FRPA Resource Evaluation Program

Scientifically Valid Evaluations of Forest Practices under the *Forest and Range Practices Act*

Baseline Datasets for Evaluating Wildlife Tree Patches

FREP Report #1

David Huggard

November 2004

British Columbia
Ministry of Forests
Ministry of Sustainable Resource Management
Ministry of Water, Land and Air Protection

Library and Archives Canada Cataloguing in Publication Data
Huggard, David J.
Baseline datasets for evaluating wildlife tree patches

(FREP report ; #1)

At head of title: FRPA Resource Evaluation Program.
Co-published by Ministry of Sustainable Resource Management and Ministry of Water, Land and Air Protection.
Includes bibliographical references: p.
ISBN 0-7726-5276-7

1. Wildlife habitat improvement - British Columbia. 2. Habitat conservation - British Columbia. 3. Forest management - British Columbia. I. British Columbia. Forest Practices Branch. II. British Columbia. Ministry of Sustainable Resource Management. III. British Columbia. Ministry of Water, Land and Air Protection. IV. British Columbia. FRPA Resource Evaluation Program. V. Title. VI. Series.

QL84.26.B7H82 2005 639.9’2’09711 C2005-960014-4

Citation:
British Columbia Ministry of Forests. 2004. Baseline datasets for evaluating wildlife tree patches. B.C. Min. For., For. Prac. Br., Victoria, B.C. FREP Ser. 001. <http://www.for.gov.bc.ca/hfp/frep/6_evaluation_reports.html>

Prepared by
David Huggard
517 E. 10th Street
North Vancouver, BC V7L 2E7

Copies of this report may be obtained, depending on supply, from:
Government Publications
PO Box 9452, Stn Prov Govt
Victoria BC V8W 9V7

In Victoria (250) 387-6409
Outside Victoria 1-800-663-6105

http://www.publications.gov.bc.ca

For more information on Forest Practices Branch publications, visit our web site at:
http://www.for.gov.bc.ca/hfp/pubs.htm

Executive Summary

The goal of this project was to compile existing datasets on tree and snag densities in unmanaged CWH, ESSF and ICH forests to allow baseline comparisons with wildlife tree patch (WTP) effectiveness monitoring conducted by the Ministry of Forests (MOF). Baseline datasets were obtained from a variety of sources across the province, representing 1175 individual sites (with a wide range of sampling intensities per site).

A number of Excel files were created to summarize the baseline data and the MOF WTP monitoring results:

1. Each baseline dataset was summarized by BEC variant or subzone and mature versus old age class (or other classifiers where appropriate) for each main species group (Douglas-fir, cedars, hemlock+true firs, spruces, pines and deciduous species), as well as all species combined. Mean densities and between-site standard deviations were calculated by height class (>10 m tall, >5 m tall, all), diameter class (12.5–20 cm, 20–30 cm, 30–50 cm, 50–70 cm, >70 cm) and various overlapping combinations of wildlife tree classes (live, classes 3+4, 5+6, 7+8, 3 to 5, 6 to 8, all snags, all stems). Live and dead stems with broken tops were also summarized. Other pathologies were not recorded often enough to summarize from the existing baseline datasets.
2. The WTP monitoring data were summarized using the same habitat elements as above, by eight groupings of subzones (CWHxm, CWHdm/ds/mm/ms, CWHvh/vm/ws, ESSFdc/mv/mw, ESSFwc/wk/wm, ICHmk/mw, ICHvk/wk and ICHmc). This was done separately for WTP reserves and dispersed retention.
3. Within each main species (and for all species combined) in each of the eight WTP subzone groupings, baseline results were combined to produce overall means and standard deviations of densities for the combinations of height classes, diameter classes and wildlife tree classes.
4. The WTP results were compared to the combined baseline data within each main species (and for all species combined) in each of the eight subzone groupings. Comparisons included the values in WTP reserves or dispersed retention expressed as a percentage of the baseline values, as well as the difference between WTP values and the baselines divided by the baseline standard deviation. The latter is potentially useful for a “range of natural variation” approach. Crude indicators of confidence intervals were estimated for all of the comparison values.

The files summarizing the baseline data and comparing them to the WTP effectiveness monitoring results are intended to allow users to make comparisons of particular habitat elements of interest. Example comparisons are presented and discussed for some basic elements (all stems, all snags, snags >10 m tall, snags and stems by size, wildlife tree class and species), but not all their innumerable combinations. The main purpose of such

comparisons is to identify the weakest points in the retention as a focus for management improvements and perhaps as a guide for further "extensive" monitoring. Within the limited range of the habitat elements examined, the weakest points of retention in WTP reserves compared to the baselines were:

- low densities of the largest stems or snags in drier CWH subzones, dry ESSF and wetter ICH;
- low overall densities of snags, especially conifers, in wetter CWH;
- low densities of tall snags, as well as snags overall and larger snags, in wetter ESSF;
- low overall live tree densities in ICHmc; and
- no specific weaknesses in drier ICH, but lowest overall percent area in WTP reserves.

Several assumptions and analysis problems, including wide confidence intervals, underlie the comparisons. Suggestions are provided on how to reduce these problems in future sampling and data summaries. Comparisons are also made with some published baseline values.

Acknowledgements

Many people supplied data for this project, provided helpful responses to my enquiries, or assisted in collecting and summarizing some of the datasets: Barb Beasley, Craig DeLong, Deb DeLong, Nancy Densmore, Glen Dunsworth, Rachel Holt, Mike Jull, Walt Klenner, Laurie Kremsater, Deb MacKillop, Todd Manning, Louise de Montigny, Janet Ohmann, Bruce Rogers, Jeff Sandford, Alf Savari, Rob Serrouya, Susan Stevenson, Doug Steventon, Jeff Stone and Kari Stuart-Smith.

Helpful comments on an initial draft were provided by Deb Delong, Nancy Densmore, Laurie Kremsater, Todd Manning, Rob Serrouya and Jeff Stone.

Table of Contents

List of Tables

List of Figures

Introduction

Wildlife tree patches (WTPs) were established under the Forest Practices Code to provide biological diversity in managed stands. One of the major benefits of WTPs is the retention of snags (standing dead trees) and suitable live trees for future snag recruitment. Snags are critical habitat features for many wildlife species.

