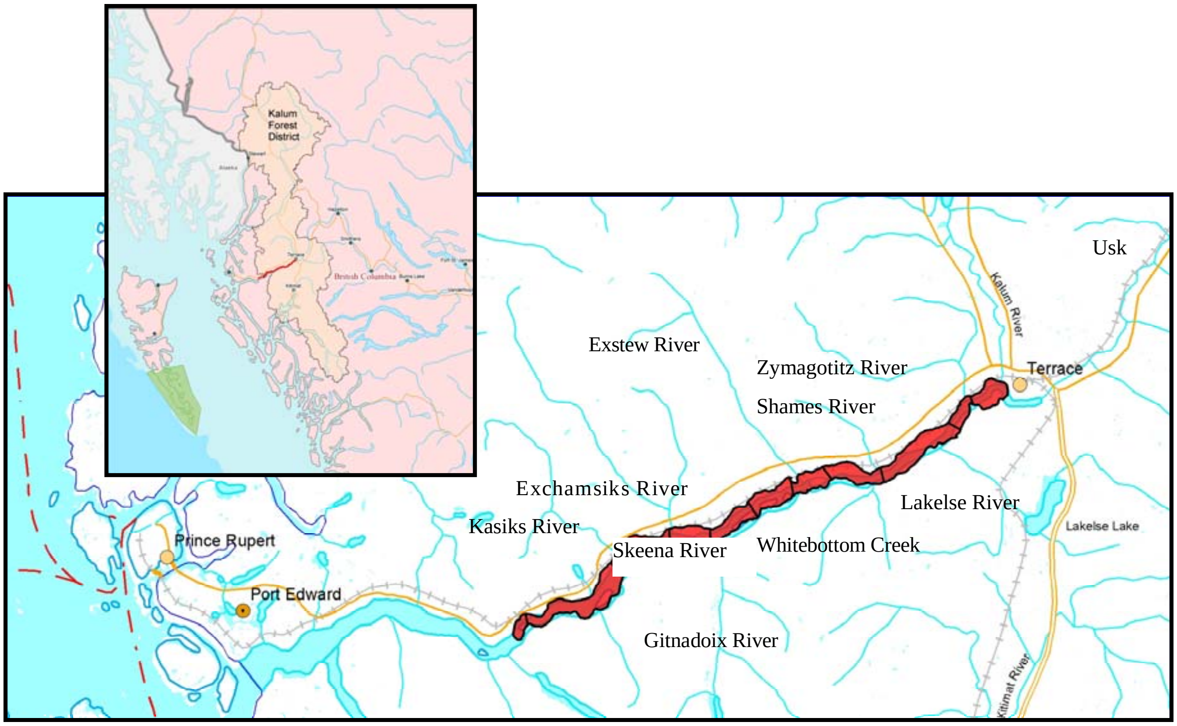

Figure 1. Location of study area.

The Skeena River is a large anastomosing alluvial river. Within the study area the Skeena River cuts through the Coast Mountain Range, and is confined by steep valley walls. The lower Skeena River has many side and back channels resulting from logjams and from shifting locations of gravel bars and islands. Islands range in size up to 300 ha, and are continuously changed by erosion and deposition (Schwab et al. 2002).

The elevation of the Skeena River floodplain ranges from near sea level at the western boundary of the study area near the Khyex River to approximately 50 m at Terrace. Tidal influence extends to the downstream boundary of the study area between the Khyex and Kasiks Rivers (Beaudry 1990). Here the frequency of vegetated islands in the Skeena River dramatically decreases.

The Skeena River has a total catchment area of 54,432 km^2 (Gottesfeld et al. 2002) and a mean annual discharge of 1,730 m^3/ha at its mouth. These statistics make the Skeena the 46th largest river in the world in terms of volume of ocean discharge (tributaries to other rivers not included) (Leopold 1994).

At the Usk gauging station, 15 km upstream of the study area, the Skeena River has a mean annual discharge of 910 m^3/second (sec) (Table 1) and a mean annual maximum and minimum discharge of 4,950 m^3/sec and 110 m^3/sec, respectively. The largest peak flow recorded at Usk was 10,194 m^3/sec in June 1936 (Septer and Schwab 1995). The annual peak flows on the Skeena are generally associated with spring snowmelt in the interior portions of the watershed.

Several large tributaries enter the Skeena River downstream of the Usk gauging station, both above and within the study area, including the Zymoetz, Kitsumkalum, Zymagotitz (a.k.a. Zymacord), Lakelse, Shames, Exstew, Exchamsiks and Gitnadoix rivers. Thus the actual discharge through the study area is higher than that recorded at Usk.

Table 1. Maximum recorded discharge and mean annual discharge for rivers in Skeena Watershed in or near the study area with water gauging stations (Water Survey Canada 2004), tributaries listed from upstream to downstream.

River Name	Period of record[1]	Maximum Recorded Discharge		Mean Annual Discharge (m^3/sec)
		(m^3/sec)	Date	
Skeena	1928 - present	10,194	June 3, 1936	910
Zymoetz	1952 - present	3,140	Nov. 1, 1978	137
Kitsumkalum	1929 – 1952	883	June 3, 1936	123
Zymagotitz	1960 – 1995	549	Oct. 10, 1974	24
Exchamsiks	1962 - present	864	Nov. 1, 1978	43

[1] Record may not be continuous for entire period.

3.0 Ecological Communities and Ranking

The study area falls within the wet submaritime (CWHws) and very wet maritime (CWHvm) subzones of the Coastal Western Hemlock biogeoclimatic zone (Banner et al. 2003). A strong Coast-Interior climatic gradient of decreasing precipitation and increasing temperature extremes across the study area is reflected in the floodplain vegetation. Maritime and estuarine species such as Pacific crabapple and false lily-of-the-valley are more abundant to the west, whereas dominantly continental species such as highbush-cranberry, Douglas maple and snowberry are more abundant inland.

There are three dominant ecological communities or site series on the Skeena River floodplain occurring on low, middle, and high fluvial benches, respectively (Banner et al. 1993). These communities represent a successional sequence, with growing conditions changing through time in response to depositional processes, and with plant and animal communities also changing as they mature (McLennan 1995a, MacKenzie and Moran 2004). Two of the dominant ecological communities are listed by the CDC. The high bench Sitka spruce – Salmonberry ecological community (CWHws1/07 and CWHvm1/09 site series) is Red-listed, while the middle bench Black cottonwood – Red-osier dogwood ecological community (CWHws1/08 and CWHvm1/10) is Blue-listed (BC Species and Ecosystems Explorer 2003)[2]. These plant communities are considered to be at risk because they are globally and provincially rare, occupying a small proportion of the coast temperate rainforest landscape. Their valley bottom location and high productivity make them prime sites for development; and they are highly sensitive to changes in river hydrological and disturbance regimes.

The low bench Black cottonwood – Willow ecological community (CWHws1/09 and CWHvm1/11 site series) is less frequent and less extensive provincially and regionally than either the high or middle bench ecological communities but is not currently listed by the CDC. Because they do not support merchantable timber and usually represent a young successional stage, this ecological community is perceived to be at lower risk. Other ecological communities on the floodplain are the Cedar – Skunk cabbage (CWHvm1/14 and CWHws1/11) found in backchannel areas and the Hemlock – Balsam - Bramble (CWHws1/01) found on inactive fluvial deposits.

The CDC uses a standardized methodology to rank species and communities (all called “elements" by the CDC) for their conservation status according to their commonness or rarity. Each element is ranked using the system developed by NatureServe in the US at two levels (Table 2):

- Global (G)
- Provincial or Subnational (S)

The global rank is based on the element’s status throughout its entire range while the provincial rank is based on its status in BC. The global rank is established by an ecologist assigned to the element by NatureServe. The provincial rank is established by ecologists at the CDC. Ranking factors include number and quality of occurrences, area, range, trend, threats, and number of protected occurrences.

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[2] Previously the CDC included the descriptor of the mature ecological community of the ecosystem of interest - often this was structural stage 7 (old forest). This was often interpreted to mean that occurrences in a younger structural stage or an earlier successional stage were not valuable, and therefore did not need special management consideration. However, younger structural stages are often valuable for conservation, as they allow for the recruitment of older stages over time. The CDC has now removed structure and successional stage considerations from their ranking.

The CDC also compiles Red, Blue and Yellow lists of elements. These lists are designed to simplify interpretation of the ranks. All plant communities ranked as S1, S1S2, S2 and S2? by the CDC are assigned to the Red list. Communities ranked S2S3, S3 and S3? are assigned to the Blue list. For purposes of this report, we use only the designation Red or Blue for plant communities. There is a lack of information about rare plant communities in the province and further inventory, classification and refinement of the lists are needed, especially for non-forest communities.

Each occurrence of an element can also be ranked. Element Occurrence (EO) ranks provide an estimate of the viability or probability of persistence of an occurrence based on its condition, size, and landscape context. In other words, EO ranks provide an assessment of the likelihood that if current conditions prevail, an occurrence will persist for a defined period of time, typically 20-100 years. The most important factor for EO rankings on the Skeena River floodplain is the structural and successional stage of the ecosystem. Many of the other EO ranking factors are similar among all element occurrences on the floodplain.

Table 2. Conservation status ranks and definitions. The prefixes G (global) and S (provincial or subnational) are used with the conservation status rank to indicate geographical extent of the rank (Douglas et al. 1998).

Conservation Status Rank	Definition
X	**Presumed extinct or extirpated** – not located despite intensive searches and no expectation that it will be rediscovered.
H	**Historic –** not located in the last 50 years, but some expectation that it might be relocated.
1	**Critically imperilled** – because of extreme rarity or some other factor(s) making it especially susceptible to extirpation or extinction. Typically 5 or fewer extant occurrences or very few remaining individuals.
2	**Imperilled –** because of rarity or some factor(s) making it very susceptible to extirpation or extinction. Typically 6-20 extant occurrences or few remaining individuals.
3	**Vulnerable –** because rare and local, found only in a restricted range (even if abundant at some locations), or because of some other factor(s) making it susceptible to extirpation or extinction. Typically 21-100 extant occurrences.
4	**Apparently Secure –** because uncommon but not rare, and usually widespread. Possible cause for long-term concern. Typically more than 100 extant occurrences.
5	**Secure –** because common to very common, typically widespread and abundant, and essentially under no threat under present conditions.
U	**Unrankable –** due to current lack of available information.
S#S#	**Range rank –** a numeric range (e.g., S2S3) is used to indicate the range of uncertainty about exact status.
Q	Question about taxonomy of the rare element.
T	Rank associated with a subspecies or variety.
?	Limited information is available and the number of occurrences is expected to be greater.

The structure and successional stage of a floodplain forest are important aspects of its contribution to overall functioning of the floodplain landscape and its value for wildlife and fish. For example, large old spruce and western redcedar trees, which provide long-term stability for logjams (Naiman et al. 2002), supply bedding, denning and nesting sites for wildlife (McComb and Lindenmayer 1999), and support nitrogen-cycling canopy lichens and bryophytes (Marcot 1997), are mostly absent in early successional stages. Large old black cottonwood trees also provide keystone ecological functions in riparian ecosystems, for example, serving as perching and nesting sites for bald eagles, providing sites for primary and secondary cavity nesting species especially bats, owls and swifts, providing large denning cavities for bears, and serving as a substrate for rare lichen species (Peterson et al. 1996, Selva 2003). While younger structural and successional stages (e.g., shrub-dominated and pole-sapling stands) also make unique and important contributions to landscape function and habitat value, these structural stages are believed to have been less compromised by human activities.

4.0 Methods

4.1 Landscape Scale Mapping and Analysis

4.1.1 Mapping

The floodplain ecosystems were mapped following TEM guidelines (Ecosystems Working Group 1998) using three sets of aerial photographs: 1947 (1:31,680), 1994 (1:15,000) and 2003 (1:30,000). The 2003 photographs were used only for portions of the study area without 1994 photo coverage. Polygons identified on air photos were digitized and orthorectified using a monorestitution process and transferred to base maps at 1:20,000. Existing TEM, which also used 1994 aerial photography (Madrone 1997), was utilized for part of the study area. Sampling intensity for the TEM, done in conjunction with stand scale sampling, was quite low as there are few terrain types and ecological communities within the study area and a good signature was obtained for air photo typing after sampling relatively few polygons.

On 1994 and 2003 air photos, it was not possible to distinguish middle bench ecological communities (CWHws1/08 or CWHvm1/10 site series) dominated by deciduous tree species (primary deciduous) from high bench ecological communities (CWHws1/07 or CWHvm1/09 site series) that had regenerated to deciduous trees after harvest (secondary deciduous). Ecological communities identified on the 1947 photographs, which predated most clearcut logging, were thus transferred to the 1994 mapping, except where erosion had removed old landforms and deposition had created new ones over the study interval. The existing TEM (Madrone 1997) was modified to reflect the 1947 stand types.

The lateral distribution of ecological communities was examined by calculating the area of each ecological community type in 200 m wide bands from the middle of the mainstem of the river (thalweg).

4.1.2 Analysis of Erosion and Deposition

Geographic Information System technology, with overlay procedures, was used to determine the current and historical extent and distribution of site series, and to determine the areal extent of erosion and deposition that occurred within the study area between the photography dates. Procedures were adapted from Richards et al*.* (2002), Schwab et al*.* (2002), and O'Connor et al. (2003). There is some uncertainty associated with quantitative assessments of changes in channel position over time. These uncertainties are mostly associated with differences in flow stage, line placement errors, and errors in registration and digitizing (O'Connor et al. 2003). The BC Ministry of Sustainable Resource Management standard for transfer of linework from photographs is that lines must be within 20 m of their location on air photos (BC Ministry of Sustainable Resource Management 2002b); this is the standard that applies to this project. The actual amount of error was greater on the smaller scale photographs from 1947 (1:31,680) and 2003 (1:30,000) photographs than the larger scale 1994 (1:15,000) photographs. O'Connor et al*.* (2002) also assumed the maximum error on recent maps and air photos to be 20 m.

Annual erosion rates (m/yr) were calculated by dividing the eroded area (m^2) by the total length of the river within the study area (81,500 m) or within a river reach and the duration of the mapping period – 47 years for 1994 photographs and 56 years for 2003 photographs.

Polygons often contain more than one terrain or ecological community (EC). In TEM, such complex polygons are indicated through the use of deciles (i.e., 7EC1, 3EC2; Ecosystems Working Group 1998). Although we used deciles to determine areal extent of ecological communities on 1947 and 1994/2003 TEM maps, it was not possible to use deciles when calculating areas in the overlay process. The leading ecological community (EC1) was therefore used to represent the entire polygon in overlays and resulting transition analyses. Minor site series such as Shrub – Herb were either merged with the most similar major site series (e.g., Black cottonwood – Willow low bench) or called Other, to produce more meaningful results, as the overlay process is sensitive both to the errors discussed above and to uncertainty in the classification (Richards et al. 2002).

The reach designations of Schwab et al. (2002) (Table 3) were used to investigate longitudinal trends along the river.

Table 3. Summary description of reaches on the Skeena River in the study area (adapted from Schwab et al. 2002).

Reach	Location	Length (km)	Valley flat extent[1]	Valley wall confinement[2]	Channel pattern[3]	Channel islands[4]
1	Telegraph Point to Kwinitsa	2.0	Continuous	Partial	Sinuous, split	Split
2	Kwinitsa to Kasiks R.	15.1	Fragmentary	Confined	Sinuous	Frequent irregular, anastomosing
3	Kasiks R. to Exchamsiks R.	9.0	Continuous	Partial	Sinuous, irregular	Frequent irregular
4	Exchamsiks R. to Gitnadoix R.	6.4	Continuous	Partial	Straight, sinuous	Anastomosing split,
5	Gitnadoix R. to Hudson Bay Flats	6.6		Partial	Straight	Anastomosing
6	Hudson Bay Flats to Exstew R.	6.6	Fragmentary	Continuous	Straight	Anastomosing
7	Exstew R. to 5 km east of Exstew R.	5.1	Fragmentary	Continuous	Sinuous	Split, Anastomosing
8	5 km east of Exstew R. to Shames R.	7.4	Fragmentary	Continuous	Sinuous	Split, Anastomosing
9	Shames R. to Lakelse R.	12.0	Fragmentary	Continuous	Sinuous	Anastomosing
10	Lakelse R. to Zymagotitz R.	4.2	Fragmentary	Continuous	Straight	Frequent irregular
11	Zymagotitz R. to Terrace	7.1	Fragmentary	Partial	Sinuous	Anastomosing

[1] Relatively flat surfaces on the valley floor subject to flooding.

[2] Extent to which the river is deflected by the valley wall.

[3] Sinuous - slight curvature to the channel; irregular - no repeatable channel pattern.

[4] Frequent irregular - frequently overlapping islands; split - continuously overlapping islands; anastomosing - continuously overlapping islands with two or more flow branches.

4.1.3 Wood Inputs

An estimate of wood inputs to the river was made by multiplying the eroded area by the average volume of wood per hectare in these stands. As detailed in Section 5.2.2, we recorded an average volume of 908 m^3/ha in primary Sitka spruce high bench stands and 491 m^3/ha in primary deciduous middle bench stands. These mean volumes were used when calculating wood inputs from primary stands. Two estimates of wood inputs are provided: potential inputs, which assumes that all stands were unharvested primary stands, and actual inputs, which adjust the input for harvesting activities and regeneration on these secondary stands, using the following assumptions:

1. An equal amount of erosion occurred each year, and affected harvested and non-harvested areas equally.

2. All harvesting occurred on high benches in 1964, the midway point between the 1958 commencement and the 1970 cessation of harvesting.

3. All harvesting was by clearcut.

4. Regeneration was to deciduous species with a uniform mean annual increment of 10.4 m^3/ha/yr based on the mean volume in secondary stands of 480 m^3/ha after 46 years (Section 5.2.2) [3]. For example, after 15 years of the 30-year regeneration period between 1964 and 1994 the input was 156 m^3/ha from the 12.4 ha of secondary middle bench calculated to have been eroded that year.

All volume calculations were for the period 1947 to 1994 for which we had data for the entire study area, and were adjusted to account for age differences between 1994 and 2003 photography.

4.2 Stand Scale Sampling and Analysis

4.2.1 Stand Selection

Floodplain forests were stratified into three dominant stand types for sampling:

1. Old unlogged Sitka spruce-dominated stands resulting from primary succession (i.e., Sitka spruce – Salmonberry high bench site series CWHws1/07 and CWHvm1/09; Figure 2).
2. Younger unlogged deciduous-dominated stands resulting from primary succession (i.e., Black cottonwood – Red-osier dogwood middle bench site series CWHws1/08 and CWHvm1/10; Figure 3).
3. Young deciduous-dominated stands resulting from secondary succession after logging (i.e., previously-logged Sitka spruce – Salmonberry high bench site series CWHws1/07 and CWHvm1/10; Figure 4).

Potential sample stands were selected non-randomly in the office from aerial photography, forest inventory and silviculture maps to obtain broad sample distribution across the study area and a good representation of map polygons. Secondary deciduous stands were preferentially located in areas with the oldest clearcut logging on the floodplain with few residual trees. Safe boat access, logistics, and cost constraints were important factors preventing a random selection of sampling sites.

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[3] This is lower than the maximum mean annual increment of 13.6 m^3/ha/yr reported by Bunce (1990) on the Skeena River floodplain.

Figure 2. Typical primary Sitka spruce stand type.

Figure 3. Typical primary deciduous stand type.

Figure 4. Typical secondary deciduous stand type.

4.2.2 Field Data Collection

Linear transects measuring 150 to 300 m were established in each stand with the starting point and orientation determined before entering the stand from air photos and maps. Canopy gap measurements were made along the length of each transect. Gaps were defined as the vertical projection onto the ground of the canopy opening (Runkle 1982). Gaps were classified as small (longest axis <1 tree canopy), medium (1 tree canopy ≤longest axis <1 tree length) or large (longest axis ≥1 tree length wide). Gap causes were classed as developmental (tree(s) uprooted, snapped, cut, or standing dead) or edaphic (wet channel). Gaps were also categorized as recent (≤5 yr), intermediate (5 <yr ≤20), or old (>20 yr), and filled (with recruited subcanopy trees) or open (no recruited trees). Understory shrubs were also categorized as either dense (≥20% cover) or sparse (<20% cover) along the length of the transect.

