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Ecology and Management of B.C. Hardwoods

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CANADA-BRITISH COLUMBIA PARTNERSHIP AGREEMENT ON FOREST RESOURCE DEVELOPMENT: FRDA II

Canada

BC

Ecology and Management of B.C. Hardwoods

Workshop Proceedings
December 1 and 2, 1993, Richmond, B.C.

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Preface

British Columbia has six major hardwood species: trembling aspen, paper birch, balsam poplar, black cottonwood, red alder, and bigleaf maple. Interest in utilization and management of British Columbia's broadleaved tree species (hardwoods) has grown substantially over the past decade. In B.C. broadleaved forests represent approximately 11% of the productive forest land base. Mixedwood forests, comprised of mixtures of conifers and broadleaves, represent approximately 35% of B.C.'s productive forest land base. In northeastern B.C. trembling aspen is being harvested for production of oriented stand board and pulp. In southwestern B.C. red alder is being harvested for sawlumber, with waste chips being used for pulp.

As markets develop for B.C. hardwood products interest in the management of hardwoods is expected to grow. In addition, broadleaves serve important ecological roles and contribute to biodiversity and to the productivity and sustainability of our forests.

This report contains summaries of papers and posters presented at a workshop held December 1 and 2, 1993 in Richmond, B.C. The purpose of the workshop was to provide field practitioners and researchers with opportunities to review and discuss the latest information on the ecology and management of British Columbia's broadleaf species.

Acknowledgements

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Hardwood Utilization and Supply in British Columbia

Michael R.C. Massie
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Abstract

An examination of British Columbia forest inventory on the basis of lead species (i.e., stands classified by the most prevalent species) indicates that there are varying concentrations of hardwoods throughout the province. These areas of concentration are estimated to be able to sustain a harvest of more than the current annual 2.0 million m^3. How much more will depend on better inventory information, the degree of management to be applied (particularly with reference to the large number of overmature stands), and policies with respect to non-consumptive allocations, tenures, and harvesting. Both domestic and foreign markets for hardwood forest products have been improving over the last decade creating opportunities to increase the harvest of British Columbia hardwoods.

Introduction

Most of the information in this paper was summarized from a recent report for the Ministry of Forests by Massie et al. 1992, which assessed the strategic importance of the hardwood resource.

In order to estimate supply and the potential for utilization in various geographic regions of the province, basic information was summarized from the statistics compiled for each Timber Supply Area (TSA) using the Provincial Summary Reporting System. The data were compiled on a lead species basis. This procedure allowed the identification of hardwoods and the location where utilization interest will likely focus. The magnitude of the utilization will depend not only on the "purity" factor for the hardwood stands but also on the hardwood component in stands where the lead species is coniferous.

Hardwoods in B.C.

Table 1 summarizes available (March 1992) inventory data on the basis of lead hardwood species.[1] The table includes most, but not all, of the lands in B.C. where the lead species is a hardwood, and where harvesting can occur. It does not include hardwoods in stands where the lead species is coniferous. It is based on concentrations of hardwoods in Timber Supply Areas of the province; it does not estimate total hardwood volumes. The table indicates the number of hectares in the Timber Supply Areas (or groups of areas) that are predominantly hardwood, and the volumes on those areas in three age class groupings.

[1] The volumes and areas are compiled on the basis of inventory type groups. Only those volumes and areas were compiled where the first or most prevalent species was a hardwood.

Table 1. Hardwood inventory in B.C. based on lead species analysis

A. Cottonwood

Regional area	Area (ha)[a]	Volume (000 m^3) Near mature	Mature	Over mature
Lower mainland	13 519	1 302	202	177
Mid mainland	6 516	480	164	497
Coast	**20 035**	**1 782**	**366**	**674**
Northeast	160 260	2 671	16 868	13 758
North central	15 600	118	444	1 186
Northwest	21 406	85	729	2 336
South central	8 100	107	661	461
Southeast	10 135	231	879	314
Interior	**215 501**	**3 212**	**19 581**	**18 055**

Geographic area/Timber Supply Areas definition:

Lower mainland	Fraser, Soo, Sunshine Coast
Mid mainland	Kingcome Mainland, Mid Coast
Northeast	Fort Nelson, Fort St. John, Dawson Creek
North central	Prince George, Mackenzie, Robson Valley
Northwest	Bulkley, Kalum, Lakes, Kispiox, Morice
South central	Merritt, Kamloops, Okanagan
Southeast	Arrow, Boundary, Kootenay Lakes, Cranbrook

Maturity/age definition:

Near mature (coast)	41 to 80 years of age
Near mature (interior)	61 to 80 years of age
Mature	81 to 120 years of age
Over mature	121 years of age or more

[a] Good, Medium, and Poor site; not including low site.

B. Aspen

Regional area	Area (ha)[a]	Volume (000 m^3) Near mature	Mature	Over mature
Northeast	2 183 811	28 277	173 762	46 812
North central	569 414	11 014	28 384	7 053
Northwest	215 049	5 044	9 420	4 027
Central	229 180	4 408	13 668	910
South central	67 500	2 170	3 342	209
Interior	**3 264 954**	**50 913**	**228 576**	**59 011**

Geographic area/Timber Supply Areas definition:

Northeast	Fort Nelson, Fort St. John, Dawson Creek
North central	Prince George, Mackenzie
Northwest	Bulkley, Kalum, Lakes, Kispiox, Morice
Central	100 Mile, Quesnel, Williams Lake, Robson Valley
South central	Kamloops, Okanagan

Maturity/age definition:

Near mature	61 to 80 years of age
Mature	81 to 120 years of age
Over mature	121 years of age or more

[a] Good, Medium, and Poor site; not including low site.

C. Paper birch

Regional area	Area (ha)[a]	Volume (000 m^3) Near mature	Mature	Over mature
Upper Fraser	8 025	486	40	1
Northeast	137 000[b,c]	3 190	6 178	661
North central	22 385	437	912	301
Northwest	12 962	476	561	113
Central	34 485	1 111	2 401	104
South central	37 265	971	1 903	173
Total	**115 122**	**6 671**	**11 995**	**1 353**

Geographic area/Timber Supply Areas definition:

Upper Fraser	Fraser, Soo
Northeast	Fort Nelson, Fort St. John
North central	Prince George, Mackenzie
Northwest	Kalum, Kispiox
Central	Quesnel, Williams Lake, 100 Mile, Robson Valley, Kamloops
South central	Okanagan, Revelstoke, Arrow, Kootenay Lakes

Maturity/age definition:

Near mature	41 to 80 years of age
Mature	81 to 120 years of age
Over mature	121 years of age or more

a Good, Medium, and Poor site; not including low site.
b In the northeast of the province paper birch would also include Alaska birch.
c In the Dawson Creek TSA the data were not adequate to report on birch on private farm land. On public land only 4515 hectares were reported with birch as the predominant species.

D. Coast alder

Regional area	Area (ha)[a]	Volume (000 m^3) Near mature	Mature	Over mature
Lower mainland	77 156	15 168	2 881	123
Mid mainland and North Vanc. Island	25 980	4 315	467	45
South Vanc. Island	36 329	9 037	317	0
Coast	**139 465**	**28 520**	**3 665**	**168**

Geographic area/Timber Supply Areas definition:

Lower mainland	Fraser, Soo, Sunshine Coast
Mid mainland and North Vanc Island	Kingcome, Mid Coast
South Vanc Island	Arrowsmith, Strathcona

Maturity/age definition:

Near mature	41 to 80 years of age
Mature	81 to 120 years of age
Over mature	121 years of age or more

a Good, Medium, and Poor site; not including low site.

E. Coast big leaf maple				
		Volume (000 m^3)		
Regional area	Area (ha)[a]	Near mature	Mature	Over mature
Lower mainland	14 131	2 842	1 626	67
South Vanc. Island	1 033	338	65	10
Coast	**15 164**	**3 180**	**1 691**	**77**

Geographic area/Timber Supply dreas Definition:

Lower Mainland	Fraser, Soo, Sunshine Coast
South Vanc Island	Arrowsmith, Strathcona

Maturity/age definition:

Near mature	41 to 80 years of age
Mature	81 to 120 years of age
Over mature	121 years of age or more

[a] Good, Medium, and Poor site; not including low site.

Source: Ministry of Forests, Inventory Branch, Provincial Summary Reporting System, Compilation Reference No. PSR12APJ, March 2, 1992. Ministry of Forests, Timber Harvesting Branch, Timber Tenures Section, Tree Farm Licence Area Summary (Including Deciduous), February 11, 1992. Ministry of Forests, Timber Harvesting Branch, Management and Working Plans for Selected TFLs, various dates, 1988–1992.

Over-mature (121 years of age or more) is intended to indicate where the resource is largely past its prime with respect to forest products manufacturing. Utilization is expected to be very limited in these stands and long-term utilization for forest products will be dependent on conversion to new stands. Mature (81–120 years of age) is intended to denote a potential for some near-term utilization, as these stands are rapidly deteriorating in quality. Utilization of these stands will require attention to waste management.

Near mature (41–80 or 61–80 years of age, depending on species) is intended to indicate the potential for forest products utilization over the next several decades. These younger, higher-quality stands will become the main resource supporting forest products manufacturinn^ Appropriate forest management strategies should be developed for both consumptive and, where appropriate, non-consumptive use of these lands.

Coast Cottonwood

Coast cottonwood occurs on the mainland on good and medium sites from the Mid-Coast to the Fraser TSA. About two-thirds of the volumes reported are in the near mature class. The opportunities for management and utilization appear excellent. Volumes for utilization can likely be expected to be assembled by water transport in most cases, as large areas of concentration do not exist. Some specified areas involving the floodplains of major rivers could be dedicated to intensive cottonwood management, but the opportunities appear to be limited in both size and number.

Interior Cottonwood

The largest concentrations of Interior cottonwood are found in the northeast of the province on medium and poor sites, and most of the volume is mature or over-mature. A much lower, but still significant, concentration can be found in the northwest of the province in the Bulkley, Kalum, and Kispiox TSAs on medium and good sites. This timber is largely over-mature.

Aspen

Aspen is the major B.C. hardwood species and the major concentrations are in the Northern Interior. The Fort Nelson, Fort St. John, and Dawson Creek TSAs have by far the largest areas and volumes where this species dominates. Most of the sites are classified as poor or medium, and most of the volume is classified as either mature or over-mature. Strategic planning for long-term management and utilization will be difficult because of the age class imbalance.