As part of government's shift towards monitoring how effectively forest practices are meeting management objectives, the Ministry of Forests (MOF) conducted an initial effectiveness monitoring project to measure the retention of snags and live trees in WTPs in British Columbia (Bradford et al. 2003). A critical aspect of maximizing the benefits of effectiveness monitoring is to incorporate comparisons with baseline data to facilitate practical learning.

The purpose of this project is to collate existing baseline data to allow comparisons with the data collected in the MOF WTP effectiveness monitoring project. The primary comparison is with baseline densities of trees and snags in unmanaged forests. There is no doubt that managed stands differ from unmanaged ones, and even WTP reserves are likely to differ to some extent from unmanaged stands in at least some habitat structures. The relevant question addressed by this comparison is, "How much do levels of various structures retained in WTPs differ from unmanaged forests?"

This question can be stated from an "accounting" point of view as, "If we retain x% of a cutblock in WTP reserves, are we retaining x% of a particular habitat element (or more, or less)?" From the "ecosystem management" perspective of trying to manage within the range of natural variation, the question can be expressed as, "How do WTPs compare to the range of variation in habitat elements within 'natural' stands?" The answer to this question would typically express differences in terms of standard deviations (SDs) from the baseline mean, rather than percent differences.

Finally, and perhaps most importantly, the practical perspective of using effectiveness monitoring results to improve forest management suggests the key question, "What are the weakest points in WTP retention?" That is, "Which structures in WTPs are at the lowest levels relative to unmanaged stands?" These weakest points should be the focus of improved management practices, and also the main emphasis for subsequent monitoring to determine whether the effectiveness of practices is improving. (There are other ways that "weakest points" could be defined — for example, relative to specified regulatory targets, or to known requirements for certain wildlife species or other values. These other approaches to assessing WTP retention are not addressed here.)

In addition to evaluating retention in WTP reserves, the MOF WTP effectiveness monitoring project also measured levels of snags and trees in dispersed retention, in which retained structures are scattered throughout the cutblock, rather than in discrete WTP reserves. This allows a secondary comparison of which management alternative (WTP or dispersed retention) is most effective at retaining different types of habitat structures.

Values from unmanaged baseline stands are also relevant here because they give a "measurement scale" to the comparison of different practices. For example, WTP retention may retain seven snags per hectare, while dispersed retention retains four. In this case, WTP retention would appear to be better; however, values from unmanaged baseline forests are required to know how to interpret these results. As an example, if there are 120 snags/ha in unmanaged forests, neither retention system is very effective, but if there are eight snags/ha in unmanaged forests, both retention systems may be acceptable. Direct comparison of management options is the essence of adaptive management; however, this is a secondary issue here, because it was not a main component of the MOF WTP effectiveness monitoring design, nor a priority of this project.

The objectives of this project are to:

1. Collect existing baseline datasets for snags and trees in unmanaged forests in the three main BEC zones sampled in the MOF WTP effectiveness monitoring project – CWH, ESSF and ICH.
2. Collate the various baseline datasets into a consistent format to allow comparisons with the MOF WTP data.
3. Conduct initial comparisons and interpretations of the baseline versus WTP data as a start towards addressing the previously discussed questions.

The main emphasis of the project was on objectives 1 and 2 due to the effort involved in tracking down and summarizing the baselines datasets.

Methods

Baseline data sources

The criteria for selecting useful baseline datasets included:

1. Data from the ESSF, ICH or CWH zones;
2. Field data (as opposed to modeling or general inventory estimates);
3. Unmanaged stands;
4. Stands of at least “harvestable” age (as opposed to young naturally-disturbed stands);
5. Classified to at least the BEC subzone level;
6. Information on dead trees, and preferably also live trees;
7. Information by size class or wildlife tree class, preferably both;
8. Information on species and stem heights; and
9. If available, information on broken tops or other additional tree descriptors (forks, conks, etc.).

In tracking down datasets, most effort was put on datasets that met all of criteria 1–8. The requirement for subzone information limited the search to BC datasets. A variety of sources were consulted:

- Ministry of Forests regional ecologists, former regional ecologists, or consultant associates, including Doug Steventon (Smithers), Dave Coates (Smithers), Craig DeLong (Prince George), Mike Jull (Prince George), Susan Stevenson (Prince George), Deb DeLong (Nelson), Rachel Holt (Nelson), and Walt Klenner (Kamloops). These contacts were also asked to identify any work done by other consultants in the regions (which can be difficult to locate if it is not published).

- A thorough annotated bibliography of deadwood studies in northern BC compiled by Bruce Rogers at UNBC (Rogers 2003).
- The coarse woody debris database compiled by Ruth Lloyd (as of fall 2003).
- The NRIN database established by FORREX. (In fall 2003, this database contained only a few records of actual projects.)
- The FII/FIA/FRBC project website. (This website was poorly organized and did not seem to contain information on most FII/FIA/FRBC projects.)
- The Ministry of Forests deadwood website, which is in its initial stages of development.
- Vegetation Resources Inventory (VRI) data were supplied by Nancy Densmore and Alf Kivari (Ministry of Forests, Victoria).
- A search of published literature, including U.S. Forest Service publications, based on keywords “snags,” “coarse woody debris,” or “deadwood,” and “British Columbia,” “Washington” or “Oregon.”
- Habitat structure projects that the author is involved with (Weyerhaeuser coastal BC, Vancouver Island regional benchmarks, silvicultural systems projects in the Interior).

Baseline datasets

The following are brief descriptions of the main baseline datasets or summaries acquired for the project. Specific information on the BEC variants or subzones, age classes and/or landbase types, sample sizes, and type of data is provided in Table 2 (see page 12).

Vegetation resources inventory (VRI)

Source: Alf Kivari and Nancy Densmore (Ministry of Forests, Victoria).

BEC zones: CWH, ESSF, ICH (and others).

This is an extensive dataset covering mature and old forests in many BEC variants. Data come from single prism plots per site, with information available on size, wildlife tree class and height. “Mature” for these data was defined as 100–140 years based on the mean total age for cored trees; “old” was >140 years. Variant or subzone was only available for half the ESSF, ICH and CWH records. Information on the VRI program is available at: http://srm.www.gov.bc.ca/tib/veginv/home.htm. The project is ongoing.

Provincial ecology program (PEP)

Source: BC Ministry of Forests (2001).