Beginning at 50 m on each transect, 1-3 plots were located at 100 m intervals. Ocular estimates of vegetation percent cover by layer (dominant tree, co-dominant tree, sub-canopy tree; tall shrub (2 – 10 m), low shrub (<2 m); herb; forest floor non-vascular and epiphytic non-vascular) and species were made within nested quadrats at each plot. Quadrat sizes were two 1 m x 1 m quadrats for non-vascular, one 10 m x 10 m quadrat for herbs and shrubs and one 30 m x 30 m quadrat for trees.

Stand age was estimated from 2 - 7 increment cores per stand and modified using silvicultural map information, where available. Old growth stands with very large decayed trees were arbitrarily assigned as >250 years old.

Diameter at breast height (DBH) was measured and total height estimated for all live and dead trees in quadrats measuring 50 m x 50 m (for all tree sizes in primary Sitka spruce stands; for trees >1 m DBH and all stumps in deciduous stands) and 30 m x 30 m (for deciduous stands with 7.5 centimetre (cm) <DBH <100 cm). Trees <7.5 cm DBH were tallied within 30 m x 30 m quadrats on half of the plots for each stand type.

At each plot, CWD volume was measured on two 30 m linear transects. Decay class, piece length, piece height, and degree of piling were recorded (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998).

Non-vascular abundance by substrate and life form (Table 4) was recorded using a line intercept approach. A 90 m transect length was used to tally fallen arboreal lichens, and a 30 m transect length was used for the remaining nine categories.

Table 4. Categories used for non-vascular plants.

Substrate	Life form
Arboreal (fallen)	Lichen
Epiphytic (live tree and shrub bases)	Lichen
	Moss
	Hepatic
Epixylic (dead wood)	Lichen
	Moss
	Hepatic
Forest floor	Lichen
	Moss
	Hepatic

The number of stands sampled per type ranged from 4 to 7, and the total number of plots per type ranged from 12 to 14 (Table 5). All stands showed evidence of flooding on tree boles, though we were unable to determine when flooding occurred (Figure 5). One primary stand had evidence of minor western redcedar pole removal; otherwise there was no evidence of human disturbance in the primary stands. A significant blowdown event affected one secondary deciduous stand, but there was no other evidence of significant natural disturbance agents such as insect outbreaks, root pathogens, or storm damage. Two of the primary Sitka spruce stands were in a mature rather than an old growth (>250 yr) structural stage (Table 5). Although dominated by Sitka spruce, these stands contained abundant residual black cottonwood trees and were evidently in a transitional successional stage.

Table 5. Number of stands and plots sampled, and stand age.

Parameter	**Stand type**		
	Primary Sitka spruce forest	**Young deciduous forest**	
		Primary	**Secondary post-logging**
# of stands sampled	4	7	6
# of plots	12	14[2]	14[3]
Average stand age (years) ± standard deviation	228[1] ± 52	82 ± 26	46 ± 6

[1] Two stands were 110 and 125 years old, the remainder were arbitrarily assigned an age of > 250 years.

[2] One plot had minor western redcedar removal.

[3] Twelve plots were clearcut, two plots had residual conifers present, one plot had significant blowdown.

Figure 5. Flooding evidence, as shown by silt deposits on tree boles, and stump from western redcedar poling (foreground). Note sparse understory under a western redcedar canopy.

The sampled stands were not evenly distributed over the study area because of the uneven distribution of stand types on the landscape. The secondary deciduous stands and the primary Sitka spruce stands were, on average, located closer to the Coast than primary deciduous stands. This makes it difficult to fully separate the effects of stand type from the effects of the Coast-Interior climatic gradient.

Wildlife habitat and usage notes were collected at all stages of fieldwork. These notes were primarily qualitative rather than quantitative and are briefly summarized in Section 5.1.4.

4.2.3 Data Analysis

Stand volume for live merchantable trees over 17.5 cm DBH was calculated using the program CruiseComp 2002.1 (ORM Resources 2002), without compensating for pathological or quality indicators. The measured diameter of the stumps was converted to DBH using formulas of Omule and Kozak (1989). CWD volume was calculated using the formula:

$$V = (\pi^2 / 8L) \times \Sigma d^2$$

Where V = volume of CWD in m^3/ha, L = length of transect in m, and d = diameter of CWD in cm at transect crossing.

Understory, tree canopy, and stand diversity were calculated using the Shannon index (Shannon and Weaver 1949) using the percent cover of all species by layers. Species richness was tallied on a per plot basis.

Differences among attributes of stand types were tested using two-way ANOVAs, with a-priori orthogonal contrasts done where the ANOVA p-value exceeded 0.10. Contrast 1 compared the primary Sitka spruce stands to primary and secondary deciduous stand types. Contrast 2 compared the primary (unlogged) and secondary (post-logging) deciduous stands. The distance inland (UTM east coordinate) was used as co-variable in all analyses as this was determined to be a significant factor affecting stand structure and composition across the Coast-Interior climatic gradient. To remove sampling bias, the person who recorded the data was also used as a co-variable for all analyses, and was found to have a significant effect on some soil and non-vascular abundance descriptors. Soil moisture regime (SMR) was initially tested as a co-variable for the diversity indices to remove any influence of soil moisture on diversity; however, this effect was found to be non-significant. For binary comparisons (i.e., % of soils with a given diagnostic character) a Pearson's chi-square statistic was used to test for the equality of proportions among stand types.

We used non-metric multidimensional scaling (NMS) (Clarke 1993) with a Bray-Curtis distance measure (Legendre and Legendre 1998) to ordinate untransformed vegetation percent cover data for the complete plant community (overstory and understory plant species) and for the understory community only (all plants <10 m in height). We used a random starting configuration, 100 iterations with real data, and a Monte Carlo test with 999 randomized runs to evaluate the significance of the ordination axes. We began with 6 axes and set a maximum stress level of 15 for choosing the final number of axes (Clarke 1993, McCune et al. 2002). Major plant species (top 20 in frequency or abundance) with Pearson's r^2 correlations >0.20 and/or Kendall's rank correlation >0.30 on one or more ordination axes were included as species vectors. Environmental and stand structural variables with r^2 >0.20 and rank correlation >0.30 on the primary axes were overlain onto the ordination using a joint plot approach (McCune et al. 2002). Sample ellipses encompassing 68.3% of the range of variability in species composition on the two dominant axes were delineated for each stand type.

Canonical redundancy analysis (RDA) was used to test for significant differences among stand types, to test for relationships between environmental variables and plant community composition, and to control for the effect of environmental factors such as distance from the coast and soil moisture regime on the expression of stand types (Legendre and Legendre 1998).

We used PC-ORD v. 4 (McCune and Mefford 1999) for NMS, CANOCO v. 4 (ter Braak and Smilauer 1998) for RDA and SYSTAT v. 11 (SYSTAT Software Inc. 2004) for univariate ANOVA, linear regression and ordination ellipses.

4.3 Conservation Value Ranks

The TEM mapping component demonstrated that the area occupied by conifer-dominated stands was reduced by 77% after 1947. A key feature of conservation and restoration efforts would therefore be protection of remaining conifer-dominated stands and recruitment of additional conifer-leading stands.

Digital air photos were taken of the study area in April 2005 before deciduous trees had leafed out, to enable identification and mapping of stands with abundant conifers, especially understory conifers.

The TEM polygons were overlaid on the orthorectified digital air photos and each TEM polygon containing high or middle bench was ranked for its conservation value. Detailed specifications for ranking EOs were developed following CDC protocols (NatureServe 2002); these specifications appear in Appendix 5. Because it is difficult to determine bench height on air photos and because there is a successional continuum of bench height, all floodplain stands were ranked as if they were high benches. However, deciduous stands were assigned a lower rank than coniferous stands in recognition of the Red-list status of the conifer-dominated high bench ecological community and the Blue-list status of the deciduous-dominated middle bench ecological community.

Each polygon or EO was ranked for its condition (seral stage, conifer abundance, degree and permanence of anthropogenic disturbance), landscape context (level of development, barriers to movement, landform stability, and hydrological regime) and size. These ranks were weighted and summed to arrive at a final rank. Because most deciduous-dominated polygons were assigned a “B” ranking, a subranking procedure was developed for B-ranked polygons. This subranking used amount of conifer regeneration and remnant conifer structure in the stand to identify stands of higher and lower conservation value. Colour-themed maps were then produced to show the spatial distribution of conservation values.

5.0 Results

5.1 Landscape Scale

5.1.1 Ecological Community Area and Distribution

Historically the Skeena River floodplain contained equal amounts of deciduous-dominated middle bench stands and conifer-dominated high bench stands, with small areas of other forest types (Table 6). The greatest change in area between 1947 and 1994/2003 occurred in the Sitka spruce – Salmonberry high bench ecological community where there was an 84% decrease in area of old growth conifer-dominated structural stage 7 from 2,516 ha to 404 ha, and a 64% decrease in area of mature conifer stands (1,380 ha to 502 ha), for an overall decrease of 77%. Of the 906 ha of structural stage 6 and 7 Sitka spruce forests presently remaining on the floodplain, 280 ha (31%) have experienced some level of forest harvesting and are no longer in pristine condition. The percentage of total floodplain forest area containing old and mature conifer stands declined from 45% to 11% (Table 7). There was a corresponding increase in area in younger structural stages on high benches. This is most evident in structural stage 4 stands, which increased from 0 ha to 1,411 ha, but there were also large increases in structural stage 1-3 and 5 stands on high benches. Not all of the decline in old and mature Sitka spruce forests can be attributed to harvesting activities, as erosion has also been actively removing forests, as discussed below.

Table 6. Change in area of ecological communities and structural stages between 1947 and 1994/2003.

Ecological community	Structural stage	1947 (ha)	1994/2003 (ha)	Change (ha)	Change (%)
Cottonwood – Willow low bench	1 - 3	499	695	194	39
	4	255	431	176	69
	5	26	6	-21	-78
	Total	780	1,132	352	45
Cottonwood – Red-osier dogwood middle bench	1 - 3	176	297	121	69
	4	1,052	1,273	221	21
	5	2,237	1,648	-589	-26
	6	625	655	30	5
	7	0	9	9	
	Total	4,090	3,882	-151	-4
Sitka spruce – Salmonberry high bench	1 - 3	42	800	758	1904
	4	0	1,411	1,411	
	5	314	897	583	285
	6	1,380	502	878	-64
	7	2,516	404	2,112	-84
	Total	4,251	4,012	-239	-6
Hemlock – Balsam – Bramble	3 – 5	0	89	89	
	6	120	21	-99	-83
	Total	120	111	-9	-22
Cedar – Skunk cabbage	1 – 3	3	80	77	2666
	4	45	63	18	40
	5	0	29	29	
	6	93	27	-66	-71
	7	99	29	-70	-71
	Total	241	227	-14	-6
Shrub – Herb		72	57	-15	-21
Gravel bar		1,118	1,237	119	11
River		4,583	4,597	13	0

Table 7. Change in area with conifer-dominated high bench structural stage 6 and 7 stands between 1947 and 1994/2003, by reach.

Year	Parameter	*Kwinitsa*		Reach						*Terrace*			
		1	2	3	4	5	6	7	8	9	10	11	Total
1947	Structural stage 6 stands (ha)	6	179	97	141	132	102	9	261	303	51	100	1,380
	Structural stage 7 stands (ha)	17	416	700	106	197	80	148	230	339	254	31	2,516
	Total (ha)	23	594	796	247	329	182	157	491	642	304	131	3,896
	Total forested area (ha)	80	1,481	1,327	711	604	726	532	819	1,319	416	686	8,701
	% of total forested area	29	40	60	35	55	25	29	60	49	73	19	45
1994/ 2003	Structural stage 6 stands (ha)	48	59	30	8	14	9	49	125	63	54	45	502
	Structural stage 7 stands (ha)	0	107	108	2	53	13	0	23	69	22	7	403
	Total (ha)	48	166	138	10	67	22	49	148	131	76	52	905
	Total forested area (ha)	126	1,431	1,193	658	614	623	525	760	1,242	406	658	8,236
	% of total forested area	38	12	12	2	11	4	9	20	11	19	8	11
Change in area with conifer stands (%)		+50	-72	-83	-96	-80	-88	-69	-70	-80	-73	-61	-77
Change in forested area (ha)		+46	-50	-134	-53	+10	-103	-7	-59	-77	-10	-28	-465

There was a large decrease in area of structural stage 5 (late immature) stands on Cottonwood – Red-osier dogwood middle benches. These stands often have a large conifer component, and would have been targeted for harvesting. Some present-day structural stage 5 stands and most structural stage 4 stands are second growth stands resulting from logging. On high and middle benches, increases in structural stages 1 and 2 are mostly due to road, railway and agricultural developments, while increases in structural stage 3 are partly due to powerline developments. Changes in minor types such as logjams, Shrub – Herb, and Cedar – Skunk cabbage, need to be interpreted with caution due to the difficulty of accurately delineating these on smaller scale air photos.

In reaches with a substantial amount of high bench forest, the decline in area with mature and old structural stages varied from 61% to 96%. There was no evidence of either an upstream or downstream longitudinal trend in the abundance of mature and old structural stages or in the proportion of these stands remaining unharvested (Table 7, Figures 6 and 7).

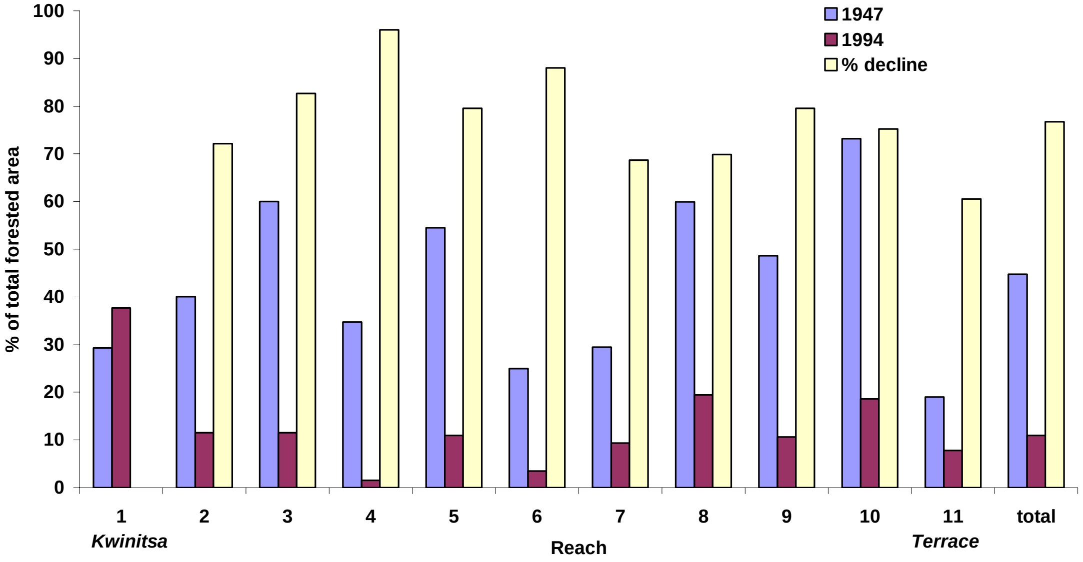

Figure 6. Change in percent of each reach with high bench Sitka spruce stands in structural stages 6 and 7 between 1947 and 1994, and percent decline.

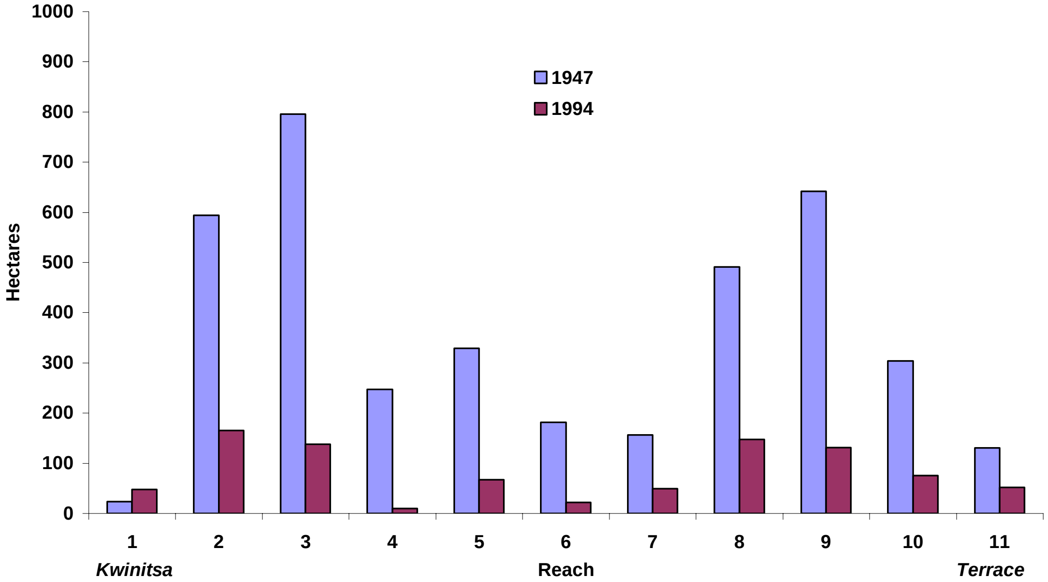

Figure 7. Total area (ha) containing high bench Sitka spruce stands in structural stages 6 and 7 in 1947 and 1994, by reach.

5.1.2 Erosion and Deposition

Assumptions made when calculating the areal extent of erosion and deposition have a major influence on the outcome. For example, the above comparison of areas of different ecological communities, done without an overlay, found an overall net loss of 259 ha of high bench area and 151 ha middle bench (Table 6). However, this analysis did not account for successional processes taking place over the 47 years between photographs. When an overlay is used, it is possible to account for successional processes and to determine the source of any transitions. For high bench ecological communities, the major transitions were: 587 ha lost to river, 100 ha lost to gravel bar, 60 ha to low bench, 312 ha lost to middle bench, 169 ha gained from river, 29 ha gained from gravel bar, 31 ha gained from low bench, and 571 ha gained from middle bench (Table 8). These figures indicate that 1,059 ha of high bench eroded with some area undergoing succession to forested ecosystems over the intervening 47 years. Given that it is not possible to recruit high bench ecological communities from river, gravel bar, and low bench in 47 years, the results in Table 8 clearly include a percentage of mapping error.

Table 8. Ecological community transitions (ha) between 1947 and 1994/2003 using leading community only. Shading indicates area that was unchanged between time periods. For example, of total area in middle bench in 1947, 2,299 ha was still middle bench in 1994/2003 while 876 ha changed to river. Of total middle bench area in 1994/2003, 529 ha was river in 1947. Minor area transitions may be due to either line error on smaller-scale 1947 photographs or polygons having minor ecological community components that could not be used in this analysis. An expanded version of this table is included as Appendix 4.

		1994/2003							
	Ecological community	**River**	**Gravel bar**	**Low bench**	**Middle bench**	**High bench**	**Other**	**Total 1947**	**% unchanged**
1947	River	2,495	654	458	529	169	24	4,330	58
	Gravel Bar	379	200	176	464	29	13	1,261	16
	Low Bench	135	57	70	347	31	13	653	11
	Middle Bench	876	302	219	2,299	571	36	4,303	53
	High Bench	587	100	60	312	3,197	89	4,345	74
	Other	28	10	4	31	97	195	370	53
Total 1994/2003		4,500	1,322	986	3,982	4,095	364	15,255	
Change from 1947 (ha)		+170	+61	+333	-321	-250	-6		
Area change (%)		+5	+5	+51	-8	-6	-2		

To address this error, we made several simplifying assumptions:

1. The transitions between middle and high bench ecological communities are due to difficulties in distinguishing between these forest types on air photos, especially post-harvesting.

2. There was more error in smaller-scale 1947 photographs.

3. Improbable transitions from river and younger successional stages to high bench were due to either minor inclusions in complex polygons, or line placement error on smaller-scale photographs.

The validity of these assumptions was checked by finding locations of the largest transition polygons (>2 ha) and determining their cause. For example, stable sidechannels were often wider on maps derived from 1947 photographs than those from 1994 photographs, indicating line placement error, most likely on the smaller scale photographs. This would appear on the transition analysis as a transition from river to a forested landform, usually high bench, because high benches dominate areas adjacent to sidechannels.

Some of the smaller changes could be due either to line placement error on smaller scale 1947 photographs (1:31,680) and 2003 photographs (1:30,000), or to the difficulty of typing out small units on smaller scale photographs. Moreover, some polygons had several ecological communities that could not be included in the transition overlay analysis.