Significant areas of concentration also exist in the northwest, the north central, and the central and south central areas of the Interior. Again, the sites are almost evenly divided between medium and poor. The age class distribution of these stands, however, is considerably better, and some 25% of the reported volumes are in the near-mature or 61–80 year age class.

Paper Birch

The largest concentration of paper birch is found in the northeast of the province, particularly in the Fort Nelson TSA. Much lower concentrations are found in the central and south central areas of the province. In the northeast most sites are poor, while in the central and south central areas of the province most of the sites are medium. About two-thirds of the volumes reported are mature or over-mature.

Coast Alder

There are significant concentrations of alder along the B.C. coast from the Mid-Coast TSA south to the Fraser TSA. The majority of these concentrations are on good and medium sites. Most of the volumes reported are in the 41–80 year age class (near mature). Given the combination of medium site and relatively large volumes of just maturing timber, the potential for utilization and management based on strategic planning appear to be excellent. Initial attention might be focused on the Sunshine Coast area, which has both the largest mature and immature volumes.

Coast Maple

Coast maple is concentrated in the Fraser TSA and to a lesser extent in the Sunshine Coast TSA. Similar to alder, most of the stands are on good and medium sites. In the Fraser TSA most of the volume is in the near mature class, while the smaller Sunshine Coast volume is largely mature. Although a much smaller resource (than alder) there appears to be a good opportunity for utilization in the Fraser TSA.

Supply and Utilization

Table 2 compares estimated current utilization with an estimated annual harvest for 20 years based on concentrations of hardwoods. The 20-year annual harvest figures were calculated on the basis of a 50% availability rate using only mature and near mature inventory volumes. The primary intent of the table is to compare a conservatively estimated level of sustainable use of the resource with current forest products utilization.

Table 2. Estimated annual utilization potential by species

Region and species	Estimated 20-year annual harvest (000 m^3)	Estimated current utilization (1992) (000 m^3)
Coast		
Maple	80	5
Alder	448	425
Cottonwood	31	156
Birch	7	2
Total coast	**566**	**588**
Interior		
Birch	317	20
Cottonwood	490	185
Aspen	5 616	1 250
Total interior	**6 423**	**1 455**
Total province	**6 989**	**2 043**

Source: Annual Harvest – Derived on the basis of the lead species inventory and the following calculations:

One half the mature volume divided by 20; plus one-fortieth of the near mature volume for Interior aspen and cottonwood, and one-eightieth for all other species if the near mature volume exceeds the mature volume.

Current Utilization – Estimated on the basis of Simons Strategic Services Division (1991) updated to 1992 on the basis of Nawitka Resource Consultants, Victoria, and R.J. Hyslop and Associates, Vancouver, file information.

Based on this very limited analysis, utilization of cottonwood and alder on the coast are at fairly high levels relative to the volumes that are estimated to be available from lead species stands. Further utilization of these species may not be prudent until better inventory information is available, as well as estimates of the volumes of these species that are harvested annually in conjunction with the softwood harvest. In the case of cottonwood, pulpwood plantations should be considered separately. Intensive management and harvesting in these stands does not, in general, affect the use or sustainability of cottonwood in natural stands.

In the Interior, current levels of utilization are well below estimated annual harvest potentials for lead species lands. In the case of aspen, large utilization commitments have been made or are pending in the Dawson Creek, Fort St. John, and 100 Mile House TSAs. There is also interest in large commitments in the western part of the Prince George TSA, and the Lakes and Morice TSAs.

Products and Markets

A variety of products can be manufactured from B.C. hardwoods for both domestic and foreign markets. Current products and markets, or those expected to develop in the next few years, are shown in Table 3. This overview is somewhat simplistic in that secondary manufacturing and remanufacturing are not presented in detail. The main purpose of the table is to indicate the major product, if not the primary product, to be derived from the timber. A good potential exists for paper birch and maple veneers or plywood in the U.S. and Pacific Rim markets. Also, provided that a large enough annual supply is available from a geographic area where the supply is concentrated, there is a potential for a small birch pulpmill.

Table 3. Products and markets, short term

Species	Products	Markets
Paper birch	veneer	U.S., Pacific Rim
	minor lumber	Domestic
	minor specialty	Domestic
	pulp chips possible	Domestic, U.S.
Maple	veneer	U.S., Pacific Rim
	minor lumber	Domestic, U.S.
	minor specialty	Domestic
Alder	quality lumber	U.S., Pacific Rim, Europe
	common lumber	Domestic
	pulp chips	U.S., Pacific Rim
Cottonwood (Coast)	logs	S. Korea, China, Japan
	veneer	Domestic, U.S.
	pulp chips	Domestic, Pacific Rim, U.S.
	pulp	Domestic
Cottonwood (Interior)	waferboard (OSB)	Domestic, U.S.
	veneer and plywood	Domestic, U.S.
Aspen	waferboard (OSB)	Domestic, U.S.
	pulp	Domestic and Foreign
	minor specialty	Domestic and Foreign
	hog fuel	Domestic

Source: Estimated on the basis of file information from Nawitka Resource Consultants, Victoria, and R.J. Hyslop and Associates, Vancouver.

There is a demand for quality alder lumber in the U.S., Europe and the Pacific Rim. Alder pulp chips can be sold to the U.S. and Japan, but demand tends to be intermittent. Currently, the use of alder on the B.C. coast for pulp does not appear to be attractive.

The outlook for coast cottonwood is good. Although intermittent, there is a strengthening demand for logs and pulp chips in Pacific Rim markets. A good market for cottonwood veneer exists in the United States. Scott Paper Ltd. in New Westminster uses and purchases cottonwood bolts and chips for the domestic manufacture of pulp and, additionally, blended tissue products. Their specifications favour young, fast-grown cottonwood with a high degree of brightness. Interior cottonwood (largely balsam poplar) is widely used for veneer and as core stock in plywood, particularly for interior applications and furniture. This market is somewhat limited in Canada but is relatively large in the U.S. Cottonwood can be used for waferboard (oriented strand-board) but preference has been given to aspen where that is available. In British Columbia aspen is used for waferboard and pulp. There are both large domestic and foreign markets for these products, but they are very competitive.

Factors Limiting Supply

The supply of hardwoods in B.C. for use in manufacturing forest products will depend on such factors as shown in Table 4, not the least of which is better inventory-related information. Definition of a sustainable harvest will require better knowledge of the resource on uncommitted Crown lands, committed Crown lands, and private lands. Three areas of information are vital to improve these land-related statistics:

1. the degree of mix or purity with respect to conifers;
2. the age of the stands in narrow age classes; and
3. updated statistics on land in various other classifications that may be adequately stocked to hardwoods and hence warrant a hardwoods classification.

In the longer term, sustainable production for forest products will depend on how much land is retained in ownerships upon which harvesting can occur. Within this framework, policies with respect to non-consumptive uses

Table 4. Factors influencing future supply

Inventory related
- TFL statistics needed
- mixed wood component reporting
- new immature, mature and overmature definition
- updated reversion and NSR, NCBr[a]

Harvesting restriction and loss
- deletion of land from provincial forests
  - no harvesting
  - harvesting (regulation change)
- environmental protection (minor to major)
- non consumptive (minor to major)

Forest management
- intensity of management and cultivation
- professional and technical training
- research

Policy
- allocation and tenure arrangements
- excessive mature and over mature stands
- mixed stand logging and regeneration
- quality, log grades and waste definition
- stumpage rates

[a] NSR = not satisfactorily restocked
NCBr = non-commercial brush

and environmental protection will further limit annual harvesting. Hardwood ecology and multiple use are discussed in the main report (Massie et al. 1992). The scope of this paper was directed at consumptive uses. Hardwoods, in general, are fast growing and respond quickly to intensive management. The degree of management applied will affect future supply. A higher level of hardwood management in B.C. will, however, require both increased research as well as increased professional and technical training in the forestry community, which to date has been largely concerned with coniferous management. New policies will be required to deal with hardwoods. These will include refined allocation and tenure arrangements, addressing the over-mature stands problem, the creation of new guidelines for mixed stand logging and regeneration, and, finally, attention to product definition in terms of specifications for hardwood timber products.

Reference

Massie, M.R.C., E.B. Peterson, N.M. Peterson, and K.A. Enns. 1994. An assessment of the strategic importance of the hardwood resource in British Columbia. B.C. Ministry of Forests and Forestry Canada, Victoria, B.C. FRDA Report 221. 206 p.

Hardwood Supply and Utilization in Oregon and Washington

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Abstract

Current estimates (1991) of hardwood inventory in Oregon and Washington show about 36 billion board feet of sawtimber, comprising about 10% of the total softwood and hardwood inventory. Over two-thirds of the hardwood is red alder. Sixty-eight percent of the hardwood resource is privately owned. The annual harvest of hardwoods is about 600 million board feet, 90% of this coming from private lands. This harvest directly supports about 7000 jobs in a stable or expanding hardwood industry.

The industry is rapidly approaching full utilization of the alder resource. Recent estimates (1991) for alder growing stock in Washington show annual removals of 136 million cubic feet (3.8 million m^3), exceeding the annual growth of 97.4 million ft^3 (2.76 million m^3). Also, a significant portion of the hardwood resource is not available for utilization due to regulations or management policies. Thus there are serious concerns about future supplies and the sustainable level of harvest.

The current high level of hardwood supply is a legacy of past forestry practices. Modern forestry practices effectively favour conifers on intensively managed lands. The large hardwood component on non-industrial private ownerships will probably be maintained by current practices. Overall, a reduced supply of hardwood in the future is already indicated for Washington by decreases in the acreage of pole-sized hardwood types from about 820 000 to 400 000 acres (340 250 to 165 975 ha) over a 10-year period (1979–1989).

Hardwoods are managed on only about 1% of the landscape, but efforts to manage hardwoods are increasing, particularly on ownerships associated with the hardwood industry. Increasing research is focused on regeneration and stand management of hardwoods.

Management and harvesting behaviour on non-industrial forests will be very important in determining the future hardwood resource.

Introduction

In a region dominated by conifers, hardwoods have historically played a minor role in the timber economy of Oregon and Washington. However, the hardwood component of Northwest forests has increased greatly since the 1920s due to low rates of utilization and due to forest practices that produced abundant hardwood regeneration. A substantial hardwood industry has become established and there is great interest in new or expanded industries based on hardwood resources.