BEC Zones: CWH, ESSF, ICH (and most others).

This dataset contains information on dead trees in inventory plots by size class in many BEC variants for mature and/or old unmanaged forests. Immature stands were excluded. The raw data for this project were unavailable, so the data were summarized from an appendix in the working paper. Only information for dead trees was utilized. Since the data were already summarized for each variant x maturity type, only means were available (no standard deviations). To calculate combined standard deviations for baseline comparisons that combine results from a number of baseline studies, the standard deviation for each value from the PEP project was assumed to be equal to its mean (see "*Combining baseline datasets*" section). This appeared to be true for other baseline studies that used similarly low sampling effort per site.

Weyerhaeuser coastal BC habitat structural monitoring

Source: Jeff Sandford, Weyerhaeuser, Nanaimo. A summary report is available from David Huggard.

BEC Zones: CWH (also CDF).

This dataset includes extensive sampling of unmanaged forests across Weyerhaeuser's coastal BC tenure, including Vancouver Island, the mainland coast and Haida Gwai'i. It uses intensive sampling with six 10 × 100 m transects per site, with information on size and wildlife tree class. Heights were available for all snags, but not all live trees. The project is ongoing.

WLAP/UBC benchmark project on Vancouver Island

Source: Laurie Kremsater (UBC). A summary report is available from David Huggard.

BEC Zones: CWH (also CDF).

This dataset contains the initial year of sampling unmanaged, generally old, forests in CWHxm and CWHvm. It uses three 10 × 100 m transects per site, with information on size and wildlife tree class. Heights were available for snags, but not all live trees. The project is ongoing.

Sicamous Creek

Source: David Huggard (consultant) and Walt Klenner (Ministry of Forests, Kamloops) (Huggard 2000).

BEC Zones: ESSF.

Intensive sampling within one large research site divided into 15 study blocks, with information on size, wildlife tree class, height and broken tops. The history of the stands in the area is well-known, including an episode of spruce beetle in the 1860s that has led to low numbers of spruce snags in the current stand because most current overstory spruce are too young to be suffering much mortality yet. In addition, endemic balsam bark beetle and high persistence rates of snags led to high levels of subalpine fir snags. This known stand history illustrates that much variation can be expected among stands in any ecosystem type due to different historical disturbance events.

Monashee spruce grouse surveys

Source: David Huggard (consultant) (Huggard 2002).

BEC Zones: ESSF.

This dataset includes multiple plots sampling 19 sites in the Monashee Ranges in the former Salmon Arm Forest District, with information on size, wildlife tree class, height and broken tops. Mostly old-growth stands.

Old-growth structure in Nelson region

Source: Deb MacKillop (consultant) and Rachel Holt (consultant) (Holt and MacKillop 2002a, b).

BEC Zones: ICH and ESSF.

This dataset includes data from two projects provided by Deb MacKillop. One compares habitat structures in mature and old-growth stands (defined as <250 and >250 years old, respectively) in the ESSF and ICH. The other project was in old ICH. Information is available on size and wildlife tree class, plus broken tops for one of the projects. Information is not available for snags <17.5 cm dbh.

Trial on partial cutting for root disease

Source: Deb DeLong and Harry Quesnel (both formerly Ministry of Forests, Nelson) (Waters and Quesnel 2000).

BEC Zones: ICH.

Intensive sampling of two large sites, each divided into 16 blocks, using nested fixed area plots. The dataset contains information on size, wildlife tree classes and height. This is the only baseline project with pathology information recorded in the same manner as the MOF WTP effectiveness monitoring project.

Arrow IFPA

Source: David Huggard and Rob Serrouya (consultants). A summary is available from David Huggard.

BEC Zones: ICH and ESSF.

Includes sampled stands in operable and inoperable landbases in the ICH and ESSF, as well as sites in the ICH that were constrained from harvesting by visual quality objectives (VQOs). Inoperable stands were not included in the baseline summaries because they had distinctly different habitat structures compared to the harvestable landbase. Sites were all approximately 100–120 years old, as this is a dominant age class in the area due to burning during historical prospecting and settlement. Information on size, wildlife tree class, height and broken tops is available.

Robson Valley EFMPP stand structure

Source: Craig DeLong (Ministry of Forests, Prince George) (Harrison et al. 2002).

BEC zones: ICH and ESSF.

Extensive sampling of older sites, but information is only available on dead trees by size classes. A different classification scheme for dead trees was used, specific to certain snag-using vertebrates.

Date Creek

Source: Doug Steventon and Dave Coates (Ministry of Forests, Smithers) (Coates et al. 1997).

BEC Zones: ICH.

Intensive sampling of four sites, each divided into 3–5 study blocks. Information is only available on live/dead trees by size class.

Northern wetbelt silvicultural systems projects

Source: Susan Stevenson (consultant) and Mike Jull (UNBC, formerly Ministry of Forests, Prince George) (Jull and Stevenson 2001).

BEC Zones: ICH.

Intensive sampling of three sites, divided into four study blocks. Information is available by wildlife tree classes for all stems ≥17.5 cm.

These are the main sources of baseline data acquired for the three BEC zones, which contain at least some combination of information by species, size, wildlife tree class and height. These data sources were used for the quantitative comparisons summarized below. Several other sources containing some relevant information for less quantitative comparisons are summarized in Appendix 1.

A number of other potentially relevant datasets were identified, but could not be obtained because the data are either in a currently unavailable form, or the person responsible has moved elsewhere. These include data from the sites of the EP703 project (Louise de Montigny and Jeff Stone, Ministry of Forests), other long-term monitoring sites (Jeff Stone, Ministry of Forests), and, in general, the many permanent sampling plots of the Ministry of Forests (some of which are in unmanaged stands). Additional information could likely be found from company (TFL) or government (TSA) inventory plots, but there seems to be no reasonable way to access these data.

In addition, a number of publications from BC and the U.S. Pacific Northwest provide summaries of snag data in unmanaged forests in various forms, such as univariate or multivariate thresholds to define "old growth," unclear calculations of "historical range of natural variation," or multivariate ordinations. The original datasets behind these analyses could be useful sources of further baseline data, but might require considerable effort to track down and analyze.