Using the above assumptions, the total area of eroded high bench is 747 ha (was high bench and now is river, gravel bar, or low bench), and the total area of eroded middle bench is 1,397 ha (was middle bench and now is river, gravel bar, or low bench) for a total of 2,144 ha of eroded forest (Table 8).

There were large increases in areas of low bench and gravel bar. The increase in gravel bar may be the result of river stage when the photographs were taken. The increase in low bench may indicate aggradation is occurring in the low bench ecosystem. To investigate this, the location of the changes in low bench by reach was calculated (Table 9). The greatest gain in low bench occurred near the downstream end of the study area in Reach 2. There was also a gain in forest area in Reach 1 (Table 7), possibly indicating aggradation in these downstream areas.

Table 9. Area and percent change in low bench between 1947 and 1994/2003, by reach.

Year	Parameter	*Kwinitsa*					Reach					*Terrace*	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
1947	Low bench (ha)	48	195	38	0	37	60	85	56	111	0	23	653
1994	Low bench (ha)	49	337	48	40	102	54	73	98	116	14	56	986
Change in area in low bench (ha)		+1	+142	+10	+40	+65	-6	-12	+42	+5	+14	+33	+333
Change in area in low bench (%)		+2	+72	+24		+176	-22	-17	+76	+4		+149	
% of total gain in low bench area		1	41	3	12	19			12	1	4	10	

The transition matrix showed which ecological communities were most stable, and where the greatest changes occurred. High bench ecological communities were most stable, with 74% of the area classified as high bench in 1947 still being classified as high bench in 1994/2003 (Table 8). The least stable ecological communities were the low bench (11% unchanged) and the gravel bars (16% unchanged). Some of the gravel bar change could be due to differences in river flow stage on the day the photograph was taken, but large transitions to low bench (176 ha) and middle bench (464 ha) due to successional processes were also evident. There were large transitions from middle bench (876 ha) and high bench (587 ha) to river, and middle bench to gravel bar (302 ha) due to erosional processes, and from river to gravel bar (654 ha), middle bench (529 ha), and low bench (458 ha) due to depositional and successional processes. Changes such as 571 ha that changed from middle bench to high bench and 312 ha that changed from high bench to middle bench may be due to the difficultly in distinguishing between high and middle bench ecological communities, especially after harvest, or where mosaics of the two ecological communities exist. Thus, we do not consider transitions between high bench and middle bench to be transitions in subsequent analyses.

Total area covered by the major ecological communities changed little, with areas of river and gravel bar each increasing by 5% and areas in middle and high bench decreasing by 8 and 6% respectively (Table 8). The greatest change was in low bench, which increased in area by 51%. These transition overlay results differ from percentage changes reported in Table 6, as we were only able to use the leading ecological community in the overlay.

Forested landform stability was measured by combining the areas for middle bench and high bench and calculating the percentage that had the same classification in 1947 and 1994/2003. This measure is similar to the channel stability index used by Schwab et al. (2002). Overall, forest stability was 75%, and varied between 68 and 89% in individual reaches. Reaches 1 (Kwinitsa), 5, 6, and 7, (Gitnadoix to Exstew) were the most unstable, while reaches 10 and 11 (Lakelse River to Terrace) were the most stable (Figure 8). Figure 12 gives a comparative example of changes on the floodplain over time due to erosion and deposition.

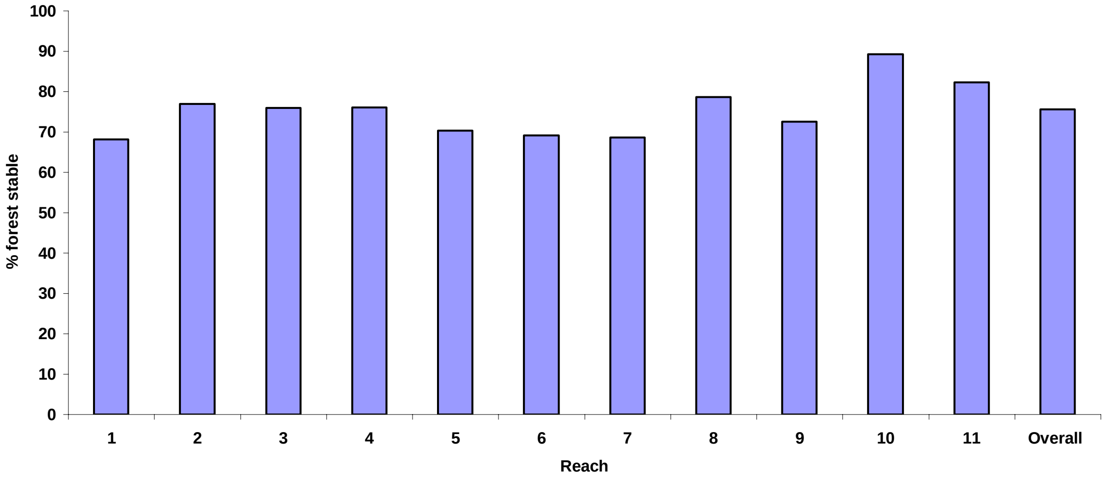

Figure 8. Forest stability assessed as the percent of area classified as forest in both 1947 and 1994/2003, by reach.

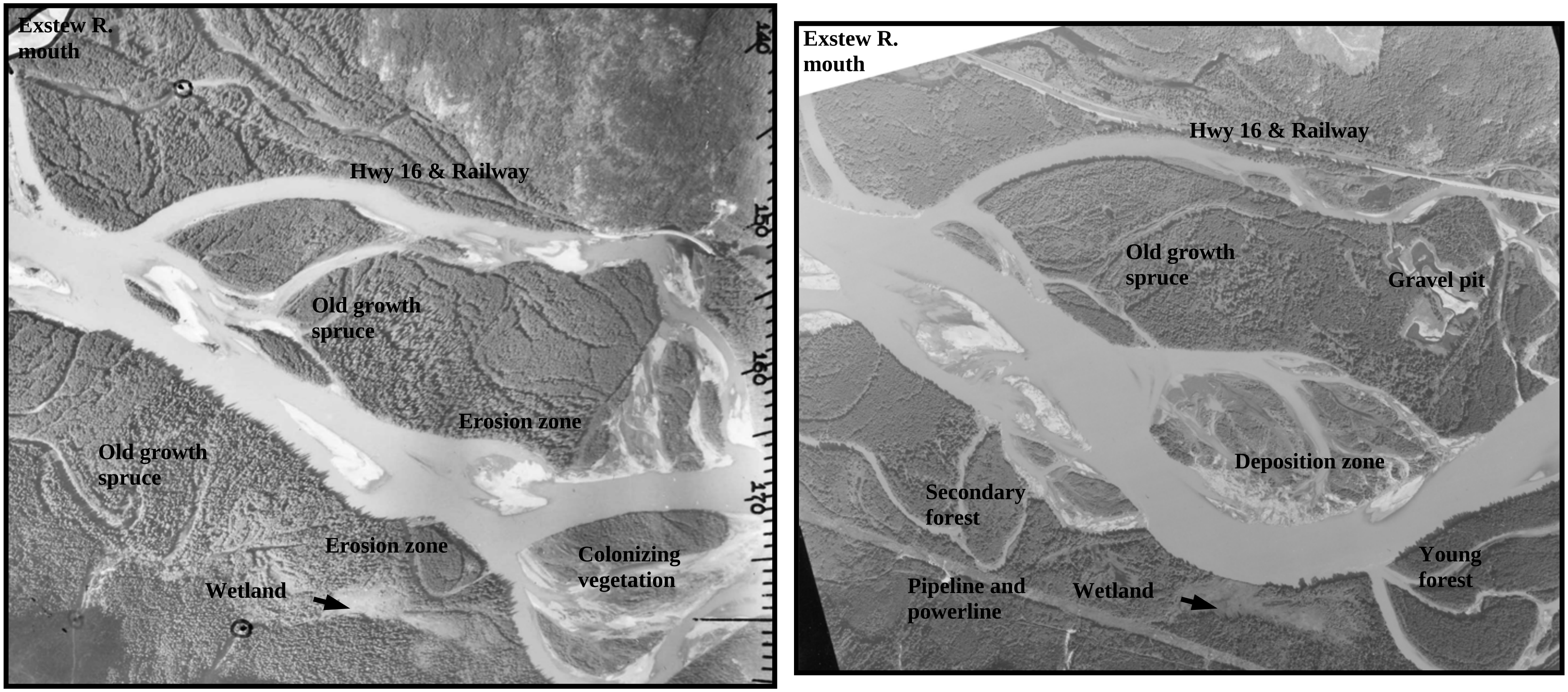

Figure 9. Example of the changes on the floodplain landscape due to erosion, deposition, succession, development, and forest harvesting between 1947 (left) and 1994 (right).

The calculation of average bank erosion rates allows for comparisons between rivers. The average bank erosion rate for the study area was 5.8 m/yr in the area mapped using 1994 photographs and 4.0 m/yr in the area mapped using 2003 photographs. This is a rate averaged over the entire time period for all channels as if they were on one bank. Actual erosion will not be at a steady state or evenly distributed (Figure 10). When erosion was examined by reach, the highest erosion rates were found in the mid-sections of the river in reaches 3 to 9, with substantially lower erosion rates in reaches 1, 2, 10, and 11.

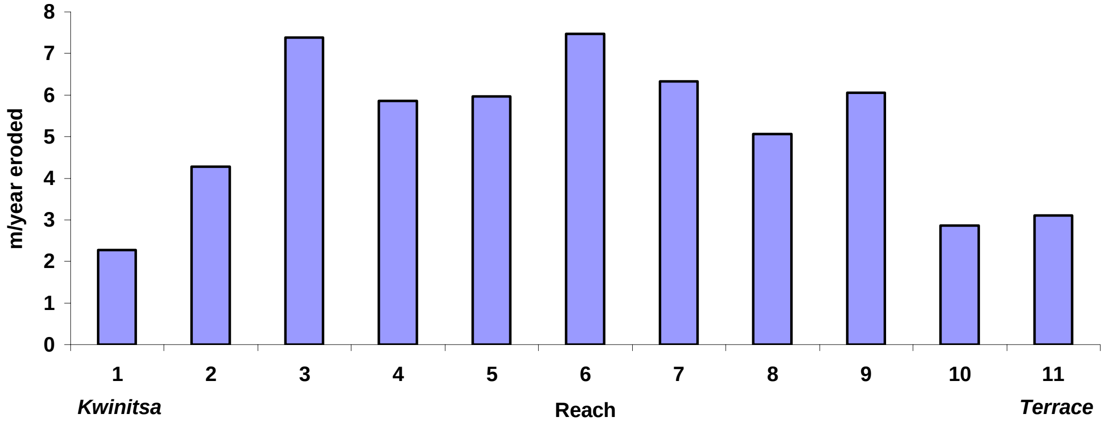

Figure 10. Erosion rate by reach.

Lateral analysis showed that older ecological communities such as high bench and Cedar - Skunk cabbage occurred, on average, further from the main channel of the river (the thalweg) than younger ecological communities such as gravel bar and low bench. Differences in ecosystem composition were most evident at distances less than 400 m and more than 800 m from the main channel (Figure 11).

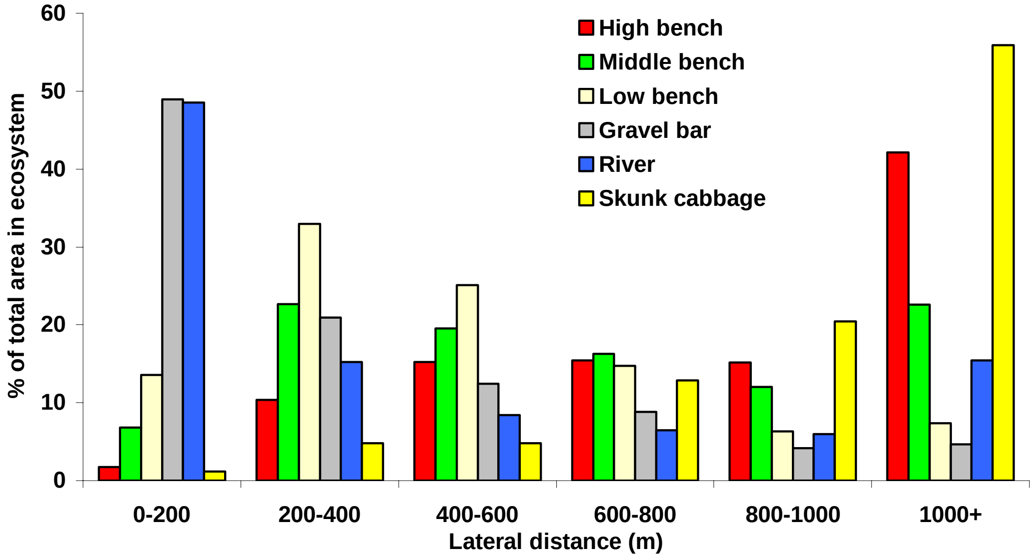

Figure 11. Lateral distribution of ecological communities in distance from the thalweg.

5.1.3 Wood Inputs

Assuming all the eroded high bench forest was in mature or old forest structural stages, and all the mid-bench forest was in young or mature forest structural stages, a total of 1.31 million m^3 of wood entered the river between 1947 and 1994, for an average of 27,850 m^3/yr (Table 10). The average input per km of river within the study area was 342 m^3/km/yr given a river length of 81.5 km (Figure 12). Allowances for harvesting reduce the average input to 280 m^3/km/yr.

Table 10. Wood inputs to the Skeena River between Terrace and Kwinitsa between 1947 and 1994.

	Area eroded (ha)[1]	**Mean m^3/ha**	**Total volume (m^3)**	**m^3/yr (47 years)**	**m^3/km/yr**
Potential inputs					
High bench	724	908	657,392	13,987	172
Middle bench	1,327	491	651,557	13,863	170
Totals	2,051		1,308,949	27,850	342
Inputs adjusted for harvesting					
High bench	724	548	388,094	8,257	110
Middle bench	1,327	491	651,557	13,863	170
Totals	2,051		1,039,651	22,120	280

[1] Area has been adjusted to account for some of the area being mapped using photographs taken in 2003.

Figure 12. Air photo of wood accumulations in main channel and side channel areas on the Skeena River near Lakelse River.

5.1.4 Wildlife

Signs of wildlife usage were commonly observed throughout the study area. Well-established game trails, moose browse, bear mark trees and recent tracks on sandbars (Figure 13) were the most abundant features noted. Game trails were most common in stands adjacent to backchannels, and were usually situated near the top of the bank. Game trails were less common adjacent to the main river channel, likely because these areas are eroded before trails can become established. Exposure to boat traffic on the river may also cause areas adjacent to the main river channel to be used less often than backchannel areas.

Figure 13. Sandbars on the floodplain provide evidence of abundant wildlife. At this site recent moose, black bear, wolf, fisher, rodent, bald eagle and Canada goose tracks were found.

Understory shrub vegetation was dominated by salmonberry, with thimbleberry, red-osier dogwood and devil's club as co-dominants. Of these species, moose browse was observed only on red-osier dogwood. Dogwood cover was highly variable among sites, being present in 70% of the plots with a mean cover of 4.5% and a maximum cover of 42%. Dogwood abundance did not differ significantly among the three stand types (P = 0.31) and was not significantly correlated with distance inland from the Coast (P = 0.78). There did, however, appear to be a bimodal distribution with respect to stand age. The highest abundance of dogwood was found in the youngest stand we sampled (26 year old primary deciduous stand) with the 2nd and 3rd most abundant being found in old growth Sitka spruce, suggesting that this semi-shade tolerant species is most abundant in either early seral stages (prior to canopy closure) or in late seral stages with abundant canopy gaps. Browsing was also commonly seen on young western redcedar. Willow, an important moose food source, was not present in any of the three stand types sampled, but commonly occurred in the non-forested low bench ecological communities.

5.2 Stand Scale

5.2.1 Soils and Forest Floor

The soils of the study area are uniform in that they all are derived from fluvial deposition. Differences in these fluvial soils resulted mostly from the conditions under which they were deposited, the thickness and texture of the deposit, and the age of the deposit. Deposits laid down by water with more energy tend to be coarser than those laid down by low energy water. High-energy areas were located nearer the main channel and in areas of deeper flow, typically gravel bars and low benches, whereas low energy areas tended to be in back channels or on high benches with shallow overbank flow. Soil texture tended to become finer towards the Coast, especially downstream of the Gitnadoix River, likely due to a lower river gradient. Older deposits were subjected to more flooding events and thus tended to have thicker deposits of silts and sands on top of the gravel base than younger deposits. Moreover, older deposits in general have greater soil horizon development and a thicker litter fibre humus (LFH) layer (Yole 2004). There was no indication that soils influenced stand type, rather soils and ecosystems developed in tandem as they both aged.

Primary Sitka spruce and secondary stands had significantly wetter average soil moisture regimes and were more likely to have some clay-containing subsurface horizons than primary deciduous stands (Table 11). Soil nutrient regimes were also assessed as being slightly higher in old Sitka spruce stands than in either deciduous stand type. There were no significant differences, however, in the amount of Brunisolic horizon development, the Ah horizon thickness, the amount of gleying, or the thickness of silt-textured horizons among stand types.

Table 11. Summary of soil characteristics.

Parameter	**Primary Sitka spruce forest**	**Young deciduous**		**P-value**	**Contrast P-value**		
		Primary forest	**Secondary forest (post-logging)**		**1**	**2**	**3**
Number of soil pits	12	14	14	n/a			
Soil moisture regime	4.7	4.2	4.6	0.0007	0.04	0.0008	0.0002
Soil nutrient regime	4.1	3.8	3.7	0.10	0.03	0.87	
Brunisolic soils (% of pits)	92	64	71	0.55	0.31	0.69	0.39
Mottling or gleying (% of pits)	29	4	18	0.25	0.16	0.28	0.14
Clay textures (% of pits)	8	0	36	0.02	0.44	0.01	0.05
Silt textured horizons thickness (cm)	54	33	64	0.40			
Ah horizon thickness (cm)	4	2.1	3.1	0.40			

The primary and secondary deciduous stands averaged 15 and 16% cover of exposed mineral soil, respectively, which was significantly greater than the 4% average in the Sitka spruce stands (Table 12). These deciduous stands also had more decaying wood cover (9 and 10% on average) than the Sitka spruce stands (5%), while the Sitka spruce stands had significantly greater cover of organic matter (90%) than either primary and secondary deciduous stands (75% for both). The higher amount of woody debris cover is likely due to active self-thinning in these young stands, while the higher amounts of exposed mineral soils is likely due to a more active flooding regime and more faunal activity in the deciduous litter. There were no differences among the stand types in litter depth or organic horizon depth.

Table 12. Summary of forest floor characteristics.

Parameter	Sitka spruce primary forest	Young deciduous		P-value	Contrast P-value	
		Primary forest	Secondary forest (post-logging)		1	2
Decaying wood (% cover)	5	9	10	0.02	0.006	0.38
Exposed mineral soil (% cover)	4	16	15	0.02	0.007	0.68
Organic matter (LFH) (% cover)	90	75	75	0.003	0.0007	0.94
Litter thickness (cm)	1.4	1.9	2.1	0.24		
LFH thickness (cm)	2.1	2.2	2.4	0.87		

Vermimull humus forms were common under the deciduous stand types, indicating the activity of earthworms (Green et al. 1993). The Sitka spruce stands generally had Mormoder humus forms, which have visible fungal mycelia as well as soil fauna activity.

5.2.2 Wood Volume, Snags, and Regeneration

Sitka spruce stands had 116 coniferous stems per ha, which was significantly more than the 46.5 stumps per ha found in the secondary deciduous stands; however, there was no difference in mean pre-logging DBH of conifers in these stands (99.5 cm vs. 97.8 cm) nor in total conifer basal area per ha (63 m^2/ha vs. 40 m^2/ha) (Table 13). Most of the conifer stumps measured had become moderately decayed over the course of 40 to 50 years and were probably somewhat reduced from their initial diameter. We did not attempt to compare the pre-logging deciduous composition of these two stand types due to the rapid decay rates of deciduous trees and stumps. There was no strong evidence that the present-day Sitka spruce stands and former Sitka spruce stands on sites now occupied by secondary deciduous stands were substantially different from one another, though the present-day stands may have had a higher stem density than the former stands on the secondary sites.

Table 13. Comparison of live conifer stems in unlogged Sitka spruce stands to conifer stumps in logged stands.