With this interest in increasing utilization, resource biologists and representatives of the hardwood industry have expressed major concerns about the future of the hardwood resource. Harvest or removal of hardwoods continues to increase but there appears to be little planning or management for sustainable hardwood resources; there is much planning and management to favour conifers and reduce the abundance of hardwoods.

This paper summarizes the major results of the report: "Hardwood supply in the Pacific Northwest: a policy perspective," (Raettig et al. 1995). The goals of this paper are to: 1) describe important attributes of current hardwood supply and utilization; 2) identify and discuss key aspects of forest practices that will determine future supplies; and 3) make recommendations for policies and practices to promote sustainable hardwood resources and industries.

Hardwood Timber

The most current estimates (1991) of hardwood inventory in Oregon and Washington show about 36 billion board feet of sawtimber or 11.9 (337 million m^3) of growing stock. Hardwoods comprise about 10% of the total softwood and hardwood timber inventory (Figure 1). Red alder (*Alnus rubra* Bong.) is by far the most important hardwood species, comprising almost two-thirds of the hardwood growing stock and sawtimber volume in the region (Figure 2). Bigleaf maple (*Acer macrophyllum*) and black cottonwood (*Populus trichocarpa*) are the next most abundant species by volume and together with red alder account for 87% of the total volume of hardwood species.

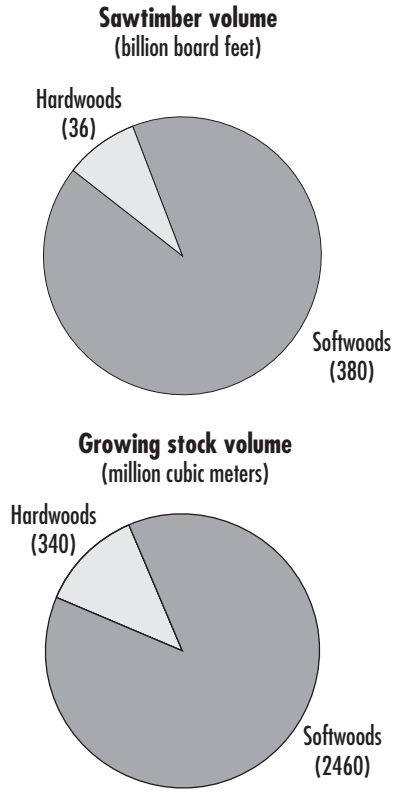

Figure 1. Hardwood sawtimber and growing stock inventory volumes for western Oregon and Washington. Washington data are from McLean et al. 1992 and estimates are as of January 1, 1991. Oregon data are from Gedney et al. 1986a, Gedney et al. 1986b, and Gedney et al. 1987; estimates are as of January 1, 1987.

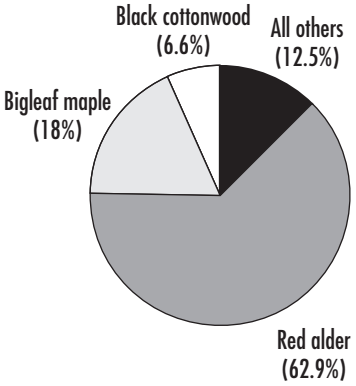

Figure 2. Percent distribution of hardwood volume by species in western Oregon and Washington. Source of data as in Figure 1.

The balance of the volume is accounted for by species such as tanoak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), Oregon white oak (*Quercus garryana*), and chinkapin (*Castanopsis chrysophyla*), which are locally important, particularly in southwestern Oregon.

Ownership

About 70% of the hardwood sawtimber and growing stock in the region is found on private lands (Table 1). State lands in Washington provide a significant public hardwood resource. Both Federal and State lands contain a significant portion of the hardwood resource in Oregon.

In the region as a whole, the inventory of private hardwood timber is evenly split between industrial and non-industrial forest ownerships. In Washington, 53% of private hardwood occurs on non-industrial (NIPF) ownerships, while in Oregon non-industrial owners have 46% of the hardwood. Red alder is more abundant on industrial lands while most other hardwood species are more abundant on NIPF lands.

Stand Characteristics

Most of the hardwood sawtimber volume in the Pacific Northwest is found in mixed-species stands of both conifers and hardwoods (Table 2). In Washington, pure

Table 1. Hardwood sawtimber inventory distributed by state and by owner[a]

	Percent of total hardwood sawtimber volume				
State	Forest industry	Other private	National forest	Other public	Total hardwood sawtimber volume billion board feet
Washington	34.8	41.4	2.5	21.4	20.6
Oregon	33.1	25.2	30.1	11.7	15.4
Region	34.1	34.5	14.3	17.3	36.0

[a] Washington data are from McLean et al. 1992 and estimates are as of January 1, 1991. Oregon data are from Gedney et al. 1986a, Gedney et al. 1986b, and Gedney et al. 1987; estimates are as of January 1, 1987.

Table 2. Hardwood sawtimber volume in pure and mixed stands by non-federal owner and state[a]

State and owner	Pure hardwood	Hardwood/conifer	Conifer/hardwood	Total
Washington				
Forest industry	615	4 270	2 270	7 155
Non-industrial private	938	6 237	1 330	8 505
Other public	152	2 792	1 453	4 397
Total	**1 705**	**13 299**	**5 053**	**20 057**
Oregon				
Forest industry	597	2 608	1 890	5 095
Non-industrial private	674	2 014	1 188	3 876
Other public	552	688	554	1 794
Total	**1 822**	**5 311**	**3 632**	**10 765**
Region total	**3 527**	**18 610**	**8 685**	**30 822**

[a] Data from Oregon are from Oregon Department of Forestry Annual Reports. Data from Washington are from Washington Department of Natural Resources timber harvest reports. Expressed as million board feet, Scribner.

hardwood stands account for only 9% of the volume while mixed stands typed as hardwood account for 73% of the volume. In Oregon, 17% of the hardwood inventory is found in pure stands and 66% is found in mixed hardwood/conifer stands.

Utilization, Products, and Employment

Harvest Volumes and Log Consumption

The harvest of hardwood sawtimber has been stable in Washington and increasing in Oregon (Table 3) with a total annual harvest of about 600 million board feet (MMBF) in the region from 1987 to 1991. Over the same period, total timber harvest in the region declined by about 4000 MMBF, due to large decreases in harvesting of softwoods on federal lands and smaller decreases on private industry lands.

It should be noted that there is considerable uncertainty in the harvest figures. Hardwood volume is not consistently assessed in timber cruises or bid volume estimates and similar problems may occur with harvest volumes. For instance, historical harvest volumes quoted by planning documents or planning personnel place the level of hardwood harvest from public lands in Oregon at about 67 MMBF per year (per. comm., Mike DeLaune, Oregon Department of Forestry). Records kept by the agencies show an average of only about 12 MMBF. Similarly, total hardwood harvest volumes estimated from state tax records in Oregon are 190 MMBF for 1992. Another estimate, derived from industry surveys of log producers and consumers, indicates a harvest of about 269 MMBF excluding firewood.

Consumption of hardwood logs by sawmills was 387 MMBF in 1990 (Washington DNR, Howard and Ward 1991), a substantial increase compared to previous estimates of 235 MMBF for 1985 (Beachy and McMahon 1987) and 150 MMBF for 1977 (Cunningham and McMahon 1978). Based on direct surveys of various log consumers, Beachy and McMahon (1987) estimated total hardwood consumption at about 573 MMBF in 1985. Using "industry accepted conversion factors" this estimate included 235 MMBF of sawlogs, 1.04 million BDUs in chips (whole log chippers plus mill residues), 18 million ft^2 of veneer, and 238 000 cords of firewood.

The estimates based on state tax records for 1990 (Washington DNR, Howard and Ward 1991) indicate that the hardwood industry processed about 478 MMBF of logs in Oregon and Washington and exported an additional

Table 3. Hardwood sawtimber harvest in western Washington and Oregon from 1987 to 1991[a]

Area and owner	1987	1988	1989	1990	1991
Oregon					
Private	104 999	117 437	172 503	166 500	203 233
Public	11 692	15 291	10 978	8 288	8 353
Total Oregon	**116 691**	**132 728**	**183 481**	**174 788**	**211 586**
Washington					
Private	323 849	370 813	457 737	375 072	373 323
Public	52 721	69 243	54 410	44 719	49 780
Total Washington	**376 570**	**440 056**	**512 147**	**419 791**	**423 103**
Pacific Northwest					
Private	428 848	488 250	630 240	541 572	576 556
Public	64 413	84 534	65 388	53 007	58 113
Region Total	**493 261**	**572 784**	**695 628**	**594 579**	**634 689**

[a] Data from Oregon are from Oregon Department of Forestry Annual Reports. Data from Washington are from Washington Department of Natural Resources timber harvest reports. Expressed as thousand board feet, Scribner rule.

16 MMBF of unprocessed logs. This is far less than the total harvest estimated by tax records and seems to indicate a much lower rate of pulpwood consumption compared to estimates from the industry survey in 1985. The 1990 figures may underestimate pulpwood consumption; industry sources suggest that recent pulpwood consumption is even greater than sawlog consumption for hardwoods.

Products and Employment

The primary products derived from Northwest hardwood lumber are pallets, wood furniture, upholstered furniture, and cabinets. Other uses include panelling, face and core stock in plywood, millwork, doors, waferboard, musical instruments, and novelties. Out of about 327 MMBF of red alder lumber shipped in 1992, 40% of the volume is used as pallets, 29% as wood furniture, 18% as upholstered furniture, and 12% as cabinets (unpublished tables, R.D. Behm Co., Vancouver, Washington). In 1991, about 52 MMBF of lumber was exported to Europe and Asia where it is used primarily in furniture and cabinets (Luppold and Thomas 1991).

Estimates of employment based on hardwood resources in the region amount to about 7400 primary and secondary manufacturing jobs (Table 4). Income generated by these jobs is about $201 million (U.S.) in payroll.

Secondary manufacturing is an important component of the hardwood industry, accounting for 2400 jobs, about one-third of the total jobs attributed to the hardwood industry in the region (Table 4). The R.D. Behm company (unpublished survey) estimates that in 1992 secondary manufacturing of red alder alone accounted for the equivalent of 23 542 jobs throughout the United States.