Other data sources undoubtedly exist. Forest wildlife studies, particularly of cavity-nesting birds, done by contractors or graduate students with government or industry funding, could likely provide relevant information. However, there appears to be no useful, coordinated way of finding these studies and their principal investigators. Also, it can be a considerable time imposition to resurrect and summarize old datasets if they have not been formally archived.

Several contributors also mentioned that they had comparable data from other zones that may be of interest for future comparisons with the MOF WTP effectiveness monitoring results, particularly in the SBS and IDF zones.

Wildlife tree patch data

The Ministry of Forests' dataset on trees and snags in wildlife tree patches was obtained from Amanda Nemec (International Statistics and Research Corp.). Details of the sampling design and field data collection are provided in Bradford et al. (2003). Briefly, retained wildlife trees were sampled in 19 BEC subzones. Sampling in wildlife tree patches used primarily prism plots, while retained trees in dispersed retention were either fully counted, or sampled with prism or fixed-area plots. The dataset contained "per hectare factors" (PHF) for each stem, used to convert the records from the different sampling schemes to density estimates.

For sampled trees and snags ≥12.5 cm dbh, observers recorded species, dbh, height, wildlife tree (decay) class based on Thomas et al. (1979), and several other variables. In dispersed areas, dbh and wildlife tree class were only recorded for 30 trees, which was assumed to be a random sample. Dbh for the other trees, calculated from the relationship between dbh and height, were provided in the dataset. Because density of stems by wildlife tree class was a basic measure used, wildlife tree classes for unclassified stems in dispersed retention were assigned using the following procedure:

1. For each species at each site, the proportion of classified trees in each wildlife tree class was calculated (combining live tree classes 1 and 2).
2. The PHF for each unclassified tree was allocated to the different wildlife tree classes in proportion to the occurrence of the classes among the classified stems of that species at that site. For example, if a site contained 10 classified pine trees – seven live, two class 3, and one class 5 – then an unclassified pine tree with a PHF of 20 would be considered to be one live pine tree with a PHF of 14 (= 0.7 × 20), one class 3 pine tree with a PHF of 4 (= 0.2 × 20), and one class 5 pine tree with a PHF of 2 (= 0.1 × 20).

This procedure preserves the overall densities and observed distribution by wildlife tree class of each species at the site. The estimation was done separately by species because different species at a site often seemed to have different wildlife tree class distributions among the observed stems. Ideally, the procedure would also have been done separately by stem size, but sampled sizes within each site and species were too low.

Other notes on processing the MOF WTP data:

- Retained trees that had fallen were sometimes recorded in the MOF WTP data, but were excluded for this project. The summaries therefore represent stems that were still standing at the time of the survey, rather than all stems that were retained at harvest.

Any retained tree with no wildlife tree class in WTP retention was considered to have fallen (even though not all such records indicated this directly).

- Stems of wildlife tree class 9 were deleted because this class was not recognized in any of the baseline studies. In the MOF WTP data, wildlife tree class 9 seemed to represent remnant stubs or stumps decayed to duff.
- Patch types "AW" (possible alternative reserves in pre-harvest stands), "DT" (temporary dispersed retention) and "PT" (temporary patches) were excluded. There were only two sites with "DT" retention in the three BEC zones of interest, and only one with "PT." The long-term fate of these temporary patches is presumably uncertain.
- Twelve records in the BEC zones of interest did not have dbh information, and were excluded.
- Any stems with dbh <12.5 cm were excluded.
- Blocks with no WTP reserves were excluded because the main focus was comparing densities of stems retained in patches to baseline areas. Blocks with no WTP reserves should be included if these results are going to be scaled up to the total amount of retention over larger areas (i.e., by multiplying retention densities in patches by the proportion of the block composed of retention patches).

Data summaries

Data were summarized as densities rather than basal areas because stems were summarized by size class, thereby making the size information inherent in basal area redundant. Reasonable approximations of basal area can be obtained from the summaries using the densities and mid-points for each diameter class. Volumes were not summarized because this variable is rarely used in describing the habitat relationships of organisms that use snags.

The baseline datasets and the MOF WTP data were summarized in the same way, with tabulations of mean density and standard deviations (using the "site" or individually defined study blocks as the sample unit) by the following variables:

BEC units

Most of the baseline datasets were summarized by the BEC variants or subzones identified in the studies. The Arrow IFPA study used combinations of site series that usually crossed subzones; summaries were by the ecosystem units used in the project. The half of the VRI data with subzone information was summarized by subzone; the complete dataset was also summarized by zone (though not used here for the comparisons with the MOF WTP sites).

The variants sampled in the MOF WTP effectiveness monitoring project were combined into eight groups of subzones to produce reasonable sample sizes in ecosystem types that were likely to have different types of snag retention, and also to allow a reasonable number of baseline sites for comparison with each WTP grouping:

- **CWHxm** (5 WTP sites): This subzone was summarized separately, because it is dominated by Douglas-fir, mostly from mature (not old) stands.
- **CWHmm, ms, dm and ds** (8 WTP sites): These moderately dry subzones on Vancouver Island and the coastal mainland were combined due to broadly similar forest types and

few samples in each. Analyses of Weyerhaeuser monitoring plots have shown similar habitat structural levels in mm and dm sites.

- **CWHvh, vm, ws** (16 WTP sites): These were combined as wetter CWH sites. Weyerhaeuser's results show similar habitat structures in vh and vm sites.
- **ESSFdc, mv, mw** (6 WTP sites): The drier ESSF sites, with more frequent fires and greater prominence of lodgepole pine, were combined because of few WTP sites in each subzone.
- **ESSFwc, wk, wm** (19 sites): These wetter ESSF sites were combined, with few of the WTP sites in wk and wm subzones (3 and 2, respectively).
- **ICHmk, mw** (15 sites): The four mk sites were combined with the 11 mw sites as drier ICH, with a prominent component of pine, fir and larch.
- **ICHvk, wk** (6 sites): The single WTP site in vk was combined with the wk as wetter ICH.
- **ICHmc** (7 sites): This subzone was summarized separately because of its geographical isolation.

Age classes

Baseline summaries were done separately for mature versus old stands, or for other relevant classifiers identified in the particular study, such as landbase type. This separation was mainly to allow future comparisons within a particular age class or landbase type. In this report, both mature and old stands were used for comparison with MOF WTP data on the basis that the harvested stands would also have been a mix of age classes.