Parameter	Primary Sitka spruce forest	Secondary deciduous forest (post-logging)	P-value
Number of plots	12	15	
Stems or stumps per hectare	116.0	46.5	0.01
Mean stem or stump DBH (cm)	99.5	97.8	0.57
Basal area per hectare (m^2/ha)	62.9	39.9	0.15

Distance from the Coast significantly affected total stand volume (P = 0.003), black cottonwood volume (P = 0.005) and red alder volume (P = 0.03); all decreased with distance inland (Table 14). Within stand types, the trend towards decreasing stand volume with distance inland was significant only for the secondary deciduous stands, where it applied to total deciduous volume (r^2 = 0.56, P = 0.0012), black cottonwood volume (r^2 = 0.24, P = 0.05), and red alder volume (r^2 = 0.23, P = 0.04) and was inversely related to stand age (r^2 = 0.35, P = 0.02).

Table 14. Summary of live and dead wood volume.

Parameter	Primary Sitka spruce forest	Young deciduous		P-value	Contrast P-value			Distance inland *P*-value
		Primary forest	Secondary forest (post-logging)		1	2	3	
Total live volume (m^3/ha)	908	491	480	0.008	0.04	0.09		0.003
Coniferous	819	98	123	<0.0001	<0.0001	0.76		
Deciduous	89	393	357	<0.0001	<0.0001	0.03	0.0002	0.006
Sitka spruce	755	50	61	<0.0001	<0.0001	0.84		
Redcedar	43	45	48	0.99				
Cottonwood	83	369	260	0.0002	0.0001	0.01	0.0003	0.005
Red alder	5	24	97	0.008	0.007	0.47		0.03
Total dead basal area (m^2/ha)	8.1	3.0	4.5	0.42				
Sitka spruce	6.2	0.2	1.1	0.15				
Cottonwood	0.7	2.0	2.9	0.57				
Red alder	1.0	0.7	0.5	0.78				
Total dead stems (stems/ha)	18	33	49	0.36				
Sitka spruce	7.4	7.1	0.8	0.31				
Cottonwood	0.3	7.1	21	0.30				
Red alder	8	7	28	0.01	0.33	0.004	0.008	0.003
Total regeneration density (stems/ha)	568	155	323	0.49				
Deciduous density (stems/ha)	80	125	58	0.80				
Conifer density (stems/ha)	489	31	265	0.42				
% conifer regeneration growing on CWD	97	0	100 (mostly on cut stumps)	<0.0001	<0.0001	<0.0001	<0.0001	

The mean volume of 908 m^3/ha in the Sitka spruce stands was significantly higher than that of both primary deciduous stands (491 m^3/ha) and secondary deciduous stands (480 m^3/ha) (Table 14). Mean volumes for the two deciduous stand types were very similar despite the 36-year difference in mean stand age. Sitka spruce stands had much greater spruce volume than the deciduous stands (755 m^3/ha), but there was no difference in spruce volume between the primary (50 m^3/ha) and the secondary (61 m^3/ha) deciduous stands (Figure 14). Deciduous stand types had a greater volume of both deciduous species, black cottonwood and red alder, than the Sitka spruce stands. The primary deciduous stands had a greater volume of black cottonwood (369 m^3/ha) than the secondary deciduous stands (260 m^3/ha), but there was no significant difference in red alder volume between the two deciduous stand types. Western redcedar volume was essentially equal among the three stand types (*P* = 0.99), ranging from 5.7 to 10.0% of total stand volume.

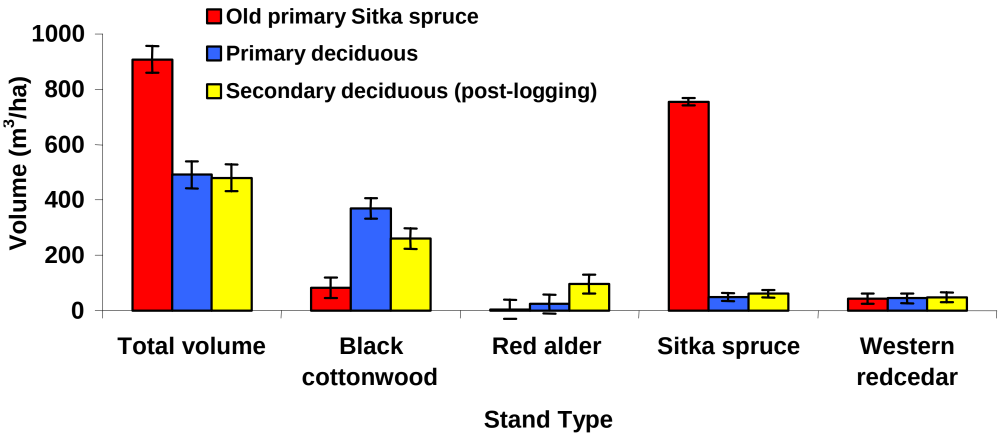

Figure 14. Volume distribution among stand types by tree species with standard error.

The density of Sitka spruce snags decreased with distance inland (*P* = 0.003), but otherwise, there were no significant effects of the Coast-Interior gradient on snag abundance. Snag basal area and density did not differ significantly among the three stand types (*P* >0.42 and *P* >0.36 respectively) (Table 14); however, the old spruce stands tended to have large coniferous snags while snags in the deciduous stands were mostly deciduous with DBH less than 40 cm (Figure 15). A few large old snags were present in secondary deciduous stands that had not been completely clearcut. Red alder snags were most abundant in the secondary deciduous stands (*P* = 0.01), but these snags tended to be small trees resulting from stand self-thinning with little value as wildlife habitat.

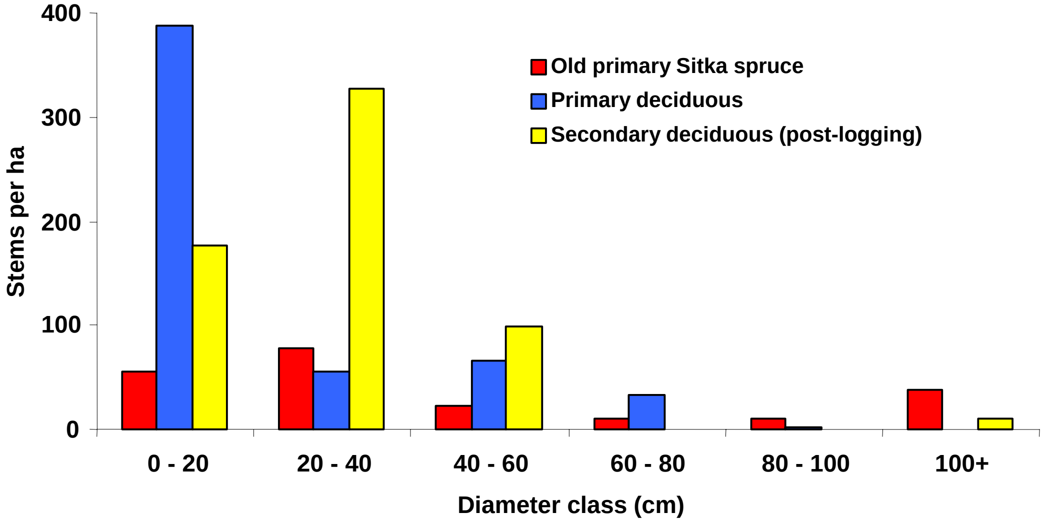

Figure 15. Snag Density by Diameter Class.

There were no differences in amount of tree regeneration among stand types (*P* = 0.49) because of the high variability in this parameter (Table 14). Coarse woody debris was a critical substrate for conifer regeneration in the Sitka spruce and secondary deciduous stands, where nearly all conifer regeneration was on CWD (97% and 100% respectively). By contrast, in the primary deciduous stands none of the conifer regeneration was on CWD.

5.2.3 Gaps and Forest Understory

The area in developmental gap in Sitka spruce stands was four times higher than that in deciduous stand types. All stands had similar area (5%) in edaphic gaps caused by wet channels (Table 15, Figure 16). Seventeen per cent of the total transect length in Sitka spruce stands consisted of large and medium developmental gaps. These gaps were larger than those in primary and secondary deciduous stands. In primary and secondary deciduous stands 1 and 4% of transect length consisted of large gaps with 7 and 3% in medium gaps, respectively (Figure 17). There were no significant differences among stand types in small developmental gaps, and no significant differences in gap size between the two deciduous stands types. All understory vegetation in gaps contained a dense cover of shrubs. Non-gap understory vegetation was less shrubby in the two primary stand types than the secondary stand type.

Table 15. Canopy gap characteristics.

Parameter	**Primary Sitka spruce forest**	**Young deciduous**		**P-value**	**Contrast P-value**	
		Primary forest	**Secondary forest (post-logging)**		**1**	**2**
# of stands	4	9	6	n/a		
Total transect length (m)	1200	1975	1760	n/a		
Ave. homogenous sector length	13	24	23	0.03	0.01	0.65
Percent of total transect length in:						
Edaphic gap (wet channels)	3	4	4	0.99		
Developmental gaps	37	8	8	0.0001	<0.0001	0.90
Small gaps	2	1	2	0.43		
Medium gaps	17	7	3	0.01	0.004	0.34
Large gaps	17	1	4	0.003	0.001	0.39
Non-gap, dense shrubby understory	41	62	83	0.04	0.03	0.10
Non-gap sparse understory	18	24	4	0.31		

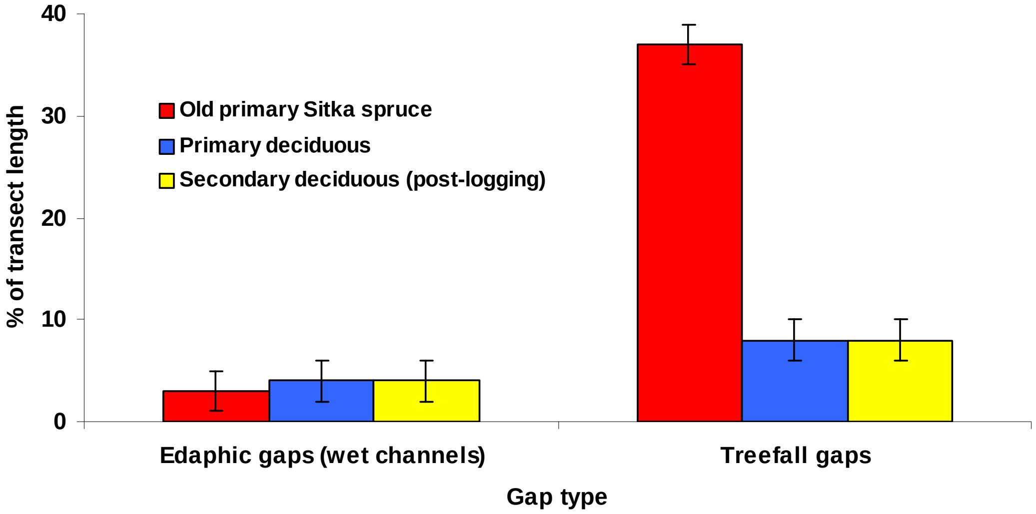

Figure 16. Percentage of transects under canopy gaps with standard error.

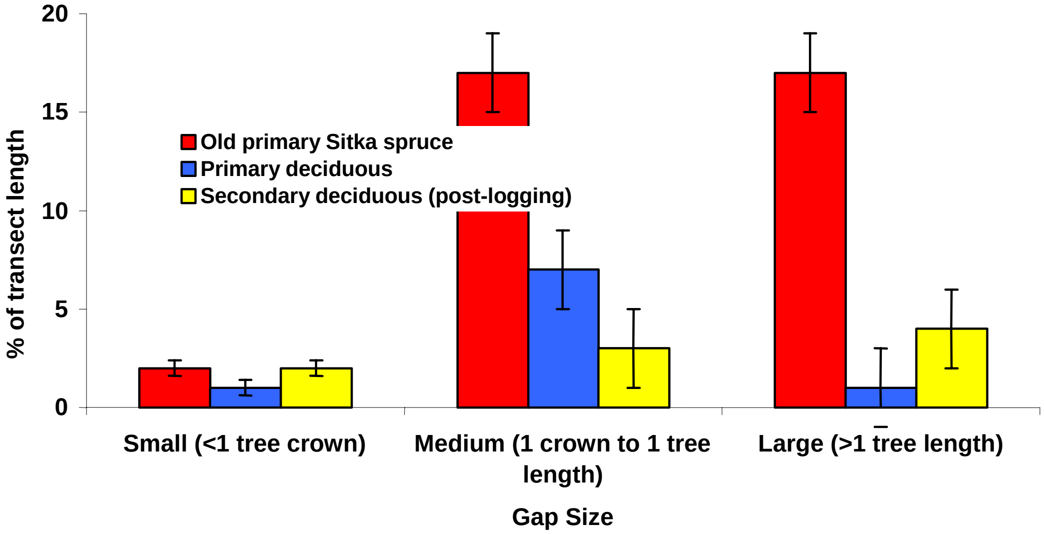

Figure 17. Percent of transect length in each gap size with standard error.

5.2.4 Coarse Woody Debris

The total volume of CWD was similar in all three stand types, with a difference of only 4 m^3/ha (Table 16). Coarse woody debris in Sitka spruce stands had a larger average diameter (35 cm) than in either primary (21 cm) or secondary (18 cm) deciduous stands. The degree of decay was also significantly greater in Sitka spruce stands, with an average decay class in methods of 2.8 compared to 2.1 for deciduous stands. There was no difference among stand types in the length class or degree of piling of the CWD, and no difference between primary and secondary stands for any of the measured CWD attributes.

Table 16. Coarse woody debris characteristics.

Parameter	**Primary Sitka spruce forest**	**Young deciduous**		**P-value**	**Contrast P-value**	
		Primary forest	**Secondary forest (post-logging)**		**1**	**2**
Number of plots	12	14	14	n/a		
Volume of CWD (m^3/ha)	116	118	120	0.995		
Average decay class	2.8	2.1	2.0	0.007	0.002	0.53
Average diameter (cm)	35	21	18	0.01	0.003	0.50
Average length class	3.8	3.9	3.7	0.50		
Average number of logs per pile	1.5	1.4	1.5	0.42		

5.2.5 Vegetation Composition and Structure

Total tree cover was highest in primary deciduous stands (73%) and lowest in Sitka spruce stands (49%) (Table 17). Sitka spruce stands had the least cover in the dominant tree layer (22%). Primary deciduous stands had the most cover in the sub-canopy tree layer (14%). The secondary stands had the highest cover of low shrubs (56% vs. 45 and 40% in other stand types). There were no differences in tall shrub cover among stand types (15% on average; $P = 0.44$), but there was a significant increase in tall shrub cover towards the coast ($r^2 = 0.10$, $P = 0.02$).

Table 17. Vegetation characteristics, percent cover by layer.

Parameter	**Primary Sitka spruce forest**	**Young deciduous**		**P-value**	**Contrast P-value**			**Distance inland P-value**
		Primary forest	**Secondary forest (post-logging)**		**1**	**2**	**3**	
Total tree cover	49	73	66					
Dominant trees	22	43	37	0.001	0.0004	0.28		
Co-dominant trees	17	16	20	0.78				
Sub-canopy trees	10	14	9	0.04	0.22	0.02		
Tall shrubs (2-10 m)	17	13	15	0.44				0.02
Low shrubs (<2 m)	45	40	56	0.09	0.56	0.03		0.096
Herbs	23	5	17	0.0001	0.001	0.004		
Total shrubs & herbs	86	59	87	0.07	0.21	0.01	0.006	
Total non-vascular[1]	21	6	4	<0.0001	<0.0001	0.25		
Forest floor	21	0.8	0.5	<0.0001	<0.0001	0.94		
Decaying wood	2.8	2.9	2.7	0.03	0.07	0.03		0.001
Epiphytes below 1.3 m	2.5	0.4	1.5	0.02	0.02	0.09		
Fallen arboreal lichens	0.9	0.4	0.1	<0.0001	<0.0001	0.009		

[1] Total non-vascular was measured in quadrats, while the non-vascular on specific surfaces was measured along transects.

There was a weak but highly significant relationship between distance inland and cover of non-vascular plants growing on decaying wood ($P = 0.001$). This relationship was strongest in secondary deciduous stands ($r^2 = 0.56$, $P = 0.0001$). Herbaceous layers, forest floor mosses and epiphytic bryophytes and lichens and arboreal lichens were all much more abundant in Sitka spruce stands than in younger, deciduous stands. Secondary deciduous stands had better developed herb layers (17% cover) than primary deciduous stands (5% cover) ($P = 0.004$), but the primary deciduous stands had more fallen arboreal lichens (0.4% cover) than the younger, secondary stands (0.1% cover) ($P = 0.009$).

Non-metric multidimensional scaling produced three dimensional ordinations (all axes $P = 0.001$) with a stress level of 10.8 for the complete plant community (Figure 18a) and 11.7 for the understory plant community (Figure 18b). In both cases, only the two dominant axes showed strong variation by stand type and significant correlation with environmental variables of interest, thus the third axis is not shown or discussed further.

Primary Sitka spruce plant communities were well separated from younger deciduous plant communities on the first axis of the full plant community ordination, which explained 35% of the variance in species composition (Figure 18a). Western hemlock; devil's club; understory herbs such as sweet-scented bedstraw, spiny wood fern, three-leaved foamflower, enchanter's nightshade and rosy twisted stalk; and badge moss and Brachythecium moss were strongly associated with older spruce-dominated late successional floodplains, while Douglas maple, snowberry and common horsetail were strongly associated with younger deciduous-dominated floodplain forests (Figure 18a). The second ordination axis, which explained 31% of the variance, separated communities with a dense understory dominated by salmonberry, red elderberry and lady fern (upper half of Axis 2) from those with a western redcedar component, which tended to have a sparser understory typified by thimbleberry, snowberry, pink wintergreen and false Solomon's seal. Western redcedar abundance was not correlated with stand types (Table 14, *P* = 0.99; note its position in the centre of Axis 1), thus the sparser understory could be found in either deciduous-dominated or coniferous stands. However, secondary (post-logged) deciduous stands were much more likely than primary deciduous stands to have the dense salmonberry-dominated understory.

The complete plant community ordination showed strong overlap among primary and secondary deciduous stands (11 of 14 secondary stands lie within the sample ellipse for primary deciduous stands), but no overlap at all between the Sitka spruce stands and the secondary post-logged stands (Figure 18a), suggesting that the species shift that accompanies logging is important and probably goes well beyond overstory tree composition.

In the understory ordination (Figure 18b), the relationship between primary and secondary types was reversed. Primary spruce and secondary deciduous stands overlapped substantially on the left side of NMS axis 1 (31% of variance) because they shared dominance of understory species such as salmonberry, red elderberry and lady fern. Primary deciduous stands located on the far right side of Axis 1 had abundant Nootka rose, snowberry, black twinberry, false Solomon's seal and pink wintergreen. The second ordination axis (28% of total variance) separated older Sitka spruce understories with an abundance of devil's club, western hemlock regeneration, late successional herbs (three-leaved foamflower, oak fern, rosy twisted stalk, sweet-scented bedstraw) and mosses from younger post-logging understories that were more heavily dominated by *Rubus* spp. and red elderberry.

Correlations between the NMS ordination axes and environmental, site history and stand structural variables (latter for the understory only) are shown as solid vectors in Figure 18 and explained in more detail in Table 17. In the full community ordination (Figure 18a), Axis 1 is most strongly correlated with stand age and the intensity of logging (clearcut = 100%, partial logging 60 - 80%) while Axis 2 is most strongly correlated with distance from the Coast (UTM east) and the SMR. In the understory ordination (Figure 18b), Axis 1 is most strongly correlated with distance from the Coast and SMR, while Axis 2 was mostly strongly correlated with Sitka spruce volume, % conifer volume and the intensity of logging.

Because both overstory and understory composition were strongly influenced by distance from the Coast and SMR, we included these two factors as covariables in the RDA to detect significant differences among stand types. Without covariables, there were highly significant differences among all combinations of the three stand types (*P* = 0.001 for full community; *P* <0.003 for understory). Soil moisture regime did not have a significant effect on compositional differences among stand types (*P* >0.23; Table 18) but distance from the Coast was a significant covariable for both the full plant community (*P* <0.02) and the understory (*P* <0.013; Table 18). Abundance of salmonberry, red elderberry, lady fern and red alder, and the richness and abundance of bryophytes (especially liverworts), were higher at more coastal locations, while species such as thimbleberry, snowberry, black twinberry, pink wintergreen, false Solomon's seal, and Nootka rose were more abundant at inland sites. When this Coast-Interior gradient was taken into account, differences in full community composition between primary Sitka spruce stands and younger deciduous stands remained highly significant (*P* <0.001), accounting for 16% of total variance in species composition, but there was no longer a significant difference in species composition between primary and secondary deciduous stands (3% of total variance, *P* = 0.12; Table 19).