Table 4. Estimated employment and income (wages paid) based on hardwood resources in western Washington and Oregon for 1990 and 1991[a]

Industrial sector	Average annual Employment number of full-time jobs	Average annual Income million U.S. dollars
Forestry	405	7.04
Logging	1018	26.53
Sawmills	1611	40.40
Veneer/plywood	398	8.68
Pulp/paper	1570	69.58
Secondary[b] manufacturing	2402	49.22
Total, all sectors	**7402**	**201.45**

[a] Employment and income for sawmills is from reports by the Oregon Department of Human Resources and the Washington Department of Employment Security. Other employment and income in this table is calculated from data reported by these same agencies.

[b] Based on an unpublished survey conducted by Richard Behm, Vancouver, Washington. Includes furniture, pallet manufacturing, and cut stock.

Regulations and Policies

Regulations and policies affecting forest practices significantly reduce the availability of hardwood inventory. Hardwoods on public ownerships are generally less available than privately owned hardwoods due to non-timber concerns, legal restrictions, and changing management strategies. This is true particularly in Oregon where public lands account for 42% of the hardwood inventory but only 7% of the harvest (Tables 1 and 3). In Washington, public lands have 21% of the inventory and provide 12.5% of the harvest.

Rules for protection of riparian areas restrict harvesting and management practices and reduce the availability of timber inventory (*Oregon Forest Practices Act*; Washington Administrative Code 1993), more so for hardwoods than for softwoods. In western Washington, 27.5% of the hardwood inventory is in or adjacent to riparian areas as compared to 22.5% of the softwood inventory. Practices are more likely to favour retention of hardwoods over

Availability of Future Supplies

The portion of the total inventory actually available for utilization is determined by factors such as forest practices regulations, landowner objectives and policies, and harvesting behaviour (which is influenced by many factors including stand volume, species composition, accessibility, and economics).

higher value softwoods due to the greater care and expense required to harvest trees that are available in riparian areas. In an analysis of pre- and post-harvest conditions, one case study in Oregon determined that an average of 76% of the live hardwood trees were retained in riparian areas while only 39% of the live conifers were retained in the same areas (Morman 1993).

Current inventory data do not allow a definitive accounting of the impact of riparian area regulations on hardwood resources and harvest volumes. Further analysis of FIA data for Washington shows about 932 000 acres or 12.6% of the total timberland within 100 feet of a class 1 or class 2 stream. Brown (1988) estimated that 11% of Oregon's hardwood sawtimber volume occurred in riparian areas near Class 1 streams; he estimated that 5–7% of the hardwood volume would need to be left to meet regulations (before the 1994 increases in protection for riparian areas).

Forest Practices Rules Favouring Conifer Regeneration

Reforestation rules have favoured regeneration of conifers over hardwoods and will affect species composition in future stands. For about 20 years, regulations have set minimum levels for regeneration or residual stocking of conifers on most harvested acres (*Oregon Forest Practices Act*; Washington Administrative Code 1993). Compliance with and enforcement of regulations appears to be good; 80–90% of regenerated stands surveyed in Oregon (Oregon Department of Forestry [n.d.]) met or exceeded minimum requirements for stocking of "free to grow" conifer trees. In this regulatory environment, it is probable that the dominance of hardwoods has been reduced compared to the stands regenerated by earlier practices.

The most recent revisions of forest practices rules in both Oregon and Washington consider hardwoods as acceptable regeneration under various conditions. As yet, relatively little is known about intentional management of hardwoods. When private landowners do invest in regeneration, they are likely to employ tried-and-true methods of regenerating conifers to ensure compliance with Forest Practices Rules. However, the way is clear for management of hardwoods if greater incentives arise.

Harvesting Behaviour

An analysis of harvesting behaviour on private lands[1] shows that the probability of a given stand being harvested increased with increasing stand volume and decreasing growth rate. Ownership category (industrial vs. non-industrial) and hardwood proportion did not significantly affect the probability of harvest. This suggests that if past trends continue (study period was 1976–1986 in Oregon, 1979–1989 in Washington) much of the hardwood inventory on NIPF lands will become available as stands mature. This seems to be supported by the increasing rate of timber harvest on NIPF lands. In Washington, removals of hardwood growing stock during 1986–1990 averaged 60 million ft^3/yr (1.7 million m^3), compared to only 25 million ft^3/year (0.7 million m^3) from 1976–1985 (Adams et al. 1992). Substantial increases in harvesting from NIPF lands also occurred in Oregon (Table 2).

Projections of hardwood supply from NIPF lands are complicated by the proximity of many acres to the urban/forest interface, along with continuing conversion of land to non-forest uses. In western Washington, 49% of the hardwood growing stock on NIPF lands occurs in low-density residential or urban zones compared to only 31% for softwoods (Oswald 1986). For western Oregon, Gedney (1991) showed a 15% decrease in the acreage of hardwood forest types on NIPF lands between the 1961–62 and 1973–76 inventories, due primarily to conversion to non-forest uses. While short-term supplies are increased by conversion to non-forest, long-term supplies are decreased as land is taken out of timber production.

Resource Dynamics, Management, and Sustainable Supplies

Historically, mortality and removal of hardwoods has been far below net growth (Figure 3A). Thus, hardwood inventories on private lands have increased from less than 2 billion ft^3 (56 million m^3) in 1933 to the current estimate (1991) of 8.2 billion ft^3 (240 million m^3, Figure 3B). In

[1] Based on characteristics of permanent forest inventory plots that were harvested during the last remeasurement period (for Oregon, the decade prior to the 1986–1987 inventory; for Washington, the decade prior to the 1989 inventory). Data from USDA Forest Service, Forest Inventory Analysis unit data files.

the last decade however, dramatic increases in removals produce a trend (Figure 3A) that could lead to diminishing supplies in the long-term.

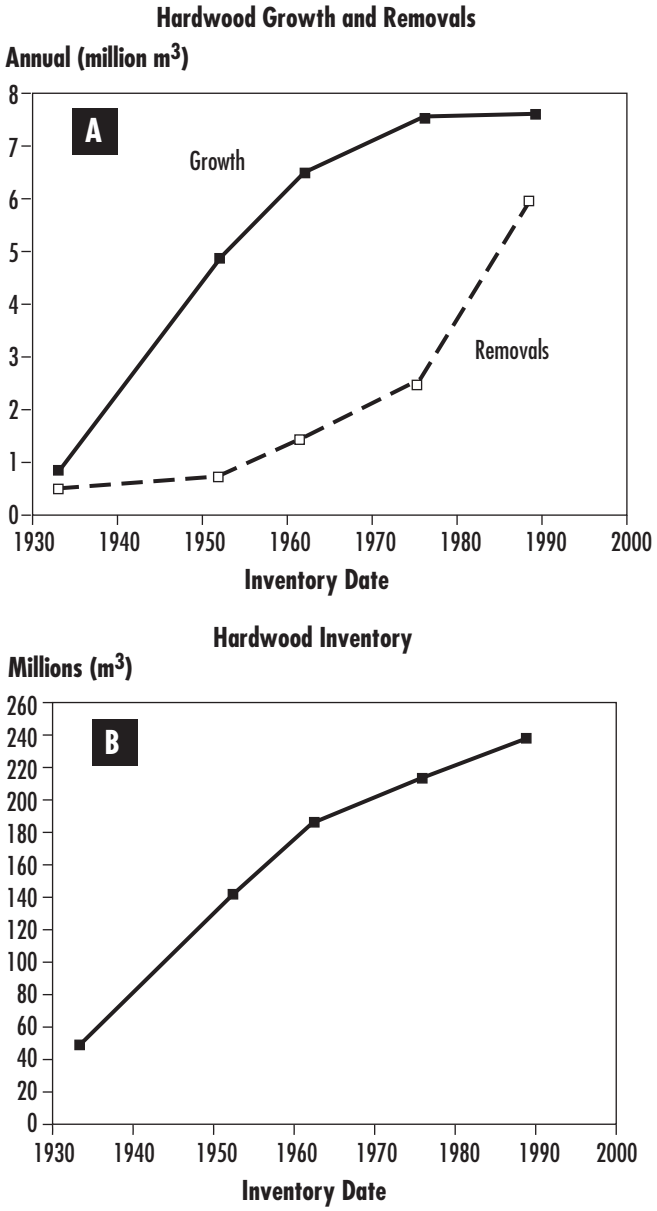

Figure 3. Changes in A) net annual growth and removal and B) total inventory volume for hardwood growing stock on private lands in western Oregon and Washington from 1933 to 1989. Sources of data: for 1933, Andrews and Cowlin 1940; for 1952–1989, Haynes 1990, McLean et al. 1992, Gedney et. al. 1986a, Gedney et al. 1986b, Gedney et al. 1987.

Of course, a long-term reduction in hardwood resources should be expected, given the emphasis placed on conifer management by the contemporary forestry community. To most foresters, the large historical increase in hardwoods represents a significant encroachment onto lands that could grow more valuable conifers. The two most recent policy-level reports on timber supply recommend (and predict) increased rates of harvesting or removal of hardwoods to more rapidly and completely bring timberland back into conifer production (Sessions et al. 1990; Adams et al. 1992).

In Washington, average annual removals of red alder growing stock from private lands amount to 136 million ft^3 (3.85 million m^3), which is 4% of the total inventory and exceeds net growth by 40%. Also, some of the net growth is on lands that will be unavailable for harvesting due to regulations or land-use conversions. After hardwood stands are harvested, forest practices have favoured conifers and reduced the component of alder in the regenerating stand. The estimated area of poletimber-sized hardwood stands has decreased from 858 000 acres (356 017 ha) in 1979 to 405 000 acres (168 050 ha) in 1989. The overall effect of modern forest management is to reduce the proportion of hardwood compared to that of previous practices, which provided for the current high level of supply and utilization.

The replenishment of hardwood timber resources therefore depends greatly on continuing regeneration via passive, "custodial" management on non-industrial forest ownerships. Incidental hardwoods that survive in actively managed conifer forests can meet only a fraction of the demand for hardwood timber. Regeneration of hardwoods on non-industrial lands does appear to be continuing at historical levels, and non-industrial forests can provide an increasing share of hardwood resources in the future. A major potential constraint on this supply from NIPF lands may arise from conversion to non-forest uses and the influence of the residential/forest interface.