Species

Summaries were done for all species combined, and for six groupings of individual species:

Douglas-fir. Kept separate because of distinct decay properties and wildlife uses. (Note: larch might have been combined with Douglas-fir due to similar properties, but unfortunately was neglected until most of the data summary was complete, and was therefore included in the "other/unknown" category. The exception was in Deb MacKillop's data, where it was already combined with Douglas-fir. Larch was a minor component of the available baseline datasets and the MOF WTP data).

Cedar. Redcedar and yellow cedar were combined as ecologically similar.

"HemBal." Hemlock and true fir species were grouped together because of similar decay properties and use of these species as snags. They also tend to be treated the same in management plans. "Hembal" is predominantly hemlock in the CWH subzones and true fir in the ESSF, with a hemlock-dominated mix in the ICH.

Spruce. The various spruce species and hybrids were combined because they are similar in decay and wildlife use.

Pine. The pine species were combined, with lodgepole pine predominant.

Deciduous. Deciduous species were combined because of similarities in use of the main species (birch, aspen and alder), and the fact that all of these species are rare, and hence poorly sampled, in the older unmanaged forests used as baselines.

Size classes

Results were tabulated in five dbh classes:

12.5–20 cm	50–70 cm
20–30 cm	>70 cm
30–50 cm	

When datasets provided information by dbh classes that did not mesh fully with these classes, densities were adjusted appropriately. For example, if a dataset included densities in a size class from 27.5–32.5 cm dbh, half of this density was added to the 20–30 cm class, and half to the 30–50 cm class. Or, if the dataset included densities from 17.5–30 cm, 80% of the density (30–20)/(30–17.5) was assigned to the 20–30 cm class, and 20% to the 12.5–20 cm class. This assumes a uniform distribution of sizes within the class reported in the dataset, which is probably a reasonable approximation for these summaries. Tabulations also included combined results for all stems ≥12.5 cm dbh.

Wildlife tree classes

Summaries were done by several groupings of the eight wildlife tree classes to allow various comparisons that different users might utilize. Live trees in classes 1 and 2 were combined because the distinction between the two live classes is arbitrary and generally highly variable among observers and different studies. Following the MOF WTP report, snags were combined as: classes 3+4, classes 5+6 and classes 7+8. They were also combined as: classes 3–5 (hard) and classes 6–8 (soft). Finally, summaries were made for all snags, and for all stems (live and dead). In some baseline studies, information was only available for dead trees.

Height classes

Summaries were done for all baseline studies for stems of all heights. Where height information was available, additional summary tables were done using only stems >5 m height and only stems >10 m height. This was to allow comparisons by users who might wish to set different minimum height requirements for useful stems.

Broken tops

Summary results were also generated for stems with broken tops, and by wildlife tree class (combining all sizes), where available. Too little information was available for baseline levels of other features, such as forks, conks, etc.

Summaries of the MOF WTP data are presented in the Excel workbook "WTP data summary.xls," which contains a worksheet for each species group. Within each worksheet, separate tables provide means and standard deviations for each combination of the eight ecosystem types and the two retention types (WTPs and dispersed retention). *Some interpretation is provided under comments in the "All species" worksheet.*

Summaries of each of the main baseline datasets are provided in **14** Excel workbooks, one per data source, named "WTP baseline [*Data set name*].xls." Each summary contains one worksheet per species group. Tables in each worksheet provide means and standard deviations for each BEC unit (and sometimes age class or landbase). *Some interpretation of individual cells is provided in the "All species" worksheet for the* ***VI benchmark file****.*

Combining baseline datasets

The eight ecosystem groupings and the six groupings of tree species are summarized in Table 1. For the comparisons, only species groups that were moderately abundant within the ecosystem grouping were used. "Moderately abundant" meant at least 10 stems/ha in the MOF WTP data, or a somewhat higher mean number if the abundances were highly variable between WTP sites. Rarer species may be of ecological interest, but simply cannot be analysed here due to limited sample sizes and high variability. Even the comparisons for the broadest categories ("All snags" or "All stems") of some moderately abundant species groups are made dubious by very high site-to-site variability and limited sample sizes in both the WTP and baseline datasets.

Table 1. Species groups examined in each grouping of WTP ecosystems.

	Fd	Cedar	HemBal	Spruce	Pine	Decid	All species
CWHxm	√	√	√			√	√
CWHdm,ds,mm,ms	√	√	√			√	√
CWHvh,vm,ws		√	√	√		√	√
ESSFdc,mv,mw			√	√	√		√
ESSFwc,wk,wm			√	√	√		√
ICHmk,mw	√	√	√	√	√	√	√
ICHvk,wk	√	√	√	√	√		√
ICHmc		√	√	√	√		

Table 2 lists all the baseline datasets, the eight ecosystem groupings for the MOF WTP data, and identifies which baseline datasets were combined as the comparison base for each ecosystem group. The "primary" combinations ("1" in Table 2) were used. These are cases where the subzone of the baseline dataset directly matches a subzone included in the ecosystem grouping for the MOF WTP data (some latitude was taken with the ICHmc grouping, where there were few baseline data). "Secondary" baseline datasets are also suggested ("2" in Table 2). These represent somewhat less similar ecosystems, which could be included for a bigger sample size of baseline sites. Including these additional baseline sites for each comparison might be most useful if more MOF WTP data were collected, in which case the sampling error from the baseline sites would be a relatively larger component of uncertainty in the comparisons. Currently, there is more uncertainty in the comparisons due to sampling error in the MOF WTP data than in the primary baseline data.

Table 2. Summary of available baseline datasets collected.