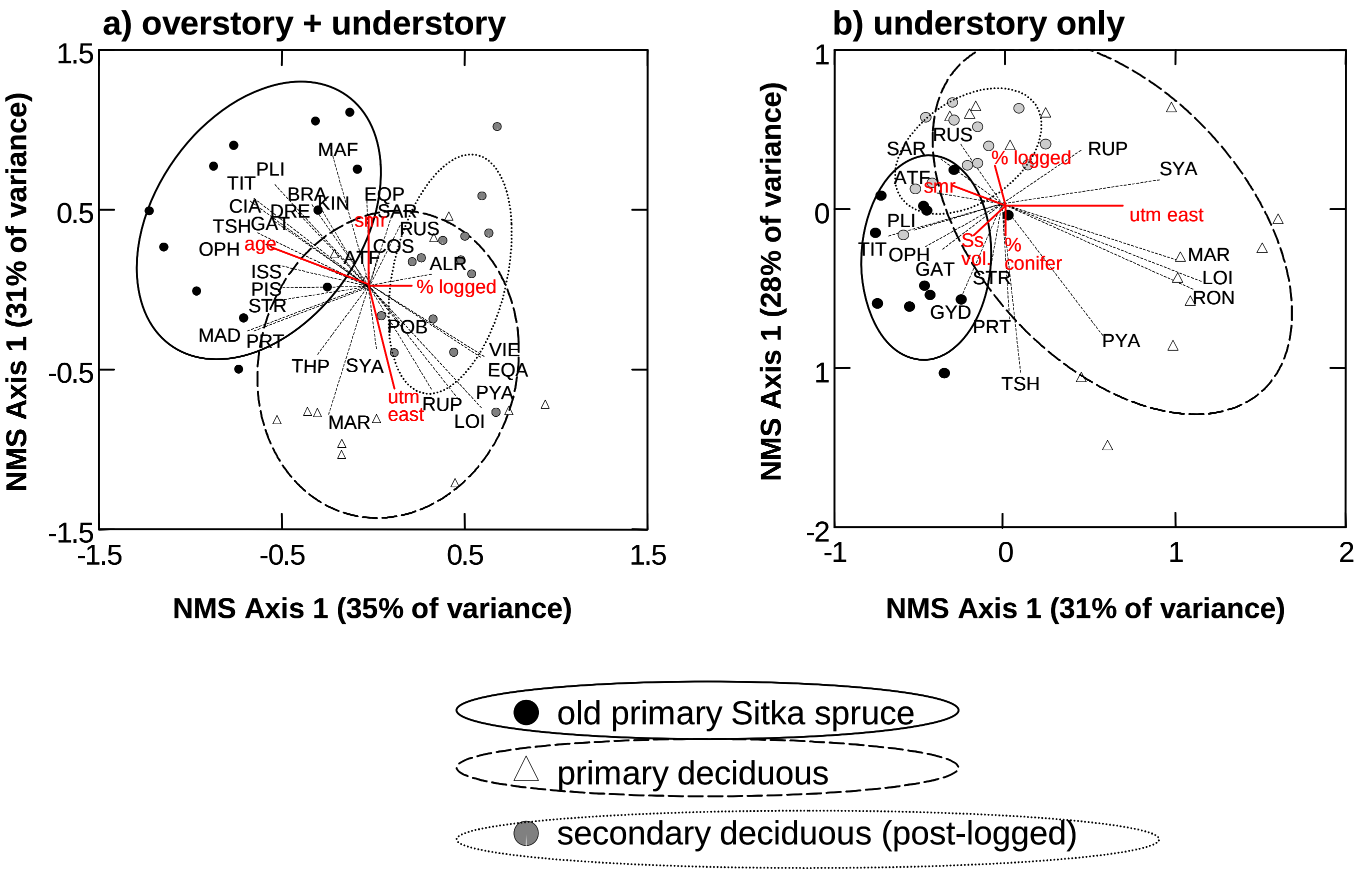

Figure 18. Non-metric multidimensional scaling (NMS) plot of Skeena Islands plant communities (a) all plant species including overstory trees; (b) understory plants only. Symbols and 68.6% sample ellipses (analogous to ± 1 standard deviation) represent stand types (black circle and solid ellipse = primary Sitka spruce; white triangle and dashed ellipse = primary deciduous; gray circle and dotted ellipse = secondary deciduous (post-logged). Dashed vectors indicate correlations of the major plant species (Appendix 3) and solid vectors indicate correlations of environmental or stand structural variables (Table 17) with the ordination axes.

For the understory, we tested whether the primary ordination axis in Figure 18 meant that primary deciduous stands had a distinct understory composition from primary Sitka spruce and secondary deciduous (Contrast 3 in Table 19). The difference in these two understory types was not statistically significant (4% of understory variance; *P* = 0.07), indicating that the Axis 1 gradient in Figure 18b was dominantly a geographic gradient. However, the difference between primary spruce and secondary deciduous stands, separated on Axis 2 in Figure 18b, was highly significant (10% of understory variance; *P* = 0.001). These two results suggest that current overstory composition and the residual effects of logging had more influence on understory composition than pre-logging composition or long-term floodplain history.

5.2.6 Stand Diversity and Species Richness

Non-vascular species richness had a strong geographical gradient, increasing from an average of two species per plot at the eastern edge of the study area to six species per plot at the western edge (*P* = 0.02). This geographic gradient makes it more difficult to isolate the effects of succession and stand development on species diversity. Nonetheless, primary Sitka spruce stands were richer in species than deciduous stand types at all three levels of species richness measured: vascular (16 species per plot vs. 11 and 14 in the primary and secondary deciduous stand types, respectively), non-vascular (5 species per plot vs. 2 and 3), and total (22 species per plot vs. 13 and 17). The primary Sitka spruce stands were also more structurally diverse at all three levels of diversity measured: vertical, canopy, and understory (Table 20, Figures 19 and 20). These results were statistically significant even after differences in soils and geographical location were taken into account. Secondary deciduous stands were significantly richer in vascular species and total species than the primary deciduous stands.

Table 20. Species (species/plot) and stand structural (Shannon's diversity index) diversity. Stand diversity used all species in all layers.

Parameter	Primary Sitka spruce forest	Young deciduous		P-value	Contrast P-value		Distance inland P-value
		Primary forest	Secondary forest (post-logging)		1	2	
Vascular species richness	16	11	14	0.009	0.02	0.04	
Non-vascular species richness	5	2	3	0.06	0.03	0.88	0.02
Total species richness	22	13	17	0.0009	0.001	0.03	
Vertical structure diversity	1.9	1.5	1.6	<0.0001	<0.0001	0.41	
Tree canopy diversity	1.6	1.1	1.1	0.0002	<0.0001	0.99	
Understory species diversity	2.2	1.3	1.4	0.0002	<0.0001	0.46	

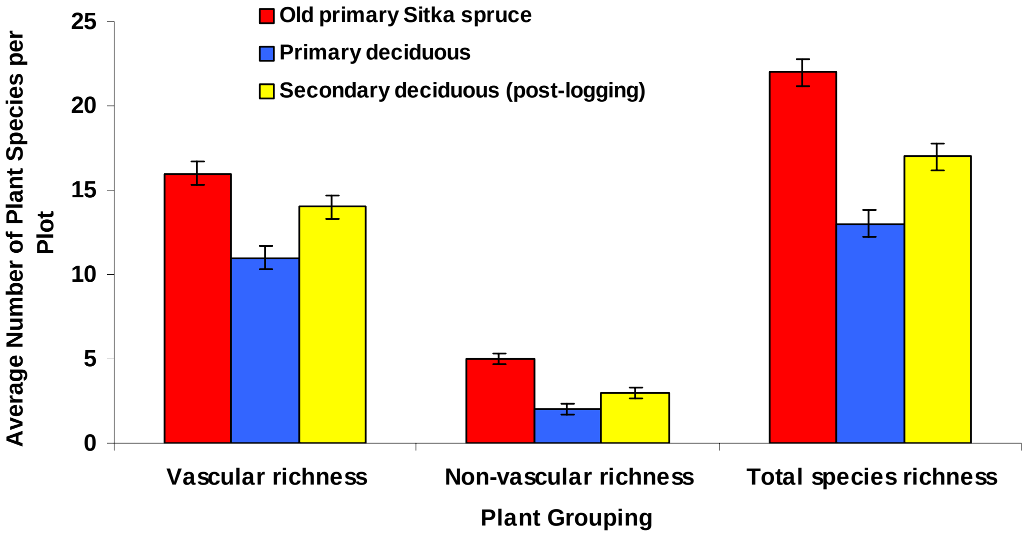

Figure 19. Plant Species Richness by Stand Type.

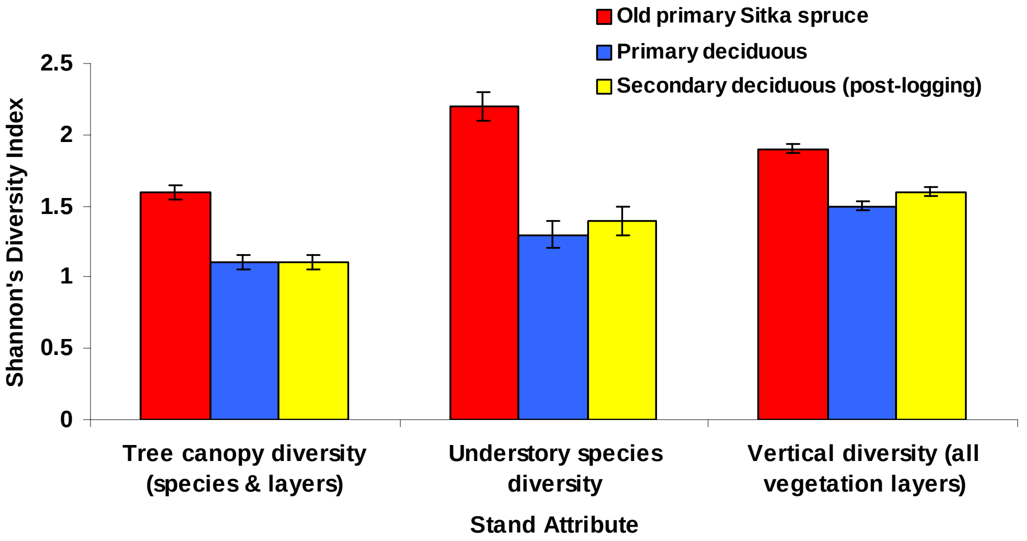

Figure 20. Stand Diversity by Stand Attribute.

5.3 Conservation Value Ranks

Stands ranked B for conservation value (good condition) dominated the study area, covering 6,812 ha or 78% of the high and middle bench area, due to the predominance of deciduous stands on high and middle benches (Table 21 and Figure 21). The sub-ranking process for B-ranked stands, based on the amount of coniferous regeneration or remnant coniferous structure, showed that most areas were in the B1 or B2 sub-ranks. A total of 1,351 ha had a conservation value rank of A (excellent condition). These areas were dominated by mature or old coniferous stands that were unharvested or had abundant remnant structure after harvesting. Areas ranked either C (marginal condition) or D (poor condition) were mostly in highway, railway, or powerline right-of-ways, agricultural or residential use. Areas that were unranked included river, gravel bar, low bench and Shrub - Herb.

Table 21. Area and percentage in each conservation value rank by stand type. The breakdown by stand type was done by overlaying the conservation ranks on the 1947 TEM map.

Rank or Subrank	Primary Sitka spruce[1]		Primary deciduous		Secondary deciduous		All stand types	
	ha	%[2]	**ha**	%	**ha**	%	**ha**	%
A excellent condition	1,009	100	342	7	0	0	1,351	15
B good condition	0	0	4,377	88	2,434	89	6,812	78
B1	0	0[3]	1,051	24	1,241	51	2,292	34
B2	0	0	1,549	35	847	35	2,396	35
B3	0	0	1,350	31	262	11	1,612	24
B4	0	0	427	10	84	3	512	8
C marginal condition	0	0	121	2	157	6	278	3
D poor condition	0	0	131	3	151	5	282	3
Total ranked	1,009		4,971		2,742		8,723	57
Total unranked							6,532	43
Grand total							15,255	

[1] Areas in the stand types were based on their classification on the 1947 TEM map.

[2] Percentage of the total area in the stand type.

[3] Percentage of the total area in the B rank in the stand type.

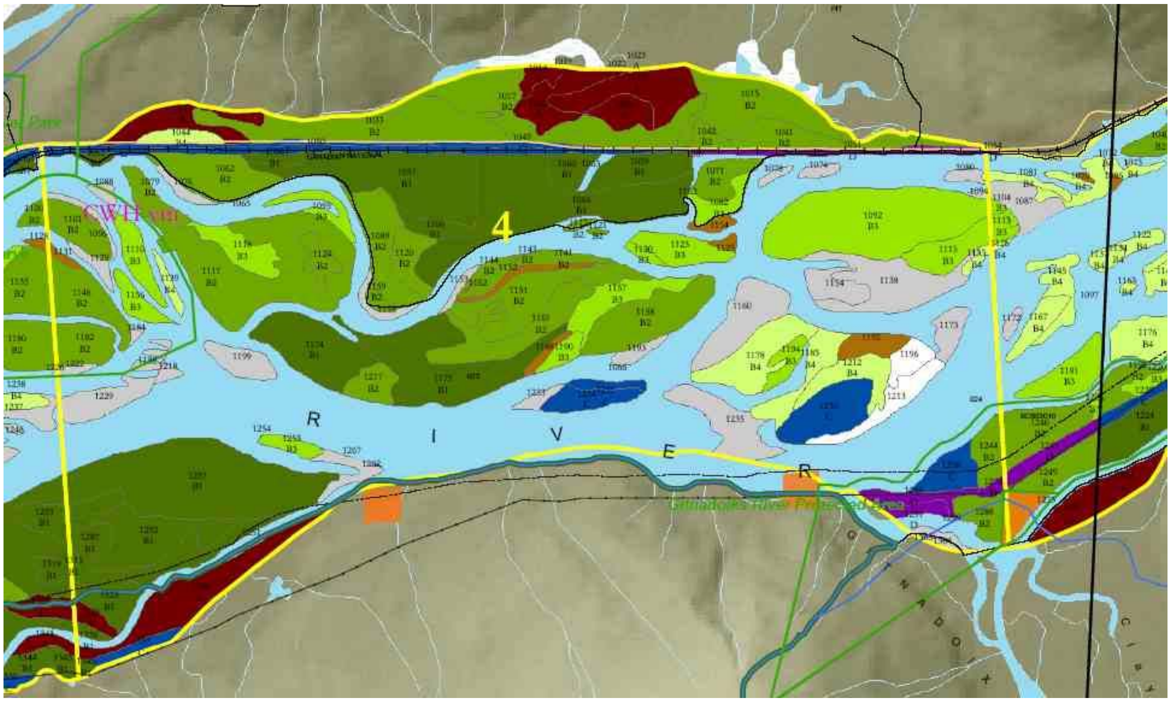

Figure 21. Example of map of conservation ranks. Red = A, Green = B (darkest green = B1, lightest green = B4), Blue = C, Purple D, grey = gravel bar, Orange = Indian Reserve.

The relatively high percentage of secondary deciduous stands ranked B1 (51% of B-ranked stands) compared to the primary deciduous (24% of B-ranked stands) indicates that the secondary stands should receive a higher priority for conservation and restoration than the primary deciduous stands. These conservation rankings corroborate the findings of the stand scale data, which showed that the secondary stands had greater species richness and tended to be more structurally diverse than the primary deciduous stands. While there is some error associated with the stand type rankings due to changes that have occurred on the floodplain since 1947, we are confident that the major trends reflected in Table 21 are valid.

6.0 Discussion

6.1 Landscape Scale

6.1.1 Ecological Community Distribution and Area

Riparian ecosystems have been modified by human activity at a high rate throughout North America, with loss of riparian vegetation being as high as 98.5% in parts of southern California, and ranging between 70 to 95% in southwestern United States (Braatne et al. 1996). The Skeena River is unique for a large temperate river in that it still has a natural flow regime and the floodplain of the lower river is still mostly forested with native vegetation. This situation allows opportunities for restoration of depleted ecosystem conditions, while planning for commercial forest management.

There have, however, been large shifts in composition of the forests on the Skeena River floodplain. In British Columbia, the Biodiversity Guidebook (BC Ministry of Forests 1995a) provides guidance for setting seral stage targets in forest landscape planning. These guidelines are based on average return intervals for stand-replacing natural disturbances in upland landscapes and are therefore not readily applicable to a floodplain ecosystem (de Groot 2005). However, as these are the only guidelines available and they are currently being used by the BC Integrated Land Management Bureau for Sustainable Resource Management Planning (SRMP) in the Kalum Forest District, they are used here for comparative purposes.

The 77% decline in structural stage 6 and 7 Sitka spruce stands has left the Skeena River floodplain with a lower percentage of total area in old stands than is recommended by the Biodiversity Guidebook for the Skeena River Kalum landscape unit in the SRMP (Table 22, Figure 21, Figure 22)[4]. In both the old and the mature + old seral stage categories the Skeena River floodplain is well below the proposed targets for the overall landscape unit. For early seral stage, the floodplain is near the target, as many of the stands harvested in the 1950's and 1960's are now in the young forest seral stage.

Seral stage targets for the floodplain should take into account that even without logging a higher percentage of the floodplain landscape will naturally be in earlier seral stages than adjacent upland areas because of erosion and deposition processes. As Table 22 illustrates, even the historic percentage of forest area in mature + old seral stages is lower than the targets set for the CWHvm1 and CWHws1 biogeoclimatic variants. These variant-wide targets are therefore unrealistic in areas affected by natural floodplain dynamics.

A more realistic target for the floodplain would be 75% of historic area; the level of mature + old recommended by the Biodiversity Guidebook as a generic guideline for areas with high biodiversity value. Applying the 75% guideline to the Skeena River floodplain produces a target of >34% for mature + old (Table 22). The amount of mature + old forest on the Skeena River floodplain is currently well below this target.

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[4] The seral stage distribution was calculated using only the forested ecosystem types on the TEM map: high bench, middle bench, Cedar - Skunk cabbage, and Hemlock - Balsam – Bramble.

Table 22. Historic and current seral stage distribution for the study area and targets for the Skeena River Kalum landscape unit using the high biodiversity option in the Biodiversity Guidebook (British Columbia Ministry of Forests 1995a).

Seral stage	Skeena River Floodplain				Biodiversity Guidebook Targets		
	Historic Area		Current Area		CWHvm1	CWHws1	75% guideline
	ha	%	ha	%	%	%	%
Old (>250 yrs)	2,515	29	457	5	>19	>13	>22
Mature + old (>80 yrs)	3,845	45	874	11	>54	>51	>34
Early (<40 yrs)	1,392	16	2,014	24	<23	<27	

Figure 22. Winter on the Skeena River showing the dominance of deciduous stands.

Table 23 examines seral stage distributions and targets by individual river reach. No river reaches presently meet either relevant CWHvm1 or CWHws1 target or the more realistic 75% of historic target for the old seral stage. Given that the both the middle bench Black cottonwood – Red-osier dogwood and high bench Sitka spruce – Salmonberry ecological communities are rare and endangered in British Columbia, and given the very high biodiversity values of old floodplain forests, measures to recruit additional old seral stage forests over time should be a management priority for this area.

Table 23. Seral stage targets, by reach, using the high biodiversity option as proposed in the draft Sustainable Resource Management Plan (SRMP) being produced by the BC Ministry of Sustainable Resource Management, with 75% of historic targets shown for the mature plus old seral stage as shown in the Biodiversity Guidebook (1995a).