With increasing values and markets for hardwood products, the status of hardwoods is changing, particularly in the institutional environment. Substantial new research and development efforts are focused on hardwoods,[2] particularly red alder (Hibbs et al. 1994; Hardwood

[2] Program of research and development presented at the Western Hardwoods Conference, October 7, 1992, World Forestry Center, Portland, Oregon. Sponsored by the Western Hardwood Association, the USDA Forest Service, and the Wood Products Center.

Silviculture Cooperative 1994). Hardwoods are no longer ignored or considered only as weed trees in forest practices regulations and management plans. There is increasing public awareness of the ecological importance and potential value of hardwood resources.

Future hardwood resources could be insured with silvicultural practices aimed at maintaining the hardwood component of the forest. However, while values have increased enough to make management of alder profitable, economic returns from conifer management are likely to be higher in most cases. The hardwood industry is making some investment in alder management, but they appear to be the only landowners willing to speculate on future hardwood values at this time. Presently, less than 1% of the harvested timberland is targeted for active regeneration and management of hardwoods. With the risks involved with investing in forest management, many landowners may feel that management of conifers provides the greatest assurance of success, both in terms of economic returns and compliance with forest practices rules.

Conclusions and Recommendations

Today's hardwood inventory is higher than at any time this century, but rates of increase are slowing, and subregional supply shortages have developed, especially for red alder. Long-term hardwood supply is uncertain, and concerns are well founded. In western Washington, current harvesting rates for red alder exceed additions to inventory, and a similar situation is developing in western Oregon. Modern forestry practices and regulations generally reduce the hardwood component to ensure regeneration of conifers. The high hardwood volumes produced by past forestry practices are unlikely to be sustained. Thus, while short-term hardwood supplies may support continued or even increased utilization, this may represent liquidation and non-sustainable utilization unless hardwoods are managed.

The demand for products made from northwestern hardwoods and the contributions of the hardwood industry to the rural economies have been increasing. Red alder is widely accepted in both domestic and foreign markets and there are good prospects for further increases in foreign markets. The large quantities of pallets, furniture, and cabinets manufactured from red alder in other states indicates the potential to increase value added manufacturing in western Oregon and Washington. With these favourable markets for products, the hardwood industry in Oregon and Washington is limited only by sustainable supply.

These policy recommendations can help ensure that the western hardwood resource plays an appropriate role in the forests and economic development of the Pacific Northwest:

- State and federal programs that promote forest management on private lands need to include emphasis on hardwood management where biologically and economically appropriate.
- Public hardwood resources should be specifically recognized in planning and harvest activities. Public timber sale procedures need to be designed to ensure that hardwood values are reflected in the sale program.
- Consistent methods of accounting and measurement of both the private and public hardwood resource in the forest inventory process are needed. Better information is needed to account for the dynamics of hardwood resources and estimate sustainable levels of supply. There is an urgent need for useful inventory information on Federal lands.
- Research is needed to determine what level of management and utilization of hardwoods is possible while still achieving the intent of forest practice regulations. Future changes in forest practice regulations should be made with a recognition of the impact on the hardwood resource.
- Policy makers and resource managers need to learn more about the benefits and the problems associated with hardwoods in order to develop a realistic vision of the place of hardwoods in northwestern forestry.
- Research and development programs targeting all aspects of hardwood biology and management need to be maintained and enhanced in order to ensure sustainable utilization.
- Secondary and value added manufacturing of hardwood products should be emphasized as part of any rural development strategy.

Literature Cited

Adams, D.M., R.J. Alig, D.J. Anderson, J.A. Stevens, and J.T. Chmelik. 1992. Future prospects for western Washington's timber supply. College of Forest Resources, Univ. Wash., Seattle, Wash. Inst. For. Resources Contrib. No. 74. 201 p.

Andrews, H.J. and R.W. Cowlin. 1940. Forest resources of the Douglas-fir region. USDA, Washington, D.C. Misc. Publ. No. 389.

Beachy, D.L. and R.O. McMahon. 1987. Economic value of the Pacific Northwest hardwood industry in 1985. For. Res. Lab., Oreg. State Univ., Corvallis, Oreg. 43 p.

Brown, R.G. 1988. Hardwoods in Oregon. P. 73–86 in G.J. Lettman, technical editor. and D. H. Stere, Prog. Dir. Assessment of Oreg. Forests. Oreg. Dep. For., Salem, Oreg.

Cunningham, C.S., and R.O. McMahon. 1978. Economic value of the Pacific Northwest hardwood industry in 1977. Oreg. State Univ., Corvallis, Oreg.

Gedney, Donald R. 1991. Change in area and ownership of private timberland in western Oregon between 1961–62 and 1973–76. USDA For. Serv., Pac. NW For. Range Exp. Stn., Portland, Oreg. Resour. Bull. PNW-92. 8 p.

Gedney, Donald R., P.M. Bassett, and M.A. Mei. 1986a. Timber resource statistics for non-Federal forest land in southwest Oregon. Portland, Oreg. USDA For. Serv., Pac. NW Res. Stn., Resour. Bull. PNW-138. 26 p.

Gedney, Donald R., P.M. Bassett, and M.A. Mei. 1986b. Timber resource statistics for non-Federal forest land in northwest Oregon. Portland, Oreg. USDA For. Serv., Pac. NW Res. Stn., Resour. Bull. PNW-140. 26 p.

Gedney, Donald R., P.M. Bassett, and M.A. Mei. 1987. Timber resource statistics for non-Federal forest land in west-central Oregon. USDA For. Serv., Pac. NW Res. Stn., Portland, Oreg. Resour. Bull. PNW-143. 26 p.

Haynes, R.W. 1990. An analysis of the timber situation in the United States: 1989–2040. USDA For. Serv., RM Res. Stn.

Hardwood Silviculture Cooperative. 1994. Annual report 1993–1994. Oreg. State Univ., Dep. For. Sci., Corvallis Oreg.

Hibbs, D.E., D.S. DeBell, and R.F. Tarrant, 1994. The biology and management of red alder. Oreg. State Univ. Press., Corvallis, Oreg. 256 p.

Howard, J.O., and F.R. Ward. 1991. Oregon's forest products industry: 1988. USDA For. Serv., Pac. NW Res. Stn., Portland Oreg. Resour. Bull. PNW-RB-183. 91 p.

Luppold, W.G., and R.E. Thomas. 1991. New estimates of hardwood lumber exports to Europe and Asia. USDA For. Serv., NE For. Exp. Stn., Radnor, Pa. Res. Pap. NE-652. 22 p.

MacLean, C.D., P.M. Bassett, and M.G. Yeary. 1992. Timber resource statistics for western Washington. USDA For. Serv., Pac. NW Res. Stn., Portland, Oreg. Resour. Bull. PNW-RB-191. 135 p.

Morman, D. 1993. Riparian rule effectiveness study report. Oreg. Dep. For. Salem, Oreg. 198 p.

Oregon Department of Forestry. [n. d.] 1991 annual reports. Oreg. Dep. For. Salem, Oreg. 9 p.

Oregon Forest Practices Act. [n.d.] [ORS 527.610, 527.770, 527.990(1) and 527.992 are known as the Oregon Forest Practices Act. {Formerly 527.010; 1991 c.634§2}].

Oswald, D.D. 1986. Inventories of timber resources in urban and developed rural areas. W. Jour. Appl. For., 1(4): 129-131.

Raettig, T.L., K.P. Connaughton, and G.R. Ahrens, 1995. Hardwood supply in the Pacific Northwest: A policy perspective. Research Paper PNW-RP-478. Portland, OR. USDA For. Serv., Pacific NW Res. Sta., 80 p.

Sessions, J. (coordinator), K.N. Johnson, J. Beuter, B. Greber, and G. Lettman. 1990. Timber for Oregon's tomorrow: the 1989 update. For. Res. Lab., Coll. For., Oreg. State Univ., Corvallis, Oreg. 183 p.

Washington Administrative Code. 1993. 1992 Washington Administrative Code, Forest Practice Rules and Regulations, Title 222.

Wildlife, Hardwoods, and Harvesting

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Abstract

The paper will address the issue of treating trees as wood and not as habitat or part of a functioning ecosystem. Many species of wildlife are highly to critically dependent on hardwoods as habitat. Forestry Program goals to grow commercial crops (conifers primarily) are in conflict with Wildlife Program goals to monitor, classify, and recover species at risk. Eighteen wildlife species are known to be at risk and another 24 are hardwood dependent.

Current provincial hardwood management can be grouped into three situations:

1. **Commercially recognized hardwoods.** These include cottonwood, aspen, and alder. When tree species have been considered commercially viable, a licence has been awarded. No volume is withheld for habitat requirements and this has a detrimental effect on wildlife species as important habitat elements are lost over time. Once habitat requirements are requested in forest development plans, these become constraints to the licensees. To rectify the current situation all new hardwood volumes would need to go through an environmental impact assessment, then an integrated resource planning process and included in the integrated resource planning process and then included in the allowable annual cut before being offered for sale.
2. **Stand conversion.** Aspen, alder, maple, and cottonwood occur in stands mixed with conifers and provide important habitat diversity. During harvest these "undesirable trees" are cut and the new stands managed as conifer stands. The cumulative effect of this conversion policy is to create a forest without a minor hardwood component. Forest policy assumes that the future market will not include hardwoods in mixedwood stands. The no-tolerance to hardwoods is enforced through mandatory conifer reforestation. A change to these trends is only possible through a change in forestry goals. The Forest Practices Code (FPC) will require maintenance of a component of minor species as well as requiring strategies to address wildlife species at risk.
3. **Non-commercial minor hardwoods and understory species.** These provide important elements of diversity within natural forests and during natural succession after disturbance. These hardwood species are competition for crop trees and are targeted for removal using a variety of treatments. The new FPC is not able to assess cumulative effects of practices over a full rotation.

At present the welfare of wildlife is tied to individual stand-level decisions, with no one being held responsible for assessing cumulative effects of habitat change across the landscape. A lower-risk strategy of ecosystem management is advocated. Ecosystem management requires

that maintenance of ecosystem health, diversity, and integrity be addressed before harvesting is approved to ensure long-term forest ecosystem sustainability. Timber harvesting plans would need to conform to the basic ecosystem needs. There is concern that increased demand for hardwoods and new funding to silviculture through the forest sector strategy will increase the risk to hardwood-dependent wildlife. Decreasing risk to species will require an environmental assessment prior to offering hardwood licences. Decreasing risk to wildlife species will also require landscape level planning capable of addressing stand conversion and changes in current stand level practices, which continue to eliminate the hardwood components from forests.