								WTP Groupings[4]							
Dataset name or contributor	**BEC**	**Other type descriptor**	**Number of sites[1]**	**Same sizes**	**WT classes**	**Ht[2]**	**BT[3]**	**CWHxm**	**CWHdm/ds/mm/ms**	**CWHvh/vm/ws**	**ESSFdc/mv/mw**	**ESSFwc/wk/wm**	**ICHmk/mw**	**ICHvk/wk**	**ICHmc**
Arrow IFPA	Drier ESSFwc4	Inoperable	6	Y	Y	Y	Y					2			
		Operable	6	Y	Y	Y	Y				2	1			
	Mesic ICH	VQO	2	Y	Y	Y	Y						1	2	2
	Submesic ICH	Inoperable	6	Y	Y	Y	Y						2		
		Operable	6	Y	Y	Y	Y						1	2	2
		VQO	6	Y	Y	Y	Y						1	2	2
	Drier ESSFwc1	Inoperable	6	Y	Y	Y	Y					2			
		Operable	6	Y	Y	Y	Y				2	1			
	Subhygric ICH	Inoperable	6	Y	Y	Y	Y						2		
		Operable	6	Y	Y	Y	Y						1	2	2
		VQO	6	Y	Y	Y	Y						1	2	2
	Xeric ICH	Inoperable	6	Y	Y	Y	Y						2		
		Operable	6	Y	Y	Y	Y						1		2
		VQO	4	Y	Y	Y	Y						1		2
Craig Delong	ESSFmm1		18	Y	Dead only	N	N				1				
	ICHmm		16	Y	Dead only	N	N						1		1
Date Creek	ICHmc2		(16)	Y	Live/dead	N	N						2		1
Deb Delong	ICHmk1		(16)	Y	Y	Y	N						1	2	2
	ICHmw2		(16)	Y	Y	Y	N						1	2	2
Deb Mackillop	ICHmw2		16	Y	Y	N	Y						1	2	2
	ESSFdk	Mature	29	N[5]	Y	N	N				1	2			
		Old	7	N[5]	Y	N	N				1	2			
	ICHwk1	Mature	7	N[5]	Y	N	N						2	1	2
		Old	30	N[5]	Y	N	N						2	1	2
Monashee grouse	ESSFwc2	Old	19	Y	Y	Y	Y				2	1			
Wetbelt silv. system	ICHvk2		(4)	N[6]	Y	N	N						2	1	
	ICHwk3		2+	N[6]	Y	N	N						2	1	1
Sicamous Creek	ESSFwc2	Old	(15)	Y	Y	Y	Y				2	1			
VI benchmarks	CDF	Old	5	Y	Y	Y	Y	2							
	CWHxm	Old	10	Y	Y	Y	Y	1	2						
	CWHvh	Old	5	Y	Y	Y	Y			1					
VRI	CWHdm	Mature	6	Y	Y	Y	N		1	2					
		Old	2	Y	Y	Y	N		1	2					
	CWHds	Mature	2	Y	Y	Y	N		1	2					
	CWHms	Old	11	Y	Y	Y	N	2	1	2					
	CWHvm	Mature	4	Y	Y	Y	N			1					
		Old	32	Y	Y	Y	N			1					
	CWHws	Old	14	Y	Y	Y	N		2	1					
	CWHxm	Old	4	Y	Y	Y	N	1	2						
	ESSFdc	Mature	9	Y	Y	Y	N				1	2			
		Old	12	Y	Y	Y	N				1	2			
	ESSFdv	Mature	6	Y	Y	Y	N				1	2			
		Old	14	Y	Y	Y	N				1	2			
	ESSFmv	Mature	23	Y	Y	Y	N				1	2			
		Old	23	Y	Y	Y	N				1	2			
	ESSFmw	Mature	9	Y	Y	Y	N				1	2			
		Old	11	Y	Y	Y	N				1	2			
	ESSFvc	Old	16	Y	Y	Y	N					2			
	ESSFwc	Mature	21	Y	Y	Y	N				2	1			
		Old	44	Y	Y	Y	N				2	1			

Table 2. Summary of available baseline datasets collected (cont'd).

Dataset name or contributor	BEC	Other type descriptor	Number of sites[1]	Same sizes	WT classes	Ht[2]	BT[3]	WTP Groupings[4] CWHxm	CWHdm/ds/mm/ms	CWHvh/vm/ws	ESSFdc/mv/mw	ESSFwc/wk/wm	ICHmk/mw	ICHvk/wk	ICHmc
VRI cont'd	ESSFwk	Mature	13	Y	Y	Y	N				2	1			
		Old	13	Y	Y	Y	N				2	1			
	ESSFxc	Mature	11	Y	Y	Y	N				2				
		Old	6	Y	Y	Y	N				2				
	ESSFxv	Mature	6	Y	Y	Y	N				2				
		Old	2	Y	Y	Y	N				2				
	ICHdw	Mature	3	Y	Y	Y	N						2		
	ICHmc	Mature	5	Y	Y	Y	N						2		1
	ICHmk	Mature	6	Y	Y	Y	N						1	2	2
	ICMmw	Mature	3	Y	Y	Y	N						1	2	2
		Old	4	Y	Y	Y	N						1	2	2
	ICHvk	Mature	12	Y	Y	Y	N						2	1	
		Old	30	Y	Y	Y	N						2	1	
	ICHwk	Mature	4	Y	Y	Y	N						2	1	2
		Old	4	Y	Y	Y	N						2	1	2
Weyerhaeuser	CWHxm		15	Y	Y	Y	Y	1	2						
	CWHdm		6	Y	Y	Y	Y		1	2					
	CWHmm		3	Y	Y	Y	Y	2	1	2					
	CWHvm		13	Y	Y	Y	Y		2	1					
	CWHvh		2	Y	Y	Y	Y		2	1					
	CWHwh		4	Y	Y	Y	Y		2	1					
PEP	CWHmm2	Old	5	Y	Dead only	N	N		1	2					
	CWHvh1	Mature	30	Y	Dead only	N	N		2	1					
	CWHvh2	Mature(+old)	42	Y	Dead only	N	N		2	1					
	CWHvm1 (+2)	Old+Mature	89	Y	Dead only	N	N		2	1					
	ESSFdc	Mature	10	Y	Dead only	N	N				1	2			
	ESSFwc	Mature	53	Y	Dead only	N	N				2	1			
	ESSFwk1	Mature	46	Y	Dead only	N	N				2	1			
	ICHmc	Mature	15	Y	Dead only	N	N						2	2	1
	ICHmk	Mature	28	Y	Dead only	N	N						1	2	2
	ICHmm	Mature	24	Y	Dead only	N	N						2		2
	ICHmw3	Mature	6	Y	Dead only	N	N						1	2	2
	ICHvk2	Mature	19	Y	Dead only	N	N						2	1	
	ICHwk	Mature	20	Y	Dead only	N	N						2	1	2
	CWHms2	Mature	11	Y	Dead only	N	N	1	2						
	CWHwh1	Mature	8	Y	Dead only	N	N	2							
	CWHws1	Mature	10	Y	Dead only	N	N	2	1						
	ESSFmc+mm	Mature	10	Y	Dead only	N	N			2					
	ESSFwv	Mature	12	Y	Dead only	N	N				2				

1 Sample sizes in brackets indicate the number of study blocks within a single large site. "+" after a sample size indicates that there were multiple study blocks in each of these sites.