Seral Stage	**Parameter**	***Kwinitsa***					**Reach**				***Terrace***	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Old (>250 yrs)	Historic (ha)	17	416	699	106	197	80	148	230	339	254	31
	Current (ha)	17	107	107	2	48	10	0	26	67	26	7
	Historic (%)	21	28	53	15	33	11	28	28	26	61	5
	Current (%)	13	7	9	0.3	8	2	0	3	5	7	1
	CWHvm1/ws1 target (%)	>19	>19	>19	>19	>13	>13	>13	>13	>13	>13	>13
Mature + old (>80 yrs)	Historic (ha)	23	594	796	247	329	182	157	491	642	304	131
	Current (ha)	22	167	139	8	62	19	31	158	137	86	45
	Historic (%)	29	40	60	35	55	25	29	60	49	73	19
	Current (%)	16	12	12	1	10	3	6	21	11	21	7
	CWHvm1/ws1 target (%)	>54	>54	>54	>54	>51	>51	>51	>51	>51	>51	>51
	75% target	22	30	45	26	41	19	22	45	37	55	14
Early (<40 yrs)	Historic (ha)	28	316	139	189	121	129	90	101	61	25	194
	Current (ha)	59	411	276	227	152	186	174	182	210	39	99
	Historic (%)	35	21	11	27	20	18	17	12	5	6	28
	Current (%)	44	28	23	35	25	30	33	24	17	10	15
	CWHvm1/ws1 target (%)	<23	<23	<23	<23	<27	<27	<27	<27	<27	<27	<27

6.1.2 Erosion and Deposition

The amount of bank erosion varies widely between river systems and among reaches within a river. A study on a small section of the Skeena River measured an erosion rate of 9 m/yr (Clague 1978), with the author stressing that erosion of this rate is very limited in extent. However, this erosion rate is within the range found on the nearby Kitimat River, where the erosion rate varied between 1.0 and 13.4 m/yr in individual reaches (Table 24) (Schwab et al. 2002). Annual bank erosion on the nearby Zymoetz River ranged from 0 m/yr in bedrock controlled reaches to 3 m/yr. O'Connor et al. (2003) measured erosion rates of 4.0 to 12.7 m/yr for reaches of the Quinault and Queets rivers in western Washington. Ott et al. (2001) calculated an average erosion rate of approximately 3.0 m/yr for the Tanana River in Alaska, with a range of 0.01 to 14.7 m/yr for 10 km segments. Bank erosion rates of 2.3 to 7.5 m/yr in reaches of the lower Skeena River lie within the range of these smaller rivers. Relatively high erosion rates in all reaches are likely a result of lack of bedrock control in this section of the river. The long time period between photography dates may have lead us to underestimate actual erosion rates, as reworking of deposits during the 47-year interval would not be detected (O'Connor et al. 2003).

Table 24. Comparison of erosion rates among rivers in the Skeena Region. The range of erosion rates among reaches is presented.

River	**Erosion rate (m/yr)**
Skeena	2.3 – 7.5
Morice	0.63 – 1.75
Kispiox	0.1 – 1.1
Kitimat	1.0 – 13.4
Zymoetz (a.k.a.: Copper)	0 – 3

The relatively high instability of gravel bar and low bench landforms compared to middle and high bench landforms (Table 8) can be attributed to the river reworking younger landforms in the active portion of the channel (O'Connor et al. 2003), and to successional processes causing changes in ecological communities, for example from gravel bar to low bench or middle bench. The fact that the majority of these early successional ecological communities are located close to the main channel of the river (Figure 11) supports this interpretation.

The loss of forested area shown in Tables 6 and 8 indicates that this is a degrading river system. Conversely, Hogan and Schwab (1990) found the same area to be a zone of net deposition. There was an increase in low bench area over the study area. Analysis by reach showed that there was an increase in forested area in Reach 1 (Table 8) and that much of the total increase in low bench was in Reach 2 (Table 9). This indicates that aggradation may be occurring in this downstream area, with some degradation in upstream area (J. Schwab, personal communication).

6.1.3 Wood Inputs

There are few estimates of wood recruitment rates to rivers in the literature, with no estimates for river as large as the Skeena. The Tanana River in central Alaska is the only river with a similar discharge to the Skeena for which wood input data were found. This river, which has a mean annual discharge of 688 m^3/sec, recruited an average of approximately 26 m^3/km/yr of wood to the river, with a range of 0.04 to 242 m^3/km/yr for 10 km segments (Ott et al. 2001). Segments with the largest volumes of wood inputs on the Tanana River were in midsections of the river, with little wood entering the river in the headwaters, and lower volumes in the lower river.

Recruitment figures from smaller rivers include the Drôme River in south-west France, which had mean annual inputs of between 13.9 and 16.4 m^3/km/yr (Piégay et al. 1999), and estimates from California (2.5 and 4.0 m^3/km/yr for old-growth and second growth forests respectively; Benda et al. 2002), and southeast Alaska (3.8 m^3/km/yr in southeast Alaska; Martin and Benda 2001).

The wood recruitment rates calculated for this portion of the Skeena River (342 m^3/km/yr) are more than an order of magnitude greater than that for the only comparably sized river with data; the Tanana (Ott et al. 2001). The large difference is due to a higher erosion rate (double that of the Tanana) and to a much higher standing volume of timber on the Skeena River, where the most productive sites had a volume of over 900 m^3/ha compared to 283 m^3/ha for the boreal white spruce forests that line the Tanana (Ott et al. 2001).

Although wood can be recruited to rivers by processes other than erosion, in this part of the Skeena River, erosion is dominant. The river channel is situated too far from adjacent mountain slopes to receive substantial inputs from landslides or debris flows, and most tree falls that we observed during fieldwork were due to erosion rather than to blowdown. Wood inputs do, however, come from upstream areas and tributaries, where processes other than erosion may be more important. For example, a large landslide in the Zymoetz River in 2000 produced significant inputs of wood to that river, much of which subsequently was carried into the Skeena River (S. Jennings, personal communication.). We did not examine wood transport or residence times as part of this project and did not determine whether the study area is a net importer or net exporter of woody debris.

6.1.4 Wildlife

The Skeena River floodplain provides the highest value moose winter range in the North Coast Forest District (Pollard 2001). Riparian habitats are recognized as important for moose winter range. In general, the most important attributes of high quality moose winter range are thermal and visual cover, abundant browse, and adequate snow interception (Pollard 2001, Keim and Vanderstar 2004). The sporadic distribution of red-osier dogwood, the most important moose browse species observed in forest stands, suggests that this species should be a management priority wherever dense patches occur, and that vegetation management practices should, in general, encourage this species. Areas heavily stocked with dogwood should be reserved as wildlife tree patches or riparian leave zones wherever possible. Dogwood vigour is likely to be enhanced by tree canopy removal, provided there is little disturbance to understory vegetation and soils (Haeussler et al. 1990). However, because residual trees provide important snow interception and cover for moose, leave areas should be situated so that dogwood patches are at outer edges of, or immediately adjacent to, residual tree patches rather than in full open conditions or in the most heavily shaded portion of leave zones.

Old black cottonwood trees provide important habitat for a wide range of small and large wildlife species, such as eagles, black bears, bats and many other cavity users (Enns et al. 1993, Bunnell et al. 1995). The riparian guidelines for S1 (major) river floodplains managed for deciduous species (BC Ministry of Forests 1995b) require that 5% of black cottonwood trees must be retained in the 20 m adjacent to the river channel after 2 rotations. The wider 50 m riparian management zones along the main channel and 30 m zones along backchannels currently used in the Kalum Forest District allow for greater retention and recruitment of black cottonwood trees than the 1995 riparian guidelines, but they must also take into account the rate at which trees will be lost over a rotation due to the average 3-7 m per year of riverbank erosion. Wildlife tree patches should be designed to incorporate some black cottonwood stems (both existing large trees and large tree “recruits”) along with the focus conifers in order to provide additional stand structure and wildlife habitat.

For wildlife management purposes, Bunnell et al. (2002b) provided a guideline for retention of 2-3 conifer snags per hectare >50 cm diameter and an additional 10-20 smaller snags throughout the rotation. They noted that recruitment of conifer snags throughout future rotations must be considered. These snags are best distributed in clumps for some species, but dispersed retention may be advantageous for perching birds and territorial users (Bunnell et al. 2002b). Targets for deciduous snags are not needed as most cavity nesters use live trees (Bunnell et al. 2002b).

The prevalence of game trails along backchannel areas indicated high use by wildlife. The Kalum Forest District’s current guideline for 30 m riparian reserve zones along backchannels does not recognize the higher wildlife values in backchannel areas. Riparian buffers should focus on functional attributes such as game trails, wildlife trees, woody debris accumulations, and access to non-forested habitats such as herb meadows and willow thickets to protect important targeted features, rather than on a fixed width (Burton 1998).

6.2 Stand Scale

Wetter soil moisture regimes in primary Sitka spruce stands compared to the primary deciduous stands were unexpected as these older ecological communities were predicted to be higher above the river level, and therefore better drained, than primary stands. The slightly higher clay contents reported in secondary deciduous and Sitka spruce stands probably explain the moisture regime difference. The higher relative elevation of the high bench ecological community results in lower energy flooding events and capping deposits that have a finer texture than those of middle bench deciduous stands. Moreover, our data indicate that primary Sitka spruce stands are predominantly located in more stable backchannel areas where lower energy water deposits finer sediments, and there is less risk from erosion (Schwab et al. 2002). These more stable and finer textured high benches should receive priority for long-term recruitment of old conifer-dominated seral stages.

6.2.1 Coarse Woody Debris

The volume of CWD in the Skeena River riparian ecosystems was one fifth of the volume reported for other ecosystems in the CWH zone. Feller (2003) found an average of 554 m^3/ha of CWD in 190 plots in the CWHvm, and an average of 750 m^3/ha in 15 plots in the more maritime CWHvh. The low volume of CWD in the Skeena riparian ecosystems is likely due to less time for accumulation of CWD compared to older upland landforms. We expected CWD volume to increase with stand age. The similar volume of CWD in all three stand types is probably due to rapid decomposition of the dominantly deciduous small diameter CWD that results from self- thinning in younger stands. This deciduous woody debris apparently does not persist until the old growth stage and thus cannot be expected to serve as a stable substrate for tree regeneration or as a long-term habitat feature for wildlife. The larger coniferous woody debris in the primary Sitka spruce stands is expected to be a more stable habitat feature. Although there was an accumulation of CWD on the edges of some islands (Figure 23), we did not find evidence of large amounts of externally derived CWD within stands.

Figure 23. Coarse woody debris carried into the edge of a young stand by flooding. Note the scar on tree where log has rubbed up and down while floating.

The finding that CWD is important as a substrate for conifer regeneration in this riparian ecosystem is consistent with other studies (Harmon and Franklin 1989, Naiman et al. 2002). Beach and Halpern (2001) showed that conifer regeneration in riparian forests depends on the interaction of proximity to seed source, presence of CWD, and low densities of shrubs, especially salmonberry. Given the importance of CWD in the regeneration dynamics of conifers in riparian ecosystems (Naiman et al. 2002), it is especially critical to adopt management strategies that ensure the recruitment of conifer CWD in these ecosystems (Figure 24).

The history of conifer harvesting on the floodplain and the low density of potential seed trees probably means that seed availability limits conifer regeneration in some areas. Beach and Halpern (2001) found no regeneration in areas greater than 170 m from the nearest potential seed source. Shrub fields have been reported to develop in some riparian areas where conifer regeneration has not occurred (Hibbs and Bower 2001). During our fieldwork, we observed large shrub-dominated patches adjacent to old Sitka spruce stands on the floodplain. The successional history of these shrub fields is not known, but they were not logging-induced. We hypothesize that the lack of conifer regeneration within these large canopy gaps results from a lack of raised seedbeds that provide protection from flooding, shrub interference, and herbivory rather than from insufficient seed rain.

Figure 24. Row of trees indicating the use of a nursery log for conifer establishment.

The amount of conifer regeneration in the two deciduous stands types, though highly variable and not significantly different, showed strong trends, with greater density in the secondary deciduous stands. The low density of conifers in the primary deciduous stands is apparently due to absence of conifer CWD, particularly stumps, in these stands. The conifer regeneration that does occur in these primary stands often establishes in the early stages of primary succession when the shrub layer is not yet fully established and mineral soil is still exposed, or after flooding events that destroy shrubs (Figure 25); small mammal population dynamics also play an important role (Coates et al. 1993). In the later stages of succession, when the understory shrub layer is well established, conifer regeneration is almost entirely restricted to CWD. Failure of conifer plantations and natural conifer regeneration is common in secondary stands on the floodplain due to a large increase in shrub density, abundant small mammals, the lack of well-decayed CWD substrate, and a limited seed source (Coates et al. 1990, Coates et al. 1993, McLennan 1995b).

Figure 25. Young primary succession red alder dominated forest with a sparse understory. Conifer establishment in this stand was on mineral soil, not on the CWD brought into the stand by flooding.

6.2.2 Stand Diversity and Species Richness

Although we found higher vascular species richness in the older Sitka spruce stand type than in the younger deciduous stand types, this pattern is not consistent with other studies, where vascular diversity often remains stable or decreases with increasing stand age (Peet 1974, Chipman and Johnson 2001, Haeussler et al. submitted). On the other hand, most studies show an increase in non-vascular species diversity, particularly for epiphytic and epixylic species (Lesica et al. 1991, Selva 1994, Crites and Dale 1998, Boudreault et al. 2000). The higher cover of non-vascular plants in the Sitka spruce stands is likely related both to the change in tree species and litter deposition that occurs during succession from deciduous to coniferous trees, and to the lower flooding frequency in the high bench Sitka spruce stands (MacKenzie and Moran 2004).

Arboreal lichen abundance is often used as an indicator of old growth stand conditions. In our study it was positively correlated with stand age and significantly different in each of the three stand types. In interior rainforests of British Columbia, *Lobaria pulmonaria* (lungwort), the dominant arboreal lichen, has been shown to be highly correlated with macrolichen diversity and has been proposed as an indicator for this attribute (Campbell and Fredeen 2004). However, the authors caution that using *L. pulmonaria* as a biodiversity indicator cannot be done indiscriminately. Although our sampling shows that we can use fallen arboreal lichens as an indicator of old growth conditions and of the overall higher plant species diversity associated with old stands, we did not sample arboreal lichens in this study. Actual sampling of arboreal lichens will be needed before we can assume that primary Sitka spruce stands have a higher diversity of macrolichens than younger deciduous stands. Old black cottonwood trees on the floodplain may also be important for lichen diversity. For example, the COSEWIC-listed frosted glass-whiskers lichen, known from only three locations in Canada, has been found on an old black cottonwood at nearby Kitsumkalum Lake (Selva 2003).

The stand scale data showed that primary Sitka spruce stands are distinct from the deciduous stands, not just in tree species composition, but also in plant species richness and structural diversity, as shown by the diversity index and the number and size of gaps. The greater species richness in primary Sitka spruce stands is likely a response to greater habitat heterogeneity due to the age of the overstory trees as well as to the age of the landform they are growing on. The fact that secondary deciduous stands had higher species diversity than primary deciduous stands, despite being younger and having similar overstory structure and gap attributes, lends support to this interpretation. The higher species richness in the secondary stands was apparently due to legacies from the Sitka spruce stands that previously occupied these sites, most notably the presence of stumps, which have been postulated to provide refugia where the density of salmonberry is very high (Kennedy and Quinn 2001). Given that secondary deciduous stands have greater species richness and tend to have more conifer regeneration than primary deciduous stands, but are very similar in most other respects, secondary stands, particularly those that were partially cut, appear to have greater potential for recruitment to Sitka spruce stands than do primary deciduous forests. Our landscape analysis (Section 5.1.2) and soils data (Section 5.2.1) also suggest that they may have greater landform stability.

6.3 Ecosystem Classification

An important question for the conservation and restoration of Red- and Blue-listed floodplain plant communities in the study area is whether three discrete ecological communities exist on the lower Skeena River floodplain that can be distinguished by floodplain bench height and flooding regime or whether the ecological communities represent a continuum of successional stages. The Biogeoclimatic Ecosystem Classification system describes three floodplain communities:

1. High bench Sitka spruce – Salmonberry community (CWHws1/07 or CWHvm1/09) characterized by intermittent flooding.

2. Mid-bench Black cottonwood – Red-osier dogwood community (CWHws1/08 or CWHvm1/10) characterized by frequent flooding.

3. Low bench Black cottonwood – Willow community (CWHws1/09 or CWHvm1/11) characterized by prolonged annual flooding and sediment deposition (Banner et al. 1993).

Our soils data (Table 10) and plant community data (Figure 18, Tables 16 and 17) do not support the existence of discrete and relatively long-lived ecological communities with distinct successional pathways leading to old-growth spruce or old growth black cottonwood. Instead, they suggest that there is a continuum of communities present that can be delineated primarily on the basis of stand age. The classification of seral stages into distinct ecological units is problematic from a conservation perspective, especially when some seral stages are designated as rare or vulnerable and others are not.

Our observation of stand dynamics and plant communities indicates that there are at least two types of low bench communities along this section of the Skeena River: backchannel or abandoned channel communities and mainstem or aggrading communities. The backchannel community is a relatively permanent community that occurs in old channels that no longer experience high velocity flooding but which have poorly to imperfectly drained soils for most of the growing season. This low bench community has a mix of tall shrubs and moist site herbs (similar to the Fl03 Pacific willow – Red-osier dogwood – Horsetail and Fl50 Sitka willow - False lily-of-the-valley communities described by MacKenzie and Moran (2004)). The mainstem community occurs on well-drained recent fluvial deposits adjacent to the mainstem of the river and is dominated by black cottonwood, willow, and a mix of pioneering grasses, horsetails and forbs (analogous to the Fl06 Sandbar willow community described by MacKenzie and Moran (2004)). The mainstem community is transient, as it is the first successional step towards middle and eventually high bench communities. The backchannel community appears to have the highest wildlife and fisheries values. Both of these low bench community types are extremely vulnerable to invasion by exotic herbaceous species such as tansy, Canada thistle, white sweet-clover, and various introduced grasses because of their moist mineral soil seedbeds, lack of tree cover, and the continual influx of water- and wind-dispersed seeds from upstream and from adjacent transportation corridors.

Young deciduous stands on the floodplain, whether they originate from primary floodplain succession or after logging of old growth spruce forest, are dominated by black cottonwood and red alder and cannot readily be distinguished from one another on the basis of soil, stand structural characteristics or understory community composition, except that secondary stands possess stumps and have somewhat higher shrub and herb cover and vascular species richness. A slight tendency towards finer textured soils on high benches was also found and there may be some spatial separation of the two forest types, with high benches more strongly associated with back channel areas. However, it is not possible to readily distinguish high and middle bench floodplain ecological communities on this portion of the Skeena River based on landscape position, soil properties or understory vegetation.

With increasing stand age, the percentage of coniferous trees increases primarily because of the shorter life span of deciduous trees and their inability to establish in the understory, rather than because of high rates of conifer recruitment. There is a corresponding increase in the abundance and diversity of conifer-associated shrubs and herbs, notably devil’s club, three-leaved foamflower, oak fern, spiny wood fern, sweet-scented bedstraw, rosy twistedstalk, and enchanter’s nightshade, and in the cover and richness of epiphytic and forest floor bryophytes and lichens. Old growth black cottonwood stands are rare, and thus worthy of conservation throughout the floodplain because those islands that escaped both erosion and logging tend to succeed relatively quickly to conifers. However, most mature and old growth stands on the active floodplain contain some remnant old growth black cottonwood trees.

Primary floodplain forests towards the eastern boundary of the study area, near Terrace, have low non-vascular and herb diversity and are more likely to include coastal-transitional species such as high-bush cranberry, snowberry, black twinberry, thimbleberry, pink wintergreen and false Solomon’s seal. Those located towards the western boundary of the study area have more abundant red alder, salmonberry, red elderberry and lady fern and a greater variety of non-vascular species, particularly liverworts. This change in species composition appears to be a consequence of a combined climatic and hydrogeological gradient. Soils become increasingly fine-textured downstream (clay lenses are more common near Exchamsiks) and there are undoubtedly other changes to the flooding regime that are unrelated to the milder and wetter oceanic climate. Surprisingly, species typically associated with seashore and estuarine communities, such as Pacific crab apple, false lily-of-the-valley and Pacific water-parsley, were not strongly associated with the east-west gradient.

6.4 Ecosystem Rarity Ranking

A recent inventory of floodplain forests in the CWHvm and CWHvh biogeoclimatic subzones of the North Coast Forest District (Ronalds and McLennan 2002) recommended that the high bench Sitka spruce – Salmonberry ecological community be downlisted from Red to Blue, and that the middle bench Black cottonwood – Red-osier dogwood ecological community be uplisted from Blue to Red. These recommendations were based primarily upon the number of element occurrences in structural stage 7 (old forest) inventoried within the North Coast Forest District, and did not consider other factors that are considered when ranking rare ecological communities, such as long and short-term trends, condition, threats, number of protected occurrences, and intrinsic vulnerability (BC Conservation Data Centre 2004).