Introduction

The objective of this paper is to increase awareness and concern over current hardwood management practices and the impact of forestry on hardwood-dependent wildlife species. Significant changes are needed before forestry practices and tenure agreements address the needs of hardwood-dependent wildlife.

There has been a transition in wildlife management priorities, from the traditional administration of hunting, guiding, and trapping licences to management that first addresses the conservation needs of species. Wildlife are an integral part of healthy forest ecosystems.

This same transition is also beginning in forest management, with a change away from the traditional priorities given to administration of forest licences towards a balance that addresses conservation needs of forested ecosystems. The Forest Practices Code (FPC) is the first, major, formal step recognizing that forest sustainability is linked to conservation of habitats and maintenance of species diversity. The traditional and dominant forestry view has been of trees as commodities (volume), and allocation has occurred without any net-down of timber volume to sustain hardwood-dependent species. This is especially evident in reviewing the history of hardwood management in B.C.

Responsibility for Hardwood-dependent Wildlife Species

The B.C. Ministry of Environment, Lands and Parks, Wildlife Branch determines the status of species and produces lists of wildlife species. These lists divide wildlife species into groups based on risk.

Hardwood-dependent Species at Risk

Hardwood-dependent species at risk are a measure of ecosystem health. The Wildlife Program and the conservation Data Centre are monitoring species and ecosystem elements that are known to be declining towards extirpation from portions of their natural range—the first step towards possible extinction. Conservation biologists refer to these species as "fine-filter species"; species for which specific recovery plans need to be developed if trends are to be reversed. Table 1 lists hardwood-dependent wildlife species that are at risk.

The Forest Practices Code will encourage management for wildlife species. Wildlife species enter into consideration in forest development and 5-year silviculture plans once a strategy for their protection has been agreed to between Ministry of Forests and Ministry of Environment. Species may receive protection through the establishment of a wildlife habitat area, a general wildlife measure, a higher-level plan, or some combination of these strategies.

Hardwood-dependent Species Not at Risk

These species may have a critical need for hardwoods, regardless of their status. The general strategy for these species is to maintain a diversity of habitats across landscapes and within forest stands to safeguard against more species becoming at risk. More importantly is the recognition that these species perform valuable and vital functions within the ecosystems from which we all benefit. Forest practices guidelines such as the Coastal Biodiversity Guidelines, Interior Fish/Forestry Wildlife Guidelines, and Wildlife Tree Harvesting Guidelines are all directed towards maintaining habitat diversity. (Since the presentation of this paper these guidelines have been combined into *Riparian Management* and *Biodiversity* guidebooks, which form part of the Forest Practices Code.) Conservation biologists refer to this form of habitat planning as "coarse filter" because it considers habitats for

Table 1. Hardwood-dependent wildlife species at risk (Enns et al. 1993 and Munro 1993)

Wildlife species (status)		Hardwood dependency
Bald Eagle	Blue	riparian cottonwood
Barn Owl	Blue	riparian cottonwood
Great Blue Heron	Blue	black cottonwood (interior)
Green-Backed Heron	Blue	red alder (coast)
Black-throated Green Warbler	Blue	aspen, birch northeast B.C.
Brewer's Sparrow (subspecies)	Blue	birch (north) aspen (south)
Williamson's Sapsucker (ssp.)	Blue	mixedwood and pure aspen stands
Williamson's Sapsucker (ssp.)	Red	
Lewis's Woodpecker	Blue	mixedwood and riparian cottonwood
Pileated Woodpecker	Blue	aspen, larger diameters
Yellow Bellied Flycatcher	Blue	shady thickets
Philadelphia Vireo	Blue	aspen and balsam poplar stands
Hairy Woodpecker	Blue	aspen, nesting, > 25 cm diameter
Western Screech Owl; both ssp.	Blue	cavities, cottonwood and red alder near water
Northern Saw-whet subspecies	Blue	aspen, poplar, and birch > 30 cm
Canada Warbler	Blue	may be associated with riparian
Southern Red Bat	Red	cottonwood southern B.C.
Grizzly Bear	Blue	reduce stocking density in wet sites

Blue = sensitive and vulnerable

Red = threatened and endangered

numerous species at once. It is also practical and efficient, since it is not possible, through single species approaches, to monitor and manage complex ecosystems. Coarse-filter habitat planning will significantly reduce the risk to wildlife species on a population level and increase the likelihood of maintaining ecosystem functions in second-growth forests.

It will become increasingly important to monitor local populations of species not at risk to ensure that forest practices are sustaining the population and to adapt forest management based on best available information. Without monitoring, it is not known when loss or extirpation of a local population and their genetic material occurs. Ledig (1993) refers to this type of loss as "secret extinctions" or extirpations that occur without notice, which may impair ecosystem health and productivity. Pileated Woodpecker has become such a species and a historic decline has been noted in the Cranbrook area (Ohanjanian 1991) (Table 2).

Responsibility for Habitat Management

Historically, habitat management has been the responsibility of foresters in accordance with the provisions within the *Forest Act*. The Forest Practices Code has introduced joint responsibility between the Ministry of Environment and the Ministry of Forests for some aspects of forest management. The preamble to the *FPC Act* identifies conserving biodiversity as well as balancing economic and cultural needs of peoples. The *FPC Act* is specific on many aspects of forest management but does not provide guidance to foresters on what takes precedence when conflicts exist. Higher-level plans are intended to provide guidance on land-use issues; however, foresters continue to have considerable discretion and flexibility to choose between biological, social, and economic concerns/emphasis within all aspects of forestry. Ministry of Environment staff review plans and provide input to foresters except where joint approval is specified.

Table 2. Hardwood-dependent species not at risk (Enns et al. 1993; B.C. Ministry of Environment, Lands and Parks 1995)

Wildlife species not at risk (yellow list, status)		Hardwood dependency
Primary cavity excavators		
Woodpeckers		
Three-toed	Yc	aspen, nesting, > 30 cm nesting
Downy	Yc	*Populus* spp., alder, > 15 cm nesting
Sapsuckers		
Yellow-bellied	Yc	aspen, balsam poplar with decay
Red-naped	Yc	*Populus* spp., birch > 25 cm
Red-breasted	Yc	maple "
Northern Flicker	Yc	cottonwood > 30 cm nesting
Secondary cavity nesters		
Boreal Owl	Yc	cavity dependent, species unknown
Great Horned Owl	Yc	cottonwood open nesting
Long-eared Owl	Yc	dense hardwoods and shrubs
Barrow's Goldeneye	Ycmg	
Common Goldeneye	Ycm	large-diameter aspen nesting
Band-tailed pigeon	Ycm	large-diameter aspen nesting
Bufflehead and cottonwood	Ycm	alder exclusively for nesting > 38 cm diameter aspen
Common Merganser	Ycm	> 50 cm diameter for nesting
Hooded Merganser	Ycm	> 50 cm diameter for nesting
Wood Duck	Ycm	cottonwood preferred
Western Bluebird	Yc	(dependent on nest boxes) aspen forests northeastern B.C.
Others		
Black-crowned Night Heron	Ye	riparian cottonwood
Mourning Dove	Ym	riparian cottonwood
Beaver	Ym	riparian willow, primary food source
Moose	Ym	riparian and early successional hardwoods
Mule deer	Ym	winter forage some areas

Status:

Y = yellow are species not at risk

c = conservation species

e = managed through ecosystem management

m = managed for hunting and trapping

g = global responsibility

Some Basic Hardwood Wildlife Ecology

Wildlife species can be grouped into four types of hardwood users.

Hardwood Tree-dependent Wildlife Species

There are approximately 30 species of primary cavity nesters, such as woodpeckers, sapsuckers, and flickers. These are often called keystone species because they create habitat essential to other secondary cavity nesting species such as flycatchers, wrens, finches, bluebirds, swallows, and owls (Post et al. 1994).

Pileated Woodpeckers require large-diameter deciduous trees (26–40 cm dbh) and sapsuckers require 30–35 cm diameter broadleaves up to 20 m in height (Enns et al. 1993).

Woodpeckers showed a high level of deciduous selection and dependence in the Interior Douglas-fir Zone with 90% of nest sites in deciduous trees (Keisker 1987). This is a very high degree of preference for deciduous trees, as they are a minor component in these forests. A recent study of sapsuckers in Hat Creek has shown that there appears to be a high degree of site fidelity as young banded birds are returning to the habitats where they were raised (T. Miller, pers. comm.).

Management of wildlife trees forms part of the Forest Practices Code requirements. Large-diameter trees and standing dead trees (snags) in various stages of decay are currently being introduced as requirements in standard operating procedures.

Thicket-dependent Wildlife Species

Hardwood thickets associated with riparian and floodplain areas, wetlands, aspen copses, and avalanche tracks provide food, shelter and hiding, calving, and nesting areas for many species. Large birds such as Coopers Hawk, Northern Hawk, Great Horned Owl, and Long-eared Owl all use thickets for nesting. Smaller birds such as warblers, vireos, and flycatchers are also thicket dependent. Beavers are also a hardwood-dependent keystone species capable of diversifying habitats.

Wildlife Species Utilizing Successional and Understory Habitats

Early seral stages are often dominated by hardwoods following either clearcutting or natural disturbances. In natural succession, deciduous species are gradually replaced with shade-tolerant conifers with minor hardwood components persisting in the overstory and the shrub communities. Ungulates, such as deer, moose, and elk, use all available hardwoods and shrubs for feeding, cover and calving. When opportunities present themselves these species will move from deciduous wetlands and riparian habitat to seral hardwoods. Moose populations, for example, increase when abundant early successional hardwoods and shrubs result from fire and clearcutting. The degree of dependence varies. For example, more than 50% of the winter diet of white-tailed and black-tailed deer is deciduous.

Vine maple, western and paper birch, red-osier dogwood, ninebark, trembling aspen, balsam poplar, black cottonwood, mountain ash, saskatoon, arbutus, snowbrush, falsebox, kinnikinnick, huckleberry, blueberry, redstem ceanthothus, and willows are rated as highly important winter forage for at least one of the following ungulates species: black-tailed deer, mule deer, white-tailed deer, Rocky Mountain elk, Roosevelt elk, moose, caribou, and mountain goat (Luttmerding et al. 1990).