2 Y = Height information was available.

3 Y = Information was available on whether the tops were broken.

4 1 = Primary comparison (baseline dataset comprised of same ecosystem type used to compare to MOF WTP results). 2 = Secondary comparison (dataset from a related ecosystem type that could be used to increase baseline sample sizes).

5 Size classes were converted to the ones used in this project; however, no information for 12.5–20 cm class for snags.

6 All stems ≥17.5 cm combined.

Different weighting factors were used for some baseline datasets (½ for Date Creek, Deb DeLong's sites, Wetbelt Silvicultural Systems, Sicamous Creek and PEP; ¼ for VRI). These fairly arbitrary values were chosen to reflect the fact that the sample sizes for different baseline datasets can mean different things. Some datasets sampled a number of study blocks within one or a few general sites. The sample size reported for these sites, and used for calculating standard deviations within the dataset, is the number of study blocks. These datasets received a lower weighting, to reflect the fact that the "samples" are not as independent as other datasets that used widely separated sites as the sample unit.

Other datasets, such as the VRI data, are given a lower weight because they used very little sampling effort per site, compared to many subsamples and/or large plots in other datasets. Limited sampling within a site adds greatly to the variation between sites, and hence the mean value for these datasets is less certain than its sample size would indicate.

A weighted average value of the "primary" baseline datasets was calculated for each grouping of ecosystem group × species group × height class × size class × wildlife tree class:

$$\bar{\bar{x}} = \frac{\sum n_i \bullet wt_i \bullet \bar{x}_i}{\sum n_i \bullet wt_i}$$

Where n_i is the sample size, wt_i the weighting, and $\bar{x}_i$ the mean value for the i'th site.

The overall standard deviation of this weighted mean was calculated as:

$$SD_{OVERALL} = [(\Sigma(n_i - 1) \bullet wt_i \bullet SD_i^2 + \Sigma n_i \bullet wt_i \bullet (\bar{\bar{x}} - \bar{x}_i)^2) / (\Sigma n_i \bullet wt_i - 1)]^{1/2}$$

Where n_i is the sample size, wt_i the weighting, SD_i the standard deviation, $\bar{x}_i$ the mean of the i'th baseline dataset, and $\bar{\bar{x}}$ the grand mean for that grouping. This is equivalent to the standard deviation of all the original samples from the combined baseline dataset around the grand mean. From a statistical point of view, this is at best an approximate value because the available individual baseline sites are clearly not independent random samples of their ecosystem groups.

Note 1:
The standard deviation for each dataset and the overall standard deviation are exaggerated measures of the variation between stands because they also include a variance component due to subsampling error within each stand. This exaggeration due to subsampling uncertainty is likely very substantial for all variables when "light" sampling was used (e.g., single prism plots), and for rarer elements (such as large well-decayed snags) for all datasets. Exaggerating the standard deviation of the baseline stands has the effect of minimizing the difference between WTPs and baseline stands for the summaries that express these differences as the number of standard deviations. This problem could be reduced by partitioning the subsampling and sample variance components for baseline studies that use multiple subsamples. This would be a fairly intensive analysis, and probably difficult, given the numerous sampling schemes used in the different baseline studies. Because of this, the example comparisons presented in the next section use percent differences rather than differences in standard deviations.

The results of this collation of baseline datasets are presented as eight Excel workbooks, one per ecosystem group, each with a worksheet for each relevant species group. The file names are "Baseline Summary for [*Ecosystem group*].xls." *Some interpretation of individual cells is provided in the "All species" worksheet for the* ***CWHxm file****.*

Note 2:
Not all baseline studies measured size class, wildlife tree class *and* height class. Therefore, not all studies provided values for each combination of size class × wildlife tree class × height class. As a result, overall means and standard deviations for different values within an ecosystem group × species group combination can be based on different sample sizes. As a result of this, some columns or rows may not add up to the totals provided because the totals would be based on a different (usually larger) set of baseline datasets than the individual cells in the tables.

Comparisons of MOF WTP and baseline data

Comparisons of the MOF WTP and baseline datasets were expressed in two ways:

1. The WTP value was expressed as a **percentage of the baseline value**:

   $$\% \text{ of Baseline} = \text{WTP/baseline} \times 100\%$$

   This form is most appropriate for the questions "What is the difference between wildlife tree attributes in baseline versus WTP reserves?" and "What are the weakest points in WPT retention?" For example, for all stems in CWHxm (see Figure 1, page 17), the WTP reserves had 1.5 times (150%) as many stems as the baselines.

   Rough 95% confidence intervals for this percentage were obtained by calculating the % difference for the lower 95% confidence limit of the WTP value (WTP mean – $t_{0.05}$ x SE) and upper 95% confidence limit of the WTP value (WTP mean + $t_{0.05}$ x SE). This totally ignores the fact that the baseline value itself is an estimate, usually with considerable uncertainty, and also the fact that this formula is not really appropriate for values that are ultimately based on count data. When lower 95% confidence intervals were meaningless negative numbers, they were simply truncated at 0. The confidence intervals are really just meant as a reminder to temper interpretations, given the wide uncertainty involved in most of these estimates.

   (A better approach for any future analyses might be to use log(x+1) transformations on the original site-level values. This would eliminate the problem of negative values, and allow easier inclusion of the uncertainty of the baseline values. This was not done because interpreting the geometric means that result from back-transforming means of log-transformed values is more difficult than interpreting simple arithmetic means.)

2. The difference between the WTP value and the baseline was expressed as the **number of baseline standard deviations (SDs)**:

   $$\text{Difference in SDs} = (\text{WTP value} - \text{baseline value})/\text{baseline SD}$$

   For example, a value of 2.0 would mean that the WTP value was 2.0 baseline SDs higher than the baseline value (i.e., it was in the upper 2.3 percentile of the baseline sites, dubiously assuming a normal distribution). A value of -0.5 would mean that the WTP value was ½ a baseline SD lower than the baseline value (i.e., it was in the lower 31 percentile of the baseline sites). The comparison expressed this way is probably most suitable for questions about how WTPs compare to the range of natural variability. [Note again, the problem of exaggerated baseline SDs minimizing the differences in WTP and baseline SDs, as previously discussed in Note 1 above.] Rough 95% confidence intervals were calculated in the same manner as comparison 1.