The successional dynamics of the floodplain ecosystems facilitate the transition of low bench ecological communities into middle bench then high bench with time, providing erosion doesn't remove them before the process is complete. McLennan (1995a) justified the classification of a successional sequence into three distinct site series because the growing conditions at each stage are distinct. However, this classification approach presents problems for mapping and conservation. As described above, distinguishing between middle and high benches is problematic, especially after logging. A greater problem is the transition of a Blue-listed ecological community into a Red-listed ecological community over time, and planning for recruitment of future high bench ecological communities. For example, when priorities are set for conservation, should a secondary high bench stand be ranked higher than a primary middle bench stand of similar stand age? The secondary stand is Red-listed as it occurs on a high bench but the Blue-listed primary middle bench stand is undisturbed.

Among young stands, we generally believe that secondary stands have a higher conservation priority due to existing stand structure and understory diversity and the potentially greater stability of high bench landforms. However, certain late stage middle bench ecological communities in transition from overmature black cottonwood to spruce - western redcedar stands may have high conservation value (second only to remaining old growth), and there are also some young fluvial benches that recruit an exceptionally high density of coniferous regeneration during early succession. The most prudent management strategy may be to recruit a mix of primary and secondary deciduous stands as future old growth Sitka spruce, based on a combination of attributes (potential landform stability, existing coniferous structure, understory diversity, lack of human disturbance) and practical considerations such as operability and risk to other values (recreation, aesthetics, wildlife use, etc.).

6.5 Conservation Value Ranks

The conservation value ranking showed that 69% of the high and midbench floodplain area either retains a coniferous canopy or has a significant amount of conifer regeneration or remnant structure. These are areas ranked either A, B1 or B2. This result indicates that there is good potential to regain the former structure and function of the forest in the study area. That the greatest potential for restoration is in secondary stands is a function of biological legacies remaining from pre-disturbance stands that take time to build up in young ecosystems (Franklin et al. 2002).

The conservation value rank maps (Appendix 6) show ranks of individual polygons as well as areas with congregations of high or low ranked polygons. Both levels of information should be used together when making management decisions. For example, if an area of interest contains only one small stand with a high potential for restoration, management priorities will be different than if that same stand were in an area with many highly ranked stands.

7.0 Management Recommendations

7.1 Landscape Scale

The TEM map and conservation value rank map (Appendix 6) provide baseline information for preparing a spatially explicit landscape plan for the Skeena River floodplain that prioritizes areas for conservation, harvesting and other uses. Some factors to consider in preparing such a plan follow.

The rapid erosion of the most valued high bench floodplain ecological community dictates the need for a dynamic management plan that will maintain representative ecological communities across the floodplain while providing for sustainable harvesting opportunities. The impacts of past harvesting are distributed across the floodplain, with no reach presently meeting the high biodiversity seral stage guidelines (BC Ministry of Forests 1995a) for the mature seral stage. The Biodiversity Guidebook targets for seral stage distribution were not developed for a flood-dominated natural disturbance regime and are problematic, particularly with respect to setting targets for younger seral stages. Locally developed seral stage targets that take into account both the active erosion/deposition regime, historic abundance of old forest, and the global and provincial rarity of these coastal floodplain ecosystems would be more appropriate for this landscape unit. Regardless of the targets selected, our data indicate that percentages of old forest (5% old and 11% old plus mature) are currently well below levels considered acceptable in landscapes of high biodiversity value. Retaining existing old forest and recruiting future old forest must therefore be a primary objective in preparing landscape plans.

To ensure maintenance of all structural stages of the forest through time and to protect biodiversity and wildlife habitat, a landscape planning process that ensures ongoing retention and recruitment of spatially well-distributed mature and old seral stages is needed. Planning is complicated by ongoing erosion of landforms, which means that riparian reserve areas or old-growth management areas established today may not be there in the future. Managers must therefore continually update plans and build in appropriate margins for catastrophic flood events.

High bench floodplains situated well back from the main river channel are preferred locations for both conservation and commercial forestry purposes because of their temporal stability. Planning should begin by identifying low conflict areas for conservation, such as small islands and areas that are difficult to access, and build from this starting point on a reach-by-reach basis.

The recruitment of new Sitka spruce stands can best be achieved through retention of existing conifer patches within the deciduous stands that dominate the floodplain today. These conifer patches occur in both primary or secondary deciduous stands ranked B1 and B2. Secondary deciduous stands have greater species richness and tend to have more conifer regeneration than primary stands, but are similar in most other aspects. Thus secondary stands, especially partially cut stands, are likely to have greater potential for future recruitment of Sitka spruce stands than primary deciduous stands of the same age. However, older primary stands in transition to high bench, and B1-ranked younger stands with an exceptionally high conifer component, should take priority over secondary stands.

Another consideration when choosing areas for the recruitment of Sitka spruce stands is susceptibility to erosion. Areas closer to the mainstem of the river are generally less stable than peripheral areas, although channel morphology and the presence of backchannels are also important in susceptibility to erosion (Schwab et al. 2002). Peripheral areas should therefore be preferentially chosen for Sitka spruce recruitment purposes. Other considerations will be accessibility for commercial purposes, island size (i.e., amount available for commercial purposes after a riparian area is set aside), and geographic location relative to other existing and former Sitka spruce stands, for purposes of maintaining landscape connectivity for wildlife habitat, biodiversity conservation, conifer seed supply, and recreational and aesthetic considerations. Ideally, each reach should be managed to contain both a few large and many smaller well-distributed conifer dominated patches in perpetuity (Diamond 1975).

Large old conifers play an important functional role in both the terrestrial and aquatic components of riparian systems (see de Groot 2005 for a review). While we have quantified the volume of wood entering the river, little is known about the importance and residence time of locally sourced wood versus wood from upstream. An ongoing supply of large coniferous wood is important to maintain the geomorphological integrity of the river and its value as fish habitat. We recommend further research on the role of locally sourced wood versus upstream wood, the stability of logjams, and trends in volume of wood in the river to assist in planning for this important component of overall ecosystem function.

7.2 Stand Scale

7.2.1 Stand Management Practices

The first step in recruiting additional conifer-dominated stands over the long term is to retain existing conifers on the floodplain. At the stand scale, this can be achieved by locating wildlife tree patches and riparian reserves in areas containing conifer regeneration during the layout of harvesting blocks. Encouraging flexibility in laying out riparian reserves to include desired conservation features such as conifer patches, game trails, and continuity with non-forest habitats will also aid in reaching conservation goals. As erosion and deposition will change the width of riparian buffer strips over time, this flexibility will provide gains with little extra cost.

While much of the focus has been on recruitment of conifers, mature black cottonwood trees are also important for biodiversity, and are often found intermixed with maturing conifers. Maintaining a component of black cottonwood in wildlife tree patches and riparian reserves will help to maintain an ongoing supply of mature, old, and standing dead black cottonwood trees.

Coarse woody debris is essential for recruitment of conifers on the floodplain, and also provides structural and understory diversity and wildlife habitat within stands. Retention of conifers and large older deciduous trees within harvested areas, as well as in riparian reserves and wildlife tree patches, will help to maintain a long term supply of CWD on the floodplain. However, ground disturbance and treatment of logging residues must also be carefully considered during harvest operations. In areas where conifer recruitment is desired, protection of existing stumps and decaying logs and distribution rather than piling of logging debris is recommended. Shaded areas with a residual canopy and nearby conifer seed sources are most likely to recruit coniferous natural regeneration. Tree planting on elevated, decaying wood microsites in areas of low shrub competition and with a partial tree canopy should also be considered.

Managing for wildlife forage and other habitat values, such as thermal and visual cover and travel corridors, is important. Red-osier dogwood is important for moose, and berry-producing shrubs including devil’s club and red elderberry are important bear forage. Areas with heavy cover of these shrubs should be identified during block layout and incorporated into, or be near, areas of cover such as wildlife tree patches.

There are few areas at present suitable for conifer management for harvesting purposes. However, with careful management, partial cutting strategies for conifer management may become an option in some areas.

Methods of accelerating the recruitment of conifers into large size classes to restore the function of lost old and mature age classes could be investigated. One approach is to remove some deciduous overstory to release understory conifers as has been recommended for mixedwood forests in other parts of Canada (e.g., McLennan 1995b, Lieffers et al. 1996, Bergeron and Harvey 1997). Some black cottonwood should be retained to provide the function of these old trees (Bunnell et al. 2002a). Stands ranked B1 or B2 with a high residual or regenerating conifer component are the best candidates for this type of accelerated development. A potential trade-off for the resultant reduced harvest is that smaller riparian buffers may be possible around the partially cut blocks.

Where the purpose of deciduous overstory removal is to accelerate restoration of old forest function, clear long-term management objectives must be established prior to harvest so that the recruitment and retention of large live and dead trees of all species is not compromised by future harvesting activities. Monitoring could include the amount of damage to conifers, growth rates of released versus unreleased conifers, and structural characteristics of the stands.

7.2.2 Stand Level Indicators for Old Growth Sitka spruce-Salmonberry Ecosystems

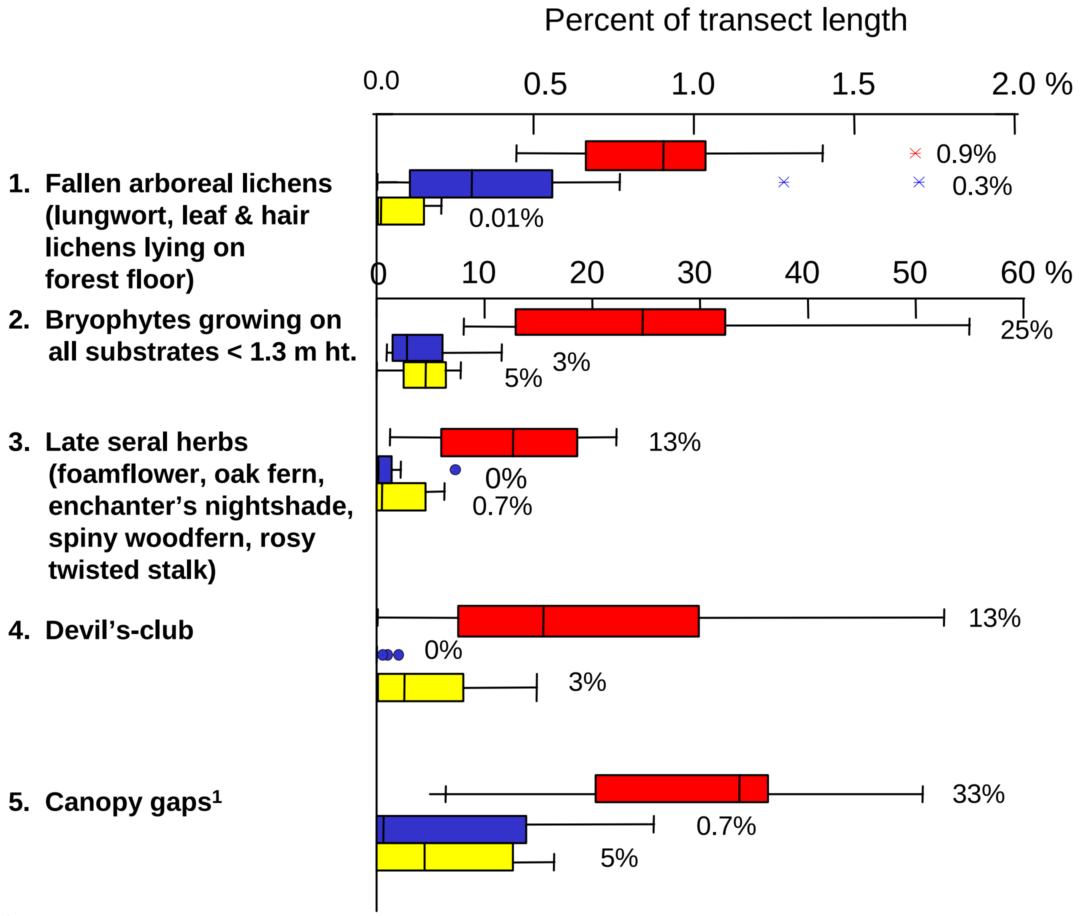
The following is a list of stand level biodiversity indicators that describe ecological attributes of old growth Sitka spruce – Salmonberry ecological communities and that can be used to differentiate these old growth conifer-dominated stands from younger primary and secondary deciduous stands:

Structural Indicators of Old Growth Stand Conditions:

- canopy gaps (% of transect length, see Figure. 24)
- structural diversity index (see Appendix 7 for details)
- coniferous trees >50 cm diameter (number of stems/ha)
- coniferous and deciduous snags >50 cm diameter (number of snags/ha)
- coniferous CWD >50 cm diameter (logs and stumps encountered on transects)

Vegetation Indicators of Old Growth Stand Conditions (measured as % of transect length, see Figure 24):

- fallen arboreal lichens (lungwort, leaf lichens and hairy lichens from the forest canopy lying on the forest floor)
- bryophytes (all mosses and liverworts) growing on all substrates
- late seral herbs (combined cover of three-leaved foamflower, oak fern, spiny wood fern, enchanter’s nightshade, rosy twistedstalk, and sweet-scented bedstraw)
- devil’s-club



[1] Includes only gaps that are wider than one average tree crown on their longest dimension. Does not include edaphic gaps caused by wet depressions or other soil conditions not suitable for tree growth.

Figure 26. Stand level indicators for Sitka spruce - Salmonberry ecological communities. These box and whisker plots show the range of variability in abundance (measured as % of transect length) for the best indicators of "old-growth" stand composition and structure, in primary Sitka spruce (red), primary deciduous (blue) and secondary (post-logged) deciduous (yellow) stands. The % figure and the vertical bar inside the box indicates median abundance, outer edges of the box and error bars represent the 2nd and 3rd, and 1st and 4th quartiles, respectively. Outliers are indicated by stars and circles.

The stand level indicators are intended to be used as local-level sustainable forest management planning tools to monitor the status and condition of the red-listed Sitka spruce – Salmonberry ecological community. During field inspections, the indicators are used to quantify the degree to which a floodplain stand possesses old growth attributes (Franklin et al. 2002). Together with the conservation ranking maps, they are can be used to prioritize stands for conservation, restoration, or commercial harvesting. After harvest treatments such as selective removal of hardwoods are carried out, the stand level indicators can be used to periodically monitor the effectiveness of restoration treatments and the rate of recovery of old growth stand attributes.

The indicators are measured by running randomly located linear transects through target stands (i.e., map or air photo polygons of uniform age). At least 100 m of transect is required per stand, with longer transects recommended for larger stands. Canopy gap percentage, CWD abundance and all of the vegetation indicators are recorded using the line intercept method (BC Ministry of Environment, Lands and Parks and BC Ministry of Forests 1998), which provides a less subjective estimate of percent cover than an ocular estimate. Information on stand structural diversity, large live conifer density and large snag density is collected on fixed radius plots located at 50 m intervals along the transect. Figure 24 indicates the range of variability for five of the proposed indicators; however, further data collection is required before the expected range of variability for the remaining stand structural indices can be described.

7.3 Conservation Value Ranks

The conservation value ranks should be used as a tool to guide management activities on the Skeena River floodplain. Forestry activities should be spatially distributed to ensure the maintenance of higher ranked areas across the landscape. This will allow species that use these areas to be distributed across the landscape. For example, moose may use the older conifer forests for only part of their habitat needs, also using younger deciduous stands. Therefore, the provision of essential older conifer stands may be critical to facilitate use of an area dominated by younger deciduous stands. For more discussion on moose winter habitat selection see Pollard (2001). In areas that currently have very few high ranked stands, management activities should be directed towards increasing the spatial distribution of conifer-dominated patches and recruiting old forest. If trade-offs are necessary between primary and secondary deciduous stands of the same rank, secondary deciduous stands should be chosen because of their greater restoration potential.

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Table 18. Pearson's r (linear) and Kendall's tau (rank) correlations of site and stand descriptors with plant community ordination axes of Figure 18 for (a) the full plant community (overstory and understory), and (b) the understory only. Only descriptors with r^2>0.20 or tau >0.30 were considered sufficiently correlated to be included here or in Figure 18. Tree volume descriptors were not used in (a) because they are trivially correlated with overstory species cover.

Site or stand descriptor		**(a) full plant community**						**(b) understory**					
		NMS Axis 1			**NMS Axis 2**			**NMS Axis 1**			**NMS Axis 2**		
Definition	**Abbrev.**	**r**	**r^2**	**tau**	**r**	**r^2**	**tau**	**r**	**r^2**	**tau**	**r**	**r^2**	**tau**
Stand age (years)	age	0.724	0.524	0.586	0.438	0.192	0.133	0.317	0.1	0.112	-0.293	0.086	-0.233
Percent of total stand previously logged[1]	% logged	-0.571	0.326	-0.454	0.074	0.006	-0.014	0.478	0.228	0.316	0.241	0.058	0.055
Distance from coast (UTM easting)	utm east	-0.181	0.033	0.023	-0.665	0.443	-0.428	-0.733	0.537	-0.462	-0.142	0.02	-0.164
Soil moisture regime class	smr	0.078	0.006	0.019	0.395	0.156	0.344	0.476	0.227	0.357	0.273	0.075	0.213
Conifers as percent of total stand volume	% conifers		n/a			n/a		-0.451	0.203	-0.383	0.194	0.038	0.237
Volume of live Sitka spruce (m^3/ha)	Ss vol.		n/a			n/a		0.435	0.189	0.328	-0.347	0.12	-0.317

[1] Based on old air photos, stumps and veteran tree density.

Table 19. Results of partial Multivariate ANOVA by canonical redundancy analysis (RDA) followed by orthogonal contrasts with 999 Monte Carlo permutations to test for differences in species composition by stand type for (a) the full plant community (overstory and understory), and (b) the understory only. Correspondence between the components of the multivariate F# statistic (defined below) and the usual univariate F statistic are more fully described in Legendre and Anderson (1999).

Source of variation	**(a) full plant community**					**(b) understory**				
	q	**$\sum\lambda$**	**trace**	**F#**	**p-value**	**q**	**$\sum\lambda$**	**trace**	**F#**	**p-value**
Covariable: soil moisture regime (SMR) not included	*1*	*0.69*	*0.02*	*1.3*	*0.24*	*1*	*0.77*	*0.03*	*1.3*	*1.23*
Covariable: distance from coast (UTM east)	1	0.71	0.05	2.6	0.02	1	0.80	0.06	3.0	0.013
Stand type	2	0.87	0.21	5.8	0.001	2	0.86	0.13	3.1	0.001
Contrast 1: old spruce vs. other stand types	1	0.82	0.16	8.9	0.001					
Contrast 2: primary deciduous vs. secondary deciduous	1	0.69	0.03	1.6	0.12					
Contrast 3: primary deciduous vs. other stand types						1	0.78	0.04	1.9	0.07
Contrast 4: primary spruce vs. secondary deciduous						1	0.83	0.10	4.7	0.001

q = number of dummy variables in explanatory matrix (equivalent to degrees of freedom)
$\sum\lambda$ = sum of all unconstrained eigenvalues (proportion of total variance in dataset after removal of other effects/covariables)
trace = sum of canonical eigenvalues (proportion of total variance accounted for by explanatory matrix); F# = (trace/q)/(($\sum\lambda$ - trace)/(N - $\sum$q – 1);
N = total number of observations = 40.

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Appendix 1 Glossary

Anastomosing - pattern of several main channels with relatively stable vegetated islands and side channels.

Backchannel - channel off the main channel that is not connected to the main channel at the upstream end.

Sidechannel - channel off the main channel that is connected to the main channel at both the upstream and downstream ends.

Thalweg - line of deepest water in a stream channel as seen from above. Normally associated with the zone of greatest velocity in the stream.