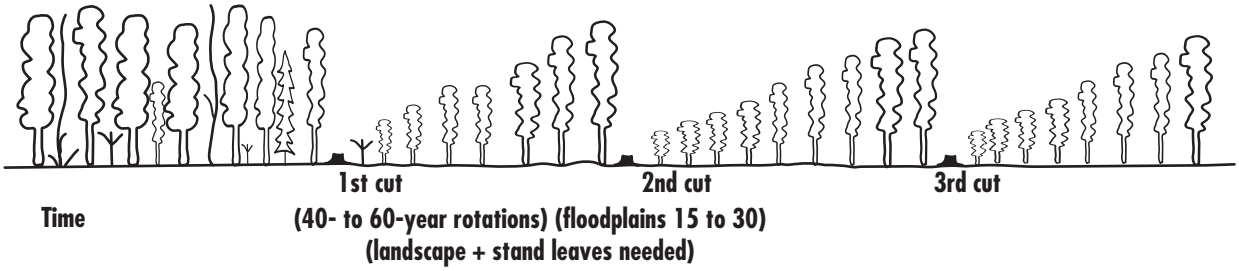
Habitats such as riparian zones, associated with streams, lakes, wetlands, and avalanche tracks are also major sources of hardwood diversity.

Forest-dependent Species

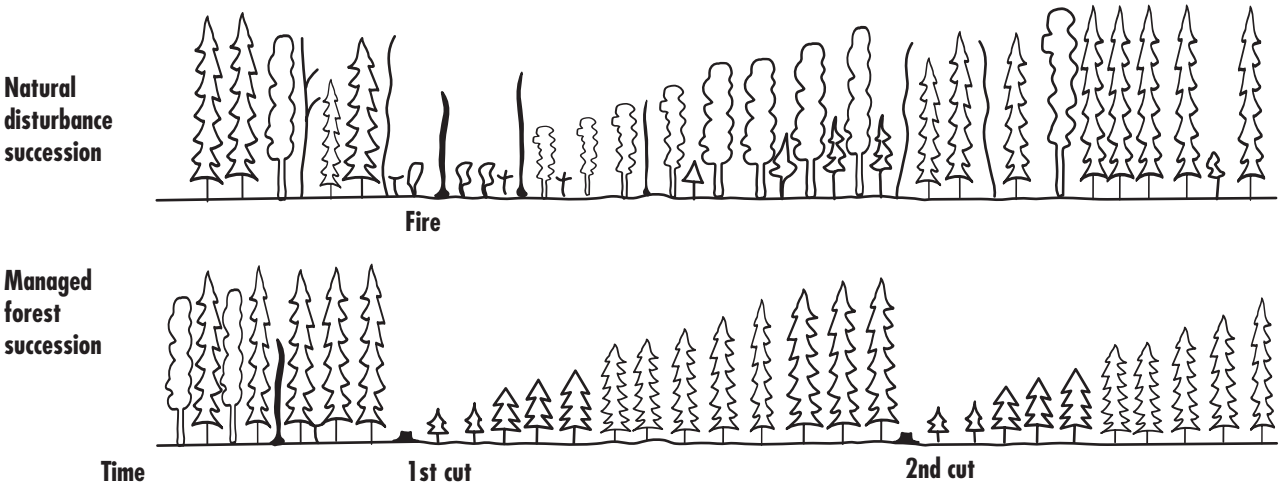
Warblers in the northeastern forests primarily use aspen and poplar forests. Aspen and poplar forests in northeastern British Columbia contain the highest diversity of forest avifauna within the province, with many "eastern Canadian wildlife species" occurring only in this portion of the province (Stevens 1995).

Figure 1 illustrates some of the differences between the three major hardwood forestry management situations found in British Columbia. This figure contrasts differences between the hardwoods that follow natural stand development and those that follow current forest management practice for hardwoods.

1. Hardwood leading (hardwood to hardwood)
(Boreal White and Black Spruce (BWBS) and coastal floodplains)



2. Mixed wood (hardwood as a minor species)
(Sub-Boreal Spruce, BWBS)



3. Hardwood as an early successional stage in forest succession
(Coastal Western Hemlock, alder, maple)

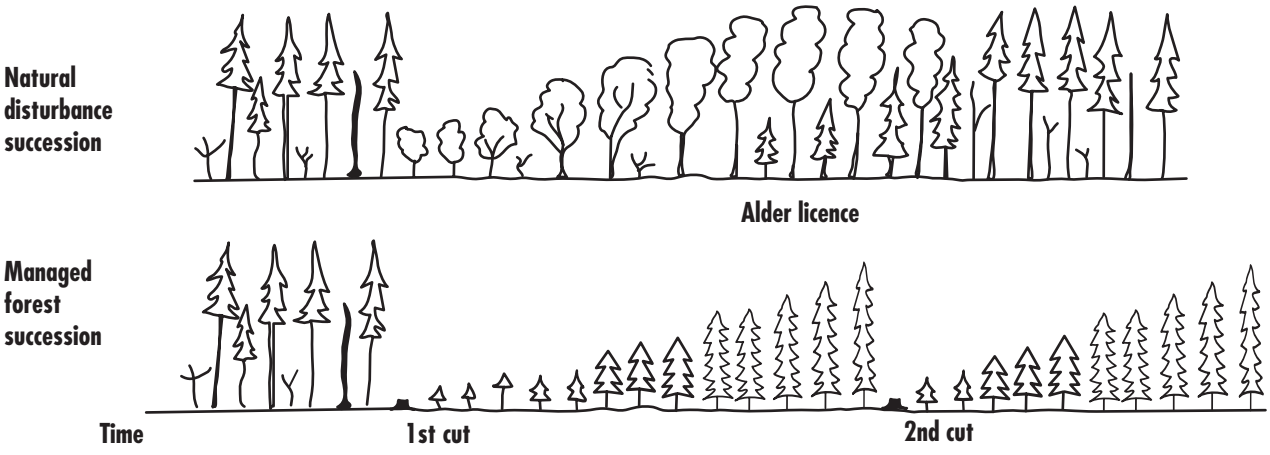


Figure 1. Major hardwood management types in British Columbia.

The Current Hardwood Management Program and Its Effects on Wildlife

There are four general management situations for hardwoods in B.C. Stands leading in hardwood tree species are discussed under currently committed volumes and uncommitted volumes. Then mixedwood forests with minor amounts of hardwoods are described, followed by shrubs and non-commercial hardwood species. These administrative, non-biological categories are selected because the habitat decisions are currently made by foresters who focus on forest development (harvesting and reforestation). Assessments of each management situation and current policies are presented, with recommendations for reducing risk to wildlife species.

Currently Committed Commercially Recognized Hardwoods

When there has been commercial interest (usually in pure stands of aspen, alder, and cottonwood) in areas where there are concentrations of hardwood volumes, forest licences have been awarded. Licences to cut aspen have been awarded in northeastern British Columbia for oriented strandboard and chopstick production. Alder licences exist on the coast for exports of alder cants, and tree farm licences exist for hybrid cottonwood plantations on several major coastal river floodplains.

These licences have been awarded using the following procedure. The hardwood volume is found within the inventory and advertised, and a bidder is selected by the Timber Harvesting Branch. The successful bidder, once assured of a fixed supply of hardwood, can obtain financing using the licensed volume as collateral. This system creates huge problems for habitat and wildlife management and conservation. The process assumes that habitat requirements can be factored into the licence through incorporation of restrictions in the short-term forest development plans after the licence volume has been fixed. Habitat requirements requested by B.C. Environment staff become constraints to an established contract, and any habitat withdrawals become a conflict within the tenure arrangements.

Over the years there have been a number of attempts to change the system for allocating new timber volumes for both conifers and hardwoods. An informal arrangement, the Forest Development Review Process (FDRP), has been in existence between the Ministry of Forests and the Ministry of Environment, Lands and Parks for approximately 10 years. The system was to parallel the Mine Development Review Process and the major project development review process required for other industrial resource developments. The FDRP does not have the benefit of institutional or legislated support, as is enjoyed by the other major review processes and it has been largely unsuccessful in addressing environmental impact concerns prior to the sale of crown timber.

Three steps are needed to correct the current tenure allocation process and to address environmental concerns.

1. **An environmental impact assessment** of the harvesting and regeneration activities must be carried out before the amounts of harvestable volume are advertised for sale. This assessment needs to determine the landscape-level role that hardwoods perform for biological diversity, and an appropriate net-down. The assessment also needs to identify specific habitat needs for wildlife species with hardwood dependency, beginning with species at risk.
2. **Assessment of integrated management role.** Hardwoods often perform other functions within local landscapes by maintaining recreational values, and viewing, hunting, fishing, and wilderness functions. The values should be determined for specific land areas, which can be done by placing their volume within the context of local Land and Resource Management plans. It is incorrect to assume that the best use and highest value for all hardwood outside the AAC can be found in forest products, without addressing the current role that hardwoods perform.
3. **Inclusion into the AAC.** When the environmental impact is known and when the other land and resource management commitments are addressed, then the uncommitted wood should be placed within the allowable annual cut, under the control of the Chief Forester. Potential bidders are then informed of the conditions of its sale. Awarding licences for exclusive harvest rights to set volumes is only one alternative, which has been historically over-used. The current tenure allocation system does not promote competition for wood after the licence has been awarded. Return to Crown (stumpage) is set by the Crown without the benefit of market bidding.

Without changes, current hardwood management puts hardwood-dependent wildlife species at high risk. A renaissance in thinking and a change in attitudes will be necessary to shift away from the narrow view that forestry is crop-tree focused.

Uncommitted Hardwoods with Commercial Potential

Some of these areas have already been harvested and alienated within current tenure arrangements without adequate assessment of the consequences to biological diversity and to species at risk. These areas would benefit from wildlife monitoring and research to determine what the cumulative effects of these licences are and whether changes in current practices and ecosystem restoration measures are needed.

Enns et al. (1993) estimated that the rate of harvest of hardwoods will likely continue to increase annually at the current rate of 10%. There are 207 million m^3 of mature hardwood currently shown in the forest inventory. This wood is outside the allowable annual cut (AAC) and classified as "uncommitted volume." This volume is principally in hardwood-dominated forest types.

Hardwood species are leading in seven of these "opportunity areas" and are most likely to attract commercial interest (Enns et al. 1993). It is recommended that all potential new hardwood volumes within these areas go through an environmental impact assessment and an integrated resource planning process, and then be included within the allowable annual cut prior to being offered for sale. It is also recommended that those responsible for integrated management and wildlife management be given the opportunity to approve the volume being offered to ensure that it does not conflict with current integrated management obligations at the local level.

Commercial opportunity areas:

1. **upland boreal aspen (Fort St. John):** Pulp Agreement 14 under negotiation. No environmental impact assessment was undertaken prior to volume being advertised.
2. **riparian cottonwood/balsam poplar:** Extremely high wildlife and timber values are in conflict. No environmental impact assessment has been undertaken.
3. **coastal cottonwood riparian:** Scott Paper has intensive hybrid poplar plantations. No environmental impact was conducted prior to licensing. Further increases in extent of intensive plantations is likely on all major coastal floodplains.
4. **coastal upland alders:** A licence was awarded in 1993 with volume conditional on an environmental evaluation. The silvicultural goal is to convert these areas to conifers.
5. **interior mixedwood with aspen dominant:** Oriented strandboard in 100 Mile House. Licence awarded prior to addressing environmental impacts.
6. **interior cottonwood on alluvial sites:** Although high in timber value, these areas are minor in extent and are critical areas for fish and wildlife. They also provide extremely diverse biological communities that play a critical role in maintaining species (particularly species at risk) within a much larger landscape.
7. **aspen clones:** These are often adjacent to grasslands and wetlands. These areas have low timber value relative to their very high biological value.

Non-commercially Recognized Mixedwood

In areas lacking a current market for hardwoods, these trees are classified as non-crop trees. This is common where hardwoods are a minor component of a landscape dominated by conifers. Current forest policy requires systematic removal of these hardwoods during harvesting and regeneration, resulting in complete conversion to conifers. Policy assumes that because there is no market for these species today, similar conditions will also exist in the future. This converts diverse old-growth forests to second-growth forests lacking in hardwood and shrub habitat. The cumulative effect of this conversion policy is the steady removal of suitable wildlife habitat. This removal will result in gradual loss of wildlife species from their natural ranges. Although harvesting of these minor hardwoods may occur in the future and separation of hardwoods for sale to different mills may become standard practice in conifer-dominated forests, current operating procedures continue to attempt to simplify and convert mixedwood forests to conifer forests. This will continue to affect areas where aspen and birch occur as minor, but potentially commercial, tree species.

Implementation of the Forest Practices Code may lower or arrest this trend by requiring maintenance of tree species diversity. However, stand-level practices will still be dependent principally on silvicultural systems and stand objectives driven traditionally by potential crop-tree silvics and current market conditions.

Large-scale herbicide spray programs currently exist to control or eliminate hardwood competition with conifer crop trees. Aspen is the principal tree species targeted for control. This is alarming, because aspen has been described as the "Cinderella species" of forestry with excellent pulping and strandboard potential, as well as serving habitat functions. It is recognized that some control of aspen is needed or else coniferous forests being harvested will naturally go through a deciduous cycle after clearcutting.

The intolerance towards hardwoods in silviculture policy is enforced by dis-incentives to forest companies who do not have free-growing conifer crops within a required time period. Forest companies carry contractual reforestation obligations and fear penalties targeting their harvest levels. The most expedient way to establish a conifer crop has become the norm throughout much of the central interior of the province. Practicing even minimal stewardship for hardwood retention in this regulatory climate is difficult. Standard operating procedures are to clearcut, remove all deciduous, mechanically prepare the site, broadcast burn, plant to conifer, and apply herbicide to eliminate hardwoods as needed. This system works well for conifer management goals, and attempts to maintain hardwood diversity have been resisted. Any alternatives to this approach require more time to prepare and may not be approved by silviculture foresters in the government. The intent of the FPC is to move away from the elimination of minor species from second-growth forests.

Non-commercial Brush

Shrubs and hardwoods (such as vine maple, birch, trembling aspen, balsam poplar, willows, hazel, black cottonwood, saskatoon, huckleberry, blueberry and red-osier dogwood) provide nodes of species richness and diversity when present as minor understory species. These species have the potential to take over a forest site after clearcutting and fire because they respond well to higher light levels. Current policy requires vegetation removal during harvest operation (3 m knock-down clauses) and vegetation control (brushing) to establish site dominance by conifers within a minimum time period.

There are several ways to improve the maintenance of these non-commercial species: (1) allowing some "brushy" areas to remain unharvested and undisturbed, (2) once harvested exclude some areas from vegetation control following natural regeneration (10%), (3) lengthen mandatory free-growing windows that serve to truncate natural succession for some areas harvested, (4) decrease stocking density in areas to allow some understory shrubs to survive in second-growth forests, (5) harvest using silviculture systems that do not favour early-successional species through partial overstory removal and under-planting of shade-tolerant species, and (6) change existing policy that requires the inclusion of a 3 m knock-down clause in cutting permits.

Some wildlife species such as grizzly bears are recognized as having legitimate understory needs, with current policy allowing reductions in stocking standards in some wet coastal ecosystems.

Summaries and Recommendations

Uncommitted Volumes (New Tenure Commitments)

There is an estimate of 207 million m^3 of mature hardwoods identified in cottonwood, alder, maple, birch and aspen species as "uncommitted hardwood volume." There is also little understanding of how much of this volume would be required for habitat to sustain dependent wildlife species (Enns et al. 1993).

Recommendations to correct the current process for awarding hardwood tenures are:

1. Conduct an environmental impact assessment to determine whether harvesting can proceed without reducing ecosystem integrity. The environmental impact assessments need to be long-term and must determine the role of hardwoods within the landscape as well as the needs of wildlife species at risk. A net-down in available merchantable volume in the forest inventory is needed.
2. Costs for new information need to be borne by the developers, to be consistent with other Environmental Impact Assessment processes. However, if the government intends to offer hardwoods for open bidding, the assessment may need to be done prior to or as part of the obligations of any hardwood licence being offered.

3. Formalize the Forest Development Review Process so that it becomes equivalent to the Mine Development Review Process, with stage 1-, 2- and 3-type requirements set for information and assessment information as government works with developers. A more formal, orderly FDRP will curb the ad hoc basis that has characterized tenure developments throughout provincial forest development history. To date, there has been uneven environmental protection information, inconsistent advice to legislators, and no accountability for hardwood-dependent species.
4. Determine the hardwood volume available, above a conservation minimum, and place this volume into a broader integrated management context through a Land and Resource Management Planning process. Hardwood forests also serve recreation and visual functions, depending on location and existing land uses. The notion that if uncommitted volume can be found within the forest inventory and there is commercial interest, it must then be available for development is an institutionalized single use. Currently, volume sales lead the process and stewardship is not addressed, nor are other land use decisions for other resource values. Resource integration has come to mean constraints to timber harvest and production. The District Manager and local Ministry of Environment need to "approve" the hardwood quantity and conditions before these are advertised. The current practice of issuing licences without a district-level approval will continue to increase future resource conflicts.
5. The hardwood volume needs to be placed within the allowable annual cut under the Chief Forester, prior to further development. It should be noted that the current traditional tenure arrangements to award fixed volumes to a single licensee for extended periods is only one approach to tenures. This approach does not establish competition for the public resource and may significantly undervalue the resource and the potential for revenue to the Crown.

Existing Tenures and Policy Commitments

A different approach is needed to address the harvesting and silviculture program goals within existing tenures. The most serious problem is the lack of long-range planning or a vision of the future forest beyond the view that forests are a source of timber volume. This lack of long-term vision or strategic land-based plan has plagued any efforts to predict the cumulative biological effects of stand conversion and the vigorous mandatory obligations for conifer re-establishment. The traditional emphasis from well-funded, crop-oriented forestry programs is to consider the forest as a series of isolated stands and allocate stand improvements opportunistically. The primary vision has been for maximum harvest volume and reforestation to maximize future crop yield. The importance of hardwoods as habitat is a requirement of the FPC but hardwoods must also be considered strategically prior to forest development action.

Never has there been a greater need for a long-term vision of the forest; a vision that includes the critical contribution hardwoods and hardwood-dependent species provide to achieving sustainable ecosystems that provide a yield of forest products. The Forest Renewal Plan, with significant silviculture funding, will enable significant investment in forest stands. These investments will need to be placed within a larger, long-term context of a landscape if hardwood-dependent species are to be maintained.

References

British Columbia Ministry of Environment, Lands and Parks. 1995. Amphibians, reptiles, birds and mammals not at risk in British Columbia: the Yellow List (1994) B.C. Min. Environ. Wildl. Br. Bull. B-74. 62 p.

Enns, K.A., E.B. Peterson, and D. McLennan. 1993. Impacts of hardwood on British Columbia wildlife: problem analysis. For. Can. and B.C. Min. For., Victoria, B.C. FRDA Rep. No. 208.

Government of British Columbia. 1993. Proposed Forest Practices Rules for British Columbia. Queen's Printer. 128 p.

Keisker, D.G. 1987. Nest-tree selection by primary cavity-nesting birds in south Central British Columbia. B.C. Min. Environ. Wildl. Rep. R-13. 67 p.

Ledig, T.F. 1993. Secret extinctions: the loss of genetic diversity in forest ecosystems. *In* Our Living Legacy: Proc. Symp. on Biological Diversity, M.A. Fenger, E.H. Miller, J. Johnson, and E.J.R. Williams (editors). Royal British Columbia Museum, Victoria, B.C. pp. 213–227.

Luttmerding, H.A., D.A. Demarchi, E.C. Lea, D.V. Meidinger, and T. Vold. 1990. Describing ecosystems in the field. 2nd ed., B.C. Min. Environ. Manual 11.

Ohanjanian, I. 1991. Inventory of mature and old-growth stands Cranbrook and Invermere Timber Supply Areas with special reference to habitat requirements for Pileated Woodpeckers. The Habitat Conservation Fund. B.C. Min. Environ., Wildl. Branch, and B.C. Conservation Foundation.

Post, K., A. Gardiner, M. Nyhof, and L. Gardinger. 1994. Wildlife trees in British Columbia. Discovering animal inns. B.C. Min. Environ., Project Wild. 56 p.

Stevens, V. [1995]. Wildlife diversity in British Columbia: distribution and habitat use in biogeoclimatic zones. B.C. Min. Environ. and B.C. Min. For. In press.