Appendix 2 List of Abbreviations

BEC	Biogeoclimatic Ecosystem Classification
CDC	Conservation Data Centre
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWD	Coarse Woody Debris
CWH	Coastal Western Hemlock
DBH	Diameter Breast Height
EC	Ecological Community
EO	Element Occurrence
GIS	Geographic Information System
LFH	Litter, Fibric, Humus
LRMP	Land and Resource Management Plan
LUP	Landscape Unit Plan
NMS	Non-metric Multidimensional Scaling
PEM	Predictive Ecosystem Mapping
RDA	Canonical Redundancy Analysis
SMR	Soil Moisture Regime
SRMP	Sustainable Resource Management Plan
TEM	Terrestrial Ecosystem Mapping

Appendix 3 Common and Latin names used in the text, with abbreviations from Figure 17

Plants

Badge moss	*Plagiomnium insigne*	PLI
Beaked moss	*Kindbergia* spp.	KIN
Black cottonwood	*Populus trichocarpa*	POB
Black twinberry	*Lonicera involucrata*	LOI
Bramble	*Rubus pedatus*	
Cat-tail moss	*Isothecium myosuruoides*	ISS
Common horsetail	*Equisetum arvense*	EQA
Devil's club	*Oplopanax horridus*	OPH
Douglas maple	*Acer glabrum*	
Enchanter's-nightshade	*Circaea alpina*	CIA
False lily-of-the-valley	*Maianthemum dilatatum*	MAD
False Solomon's-seal	*Maianthemum racemosum*	MAR
Frosted glass-whiskers	*Sclerophora peronella*	
High-bush cranberry	*Viburnum edule*	VIE
Lady fern	*Athyrium filix-femina*	ATF
Lungwort	*Lobaria pulmonaria*	
Nootka rose	*Rosa nutkana*	RON
Oak fern	*Gymnocarpium dryopteris*	GYD
Pacific crab apple	*Malus fusca*	MAF
Pacific water-parsley	*Oenanthe sarmentosa*	
Pink wintergreen	*Pyrola asarifolia*	PYA
Ragged moss	*Brachythecium* sp.	BRA
Red alder	*Alnus rubra*	ALR
Red elderberry	*Sambucus racemosa* ssp. *pubens*	SAR
Red-osier dogwood	*Cornus stolonifera*	COS
Rosy twistedstalk	*Streptopus lanceolatus*	SRR
Rough-fruited fairybells	*Prosartes trachycarpa*	PRT
Salmonberry	*Rubus spectabilis*	RUS
Sitka spruce	*Picea sitchensis*	PIS
Skunk cabbage	*Lysichiton americanum*	
Snowberry	*Symphoricarpos albus*	SYA
Spiny wood fern	*Dryopteris expansa*	DRE
Sweet-scented bedstraw	*Galium triflorum*	GAT
Thimbleberry	*Rubus parviflorus*	RUP
Three-leaved foamflower	*Tiarella trifoliata*	TIT
Western hemlock	*Tsuga heterophylla*	TSH
Western redcedar	*Thuja plicata*	THP
Willow	*Salix sp.*	
Wood horsetail	*Equisetum pratense*	EQP

Animals

Black bear	*Ursus americanus*
Bald eagle	*Haliaeetus leucocephalus*
Canada goose	*Branta canadensis*
Fisher	*Martes pennanti*
Moose	*Alces alces*
Wolf	*Canis lupus*

Appendix 4 Expanded Transition Table

Transition of area (ha) between ecological communities between 1947 and 1994/2003 using leading ecosystem component only. For example, of the total area in middle bench in 1947, 2,299 ha was still middle bench in 1994/2003 and 876 ha changed to river by 1994/2003. Also of the total middle bench area in 1994/2003, 529 ha was river in 1947. Shading indicates area that was unchanged between time periods. Minor area transitions may be due to either line error on the smaller-scale 1947 photographs or polygons having minor ecosystems components that could not be used in this analysis.

			1994/2003															
			River	Gravel bar	Low bench	Middle bench					High bench						Other	Total 1947
	Ecosystem	Structural stage				1 - 3	4	5	6 - 7	Total	1 - 3	4	5	6	7	Total		
1947	River		2,496	654	458	17	238	217	58	529	24	81	34	16	14	169	24	4,330
	Gravel Bar		379	200	176	6	125	235	100	464	9	6	5	8	0	29	13	1,261
	Low Bench		135	57	70	7	38	248	54	347	2	16	0	11	3	31	13	659
	Middle Bench	1 - 3	3	2	0	1	0	9	0	10	4	0	0	0	0	4	0	19
		4	227	92	53	55	119	249	135	558	20	27	102	5	4	158	2	1,088
		5	518	155	126	56	485	599	253	1,392	32	97	59	105	21	314	24	2,522
		6	128	53	36	79	93	109	59	339	7	19	16	50	4	95	14	674
		Total	876	302	219	191	697	966	446	2,299	62	153	173	132	27	571	36	4,303
	High Bench	1 - 3	17	2	0	0	0	0	0	0	2	0	0	2	0	4	0	23
		5	24	3	0	0	0	2	4	5	35	83	59	9	23	210	3	246
		6	138	31	26	8	55	29	10	101	187	533	171	91	42	1,024	14	1,332
		7	412	63	50	8	132	56	10	205	435	666	382	165	312	1,960	59	2,744
		Total	587	100	60	17	186	86	23	312	660	1,282	612	267	377	3,197	89	4,345
	Other		28	10	4	4	10	8	8	30	35	2	6	48	7	97	195	358
Total 1994/2003			4,500	1,322	986	242	1,294	1,760	688	3,982	792	1,530	833	509	431	4,095	364	15,255
Ha change from 1947			+170	+61	+333	+223	+206	-762	+14	-321	+769	+1,530	+587	-823	-2,313	-250	-6	
% change from 1947			+5	+5	+51	+1,173	+19	-30	+2	-7	+3,343	n/a	+239	-62	-84	-6	-2	

Appendix 5 Rare Ecosystem Conservation Value Ranking

Rare Ecosystem Condition Ranking for Linear Community Type

Sitka spruce – Salmonberry (high bench) and Black cottonwood – Red-osier dogwood (middle bench) on the Skeena River floodplain

These two communities are not being separated due to the difficulties in separating them on the land. Recommended management practices will strive to maintain older black cottonwood trees and other features of middle benches such as red-osier dogwood, important in the Blue-listed middle bench, on the floodplain.

These forests are linear in character, only occurring on floodplains of rivers and streams.

Minimum size – 0.5 ha (not really used as small polygons, may be embedded within larger ones).

Element Occurrence Separation

Polygons produced during the TEM process were used to define Element Occurrences. While this is not ideal, it was the only practical solution given the available TEM base map. The following are separation factors used in other linear ecosystems that could be adapted to the Skeena River situation:

1. Substantial barriers to natural processes or species movement, including cultural vegetation or very degraded example of same community greater than .25 km wide, major highways, urban development, large bodies of water.
2. Different natural community wider than 1 km along a river corridor, or 0.5 km in other situations.
3. Major break in topography, soils, geology, etc, especially one resulting in a hydrologic break.

Separation Justification

Riparian forest associations are usually intermixed because of the complexity of erosion and deposition dynamics on the floodplain, producing many mapable units. When combined with the forest harvesting history of the area, the results are a complex mix of stand ages that were important to separate into distinct polygons, though these polygons may be one EO by usual CDC standards.

Rank Procedure

Landscape context is usually the primary factor in linear communities, with condition being secondary and size tertiary. Here we are weighting condition higher than landscape context as there is little difference in landscape context among EOs in the Skeena River study area, and we feel condition is the most important factor in the area. With the long time needed to recruit stands to old forest structural stage, even small EOs are important so size is given little weight. Size is problematic because we used TEM polygons to define an EO, but usually a number of polygons could be merged to form one EO using CDC standards. The weighting will be 60:30:10. The letter ranks given are subsequently converted to numeric, weighted, and summed to arrive at an overall ranking for each polygon. For the condition and landscape context rank factors there are several components to consider when arriving at a rank. A rank is assigned using best professional judgement, within those considerations.

Rank Factor – Condition

A consideration in ranking condition in this landscape is the age of the landform. How should a young primary deciduous stand, i.e., on a recently created island, be ranked relative to an older primary coniferous stand on an older island? The older stands have been ranked higher due to the long recruitment time, and the uncertainty that the younger stand will reach the older stage without being eroded away.

A

- i) No history of previous forest harvesting, or if previous harvesting occurred it was selective, taking out <25% of the basal area or stems.
- ii) Presence of old-growth Sitka spruce and or western redcedar visible on air photos.
- iii) Little presence of exotic species.

B[5]

- i) Previous history of forest harvesting removed >25% of stems or basal area but succession is producing a stand with similar characteristics to original stand, due to presence of understory conifers.
- ii) Presence of understory Sitka spruce and/or western redcedar under a canopy of black cottonwood or red alder visible on air photos.
- iii) Some exotic species may be present.

C

- i) Previous forest harvesting, being maintained in a forested state but where the original stand characteristics will not be developed.
- ii) Understory conifer species are not visible on air photos.
- iii) Disturbance has allowed a large number or percentage of ground cover of exotic species to become established.

D

- i) Being maintained in a non-forested state.

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[5] The majority of the stands on the floodplain with a history of harvesting are in this category, so there was a regional need for a finer scale ranking process to prioritize the occurrences for conservation and planning purposes; see details below. Conifer regeneration is difficult in these stands because of the dense salmonberry and absence of large logs and stumps that provide regeneration sites, but conifers provide essential stand structure and silviculture options, so conifer regeneration presence is an important factor in ranking within this category.

Justification sub heading under rank factor

A. Old-growth structure is important for wildlife values such as thermal cover, denning and escape cover, while the flooding hydrological regime, including sediment deposition, is important for forming and maintaining these ecosystems.

B. Succession can bring the community back sooner, so that it functions as a mature or old forest, especially if hydrological regime is somewhat natural. Areas behind linear barriers may have flooding regime but without the sediment deposition.

C. Forest may allow the area to be used in a limited way by wildlife species that use older forest for thermal or visual cover, denning, or nesting, but will not have mature or old forest characteristics. Changed hydrological or erosion or deposition regime may ultimately change community to a different type.

D. No characteristics or structure that allow function as a forested floodplain community.

Rank factor – Landscape context

A

i) In a landscape without substantial urban or agricultural development, and low amounts of recent forest harvesting. This will allow the unit to provide benefits such as thermal cover, nesting, denning or roosting trees to the landscape area that animals may use for other parts of their life history.

ii) No barriers to movement. This connectivity to other forest patches allows plant species to disperse between suitable areas.

iii) Landscape is geomorphically very stable so will continue to provide benefits for the foreseeable future.

iv) Natural hydrological regime is still operating.

B

i) In a landscape with some urban or agricultural development, and/or some recent forest harvesting.

ii) Few barriers to movement. This connectivity allows movement between patches, but the surrounding landscape is of lower quality than optimum for these species.

iii) Landform is geomorphically quite stable and is not likely to be eroded away in the near future, and if so other areas nearby may be recruited to contain mature or old forest structure to replace it.

iv) Natural hydrological regime still mostly operating.

C

i) In a landscape with moderate amounts of urban or agricultural development, and/or moderate amounts of recent forest harvesting.

ii) Some barriers to movement. Poor connections to other habitat areas for wildlife, and these areas are of lower quality. Poor connectivity to other old or mature forest patches in general area so little chance of plant species dispersal between suitable areas.

iii) Landform may be eroded away and there is little area nearby for potential to be recruited to contain mature or old forest structure to replace it.

iv) Natural hydrological regime changed by diking, road or rail construction, i.e., flooding may still be occurring but erosion and depositional processes disrupted.

D

i) In a landscape with high levels of urban or agricultural development, and/or heavily developed for recent forest harvesting.

ii) Not connected to other habitat areas that can be used for other portions of animals' life history or to other old or mature forest areas to allow plant species dispersal between patches.

iii) Unstable landform that likely will be eroded in the foreseeable future and no area nearby for potential recruitment to contain mature or old forest structure to replace it.

iv) Natural hydrological regime totally changed and not likely to be reinstated.

Justification for A-ranked criteria

These forest types provide important habitat values to the landscape by providing forest structure that wildlife species use for specific parts of their life history. Without these forest structure attributes nearby the younger forests in the landscape may not be used as fully by wildlife. Rare plant species, especially non-vascular species, are often associated with mature or old forest structural stages. The erosional and depositional dynamics of the floodplain mean that areas of the floodplain can disappear taking away habitat values. These values are normally replaced as landforms age and older forests develop on them.

Justification for C/D threshold

C-ranked occurrences still provide some function to the natural landscape, whereas D-ranked occurrences are not in a natural state at all and may be agricultural, cleared Right-of-Ways, or residential areas.

Rank factor – Size

A. Very Large (>25 ha).

B. Large (10-25 ha).

C. Moderate (2-10 ha).

D. Small (<2 ha).

Justification

Polygons are rated from a TEM exercise; several polygons may actually be one EO, as the TEM was not designed to find EOs but to give an overall picture of the state of ecosystems on the floodplain. The EO sizes shown were subjectively determined based on the sizes of the polygons established during the TEM mapping process.

Overall Condition Ranking

The alphabetical ranks used are given numeric values as follows to allow calculation of a score: A = 4, B = 3, C = 2, and D = 1.

Condition will be the most heavily weighted conservation value factor among many of the polygons in the study area, as many polygons have very similar stands that have developed through primary succession or through secondary succession post-harvesting, and that these stands would be ranked "B" for condition. We felt that to distinguish these similar stands a subrank system within the "B" condition score was needed to set priorities for conservation and to give more specific direction for results and strategies under the BC Forest and Range Practices Act (FRPA). The amount of conifer regeneration in the polygons and the amount of remnant structure in logged polygons was thought to be important in this subrank process (Table 1).

Table 1. Condition subrank factors for the "B" condition rank.

% polygon area with visible conifer regeneration in understory	**Score**	Visible remnant structure from previous old growth stand	**Score**
>60	3.75	Abundant	3.75
30-60	3.5	Moderate	3.5
10-30	3.25	Little	3.25
<10	3.0	None	3.0

The scores given for the two subrank factors were averaged and then weighted and combined with the weighted scores for Size and Landscape Context to arrive at a rank value (Table 2) and EO letter rank and subrank (Table 3), based on CDC guidelines.

Table 2. Example of how factor ranks are used to calculate an overall ranking for an EO.

Polygon	Condition (60%)					Landscape context (30%)			Size (10%)			Calculated rank value and EO rank
	Rank	**Regen**	**Structure**	**Score**	**Weight**	**Rank**	**Score**	**Weight**	**Rank**	**Score**	**Weight**	
1	A			4	2.4	A	4	1.2	C	2	0.2	3.8 A
2	B	3.75	3.5	3.625	2.175	A	4	1.2	B	3	0.3	3.675 A
3	B	3.0	3.75	3.375	2.025	B	3	0.9	B	3	0.3	3.225 B2
4	C			2	1.2	A	4	1.2	D	1	0.1	2.5 C

Table 3. Overall ranking of Element Occurrences.

EO Rank and subrank	**Numeric Value**
A	3.5 to 4.0
B	2.5 to <3.5
B1	3.25 to <3.5
B2	3.0 to <3.25
B3	2.75 to <3.0
B4	2.5 to <2.75
C	1.75 to <2.5
D	<1.75

Rank Specifications Author – Adrian de Groot

Rank Specifications Edition Date – June 23, 2005

Rank Specifications Notes

This ranking document was written as part of the Skeena Islands Project, which aimed to determine dynamics and guide management of the Skeena River floodplain between Terrace and Kwinitsa. The area is dominated by listed plant communities and a ranking method was needed to determine the highest priority areas for conservation purposes.

Other Considerations

The above ranking methodology relates purely to the conservation ranking of EOs. Planning for forest harvesting occurring within the study area is needed. Two factors thought to be of importance to operational planning may possibly be seen on air photos. Dispersal of conifer regeneration, whether clumped or even, influences operability of an area. Areas of clumped regeneration are easier to work around, and delineation of riparian and Wildlife Tree Patch boundaries is simpler, compared to areas where regeneration is dispersed throughout the block. Areas with few channels, or other water features needing riparian management zones, will also be more operable than areas where these features are abundant. These two factors will be ranked on their own to help set priorities for conservation and to describe desired results for forest harvesting based on levels of risk to rare plant communities and values for fish and wildlife.

Table 4. Factors affecting the operability of areas that were considered.

Regeneration clumped or dispersed	Occurrence of channels or other water features
Dispersed throughout polygon	Abundant
Mostly dispersed	Moderate
Mostly clumped with some dispersed	Little
All clumped	None

Appendix 6 TEM and Conservation Value Ranks Maps

Contained in CD in back cover pocket.

List of files:

1947 TEM map reaches 1 & 2.pdf
1947 TEM map reaches 3 & 4.pdf
1947 TEM map reaches 5, 6 & 7.pdf
1947 TEM map reaches 8 & 9.pdf
1947 TEM map reaches 9, 10, & 11.pdf

1994 – 2003 TEM map reaches 1 & 2.pdf
1994 – 2003 TEM map reaches 3 & 4.pdf
1994 – 2003 TEM map reaches 5, 6 & 7.pdf
1994 – 2003 TEM map reaches 8 & 9.pdf
1994 – 2003 TEM map reaches 9, 10 & 11.pdf

Conservation rank map reaches 1 & 2.pdf
Conservation rank map reaches 3 & 4.pdf
Conservation rank map reaches 5, 6 & 7.pdf
Conservation rank map reaches 8 & 9.pdf
Conservation rank map reaches 9, 10 & 11.pdf

Appendix 7 Structural Diversity Index

A variety of indices of structural diversity have been proposed for use in coniferous and mixed forest stands (Staudhammer and LeMay 2001). However, these can be time consuming and difficult to apply and like most diversity indices, they are value-neutral. That is, they do not rank one component of structural diversity (e.g., large diameter Sitka spruce trees) as being of higher value than another component (e.g., small diameter red alder trees). A value-neutral structural diversity index is not appropriate for red-listed Sitka spruce – Salmonberry ecological communities where certain elements that play very important biodiversity and functional roles in the ecosystem are known to be at high risk (large old coniferous trees), whereas other elements are clearly not at risk (small young deciduous trees).

The following is a simple structural diversity index that has been specifically developed for the red-listed Sitka spruce – Salmonberry ecological community on the Skeena River floodplain based on analysis of field data collected in this study. Large trees and snags are assigned a higher weight than small trees and snags. The index can be very quickly calculated in the field based on visual examination of the stand at 50m intervals along the linear transect used to record the other stand level indicators identified in Section 7.2.1. The index will need to be field tested before being widely applied.

Instructions for calculating Structural Diversity Index:

Multiply the number of tree and tall shrub[1] *species* (not individuals) present in each layer by the number in the appropriate live or dead column. Sum the total for all layers live and dead.

Layer	**Live**	**Dead**[2]
>40m	10	5
25 - 40m	5	4
15 - 25m	4	3
7 - 15m	3	2
2 - 7m	2	1
<2m	1	1

[1] Tall shrubs are those species that exceed 2 m in height. Note that presence at <2 m height is recorded.

[2] Includes all snags, stumps and tall shrubs with basal diameter >10 cm. There is no diameter limit for live trees and shrubs.

Example 1. Old growth multi-layered mixed species stand with well-developed shrub layer.

Layer	Live											Dead				Total
	Score	Ss	Act	Dr	Hw	Cw	Crabapple	Elderberry	Salmonberry	Dogwood	Devil's club	Score	Ss	Act	Dr	
>40m	10	x	x									5				
25 – 40 m	5	x	x	x								4		x		
15 – 25 m	4			x	x							3			x	
7 – 15 m	3					x	x					2	x		x	
2 – 7 m	2	x						x	x	x	x	1				
<2 m	1	x			x	x			x	x	x	1	x=stump			
		18	15	9	5	4	3	2	3	3	3		3	4	5	77

Example 2. 40 year old secondary deciduous stand (previously logged) with uniform shrub layer.

Layer	Live						Dead						Total
	Score	Ss	Act	Dr	Hw	Salmonberry	Score	Ss	Cw	Act	Dr	Willow	
>40 m	10						5						
25 – 40 m	5		x				4						
15 – 25 m	4		x	x			3				x		
7 – 15 m	3	x		x			2			x	x	x	
2 – 7 m	2	x				x	1						
<2 m	1	x			x	x	1	x=stump	x=stump				
		6	9	7	1	3		1	1	2	5	2	37

Example 3. 10 year old young primary floodplain with sparse understory.

Layer	Live				Dead			Total
	Score	Ss	Act	Dr	Score	Act	Dr	
>40 m	10				5			
25 – 40 m	5				4			
15 – 25 m	4				3			
7 – 15 m	3		x	x	2	x		
2 – 7 m	2				1	x	x	
<2 m	1	x			1			
		1	3	3		3	1	11