These two types of comparisons and associated confidence intervals were calculated for each combination of the eight ecosystem groups and the relevant species groups (see Table 1), a total of 39 combinations. Within each, the comparison was done for the three height classes × five size classes + all sizes + broken tops × eight combinations of wildlife tree classes. Furthermore, the comparisons with baseline values were done separately for results from WTP reserves and from the dispersed retention that was also surveyed by the MOF WTP effectiveness monitoring project. The resulting overwhelming amount of numbers reflects the fact that the main priority of this project was to collect and collate the baseline data, and provide values that would allow users to make comparisons of whatever particular elements they choose.

The results of the comparisons are presented as eight Excel workbooks, one per ecosystem group, each with a worksheet for each relevant species group. The file names are "WTP vs Baseline – [*Ecosystem group*].xls." *Some interpretation of individual cells is provided in the "All species" worksheet for the* ***CWHxm file***.

Some Results and Interpretation of Comparisons

This section presents and discusses a few of the most basic and relevant results in these numerous comparisons as examples of how these comparisons might be used, as well as discussing their limitations. Further interpretations of the comparisons summarized in the Excel files could focus on specific elements of WTP retention that are identified as important to various organisms.

Appendix 2 contains boxplots of WTP and baseline values for several habitat elements, by BEC group. These plots allow more direct comparisons of the ranges of values in the WTPs versus baselines. However, they were placed in an appendix because they have two caveats:

1. Different studies with different levels of effort per site could not be weighted differently.
2. Visual comparisons of boxplots have no "confidence intervals."

Conclusions should be made cautiously when comparing the boxplots in Appendix 2, especially where sample sizes are small.

All stems, all snags, and snags >10 m tall

A basic variable to assess WTP reserves is the total density of stems, live and dead, compared to the baseline sites. Densities in WTP reserves were very similar to baseline values for four of the eight ecosystem groupings, but the WTP reserves were considerably denser in the drier subzones of the CWH and ESSF, and in the ICHvk/vw grouping (though highly variable in the latter) (see Figure 1).

Depending on the forest type, denser WTP reserves could be associated with retention in poorer sites (in which case the retained trees should be smaller than in baseline sites), or denser WTP reserves could indicate retention in more productive sites (in which case tree sizes should be similar or larger than in baseline sites). Figures 4a and 5b (see pages 19 and 20), showing retention by size class in the drier ESSF subzones and ICHvk/vw, support the former case — the WTP reserves are composed of dense patches of smaller trees than baseline sites.

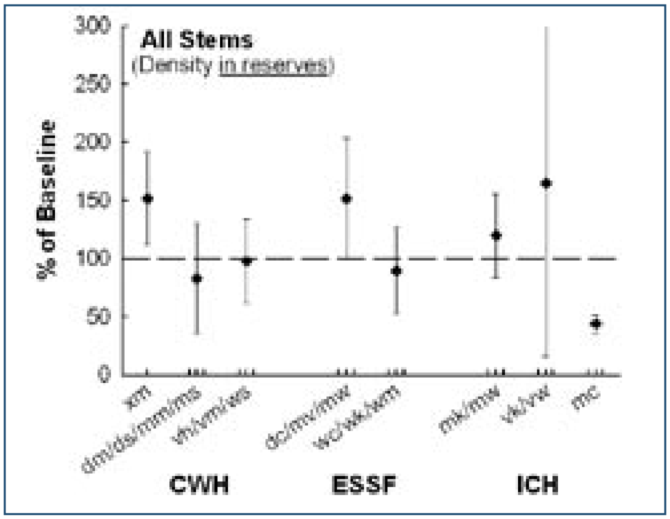

Figure 1. ***Density of all stems in WTP reserves, expressed as a percentage of densities in baseline sites. Error bars are (rough) 95% confidence intervals.***

The situation in CWHxm is less clear, with mid-size trees being predominant in WTP reserves compared to baselines (see Figure 3a). The low relative densities in the ICHmc are difficult to explain, but this is the grouping with the least amount of data for WTPs and baseline sites. Sampling error in the baseline dataset or differences in forest type between WTPs and baseline sites are most likely to be higher in this ecosystem type.

Densities of snags in the WTP reserves are more variable than total stems (note the wider confidence intervals in Figure 2a), but are similar to baseline levels in five of eight groupings (see Figure 2a). In ICHvk/vw, average snag retention in WTP reserves was considerably higher than in baseline sites, but highly variable. Lower overall densities of snags occurred in WTP reserves relative to baselines in the wetter subzones of the CWH and ESSF. Snag falling around the edges of WTP reserves may be more prominent in these subzones, for unknown reasons. This idea is loosely supported by the observation that these two subzone groupings show the greatest relative reduction in larger snags, which would tend to be taller and hence more subject to falling for safety reasons (see Figures 3 and 4). If these results are considered reliable, greater emphasis could be placed on retaining higher densities of snags in the wetter CWH and ESSF zones. This might involve larger WTP reserves if falling snags is an important factor, or selecting snag-rich WTP reserves during block layout. However, snag density alone should not be the only consideration in choosing WTP reserves, particularly if snags in high density areas are mainly small suppressed stems.

Perhaps contrary to expectations, densities of tall snags (>10 m tall) are not at substantially lower percentages relative to baselines than all snags (see Figure 2b). In the ICH groupings, tall snags tend to be at considerably higher relative abundances in WTP reserves than in baselines (though again, this is highly variable). The increase in relative percentage for tall snags compared to all snags in the ICH must be due to a substantially lower proportion of tall snags in the baseline sites (since there cannot be more tall snags than total snags in the WTP reserves). Overall, this suggests that retention of tall snags is not any more of a management concern than retention of snags overall. (In contrast, Weyerhaeuser's habitat structure monitoring did identify retention of tall snags as a major initial weakness, possibly due to the use of more small-area patches and a strong emphasis on safety, which would require the felling of tall snags within these smaller patches. Operational adjustments have partly mitigated this problem.)

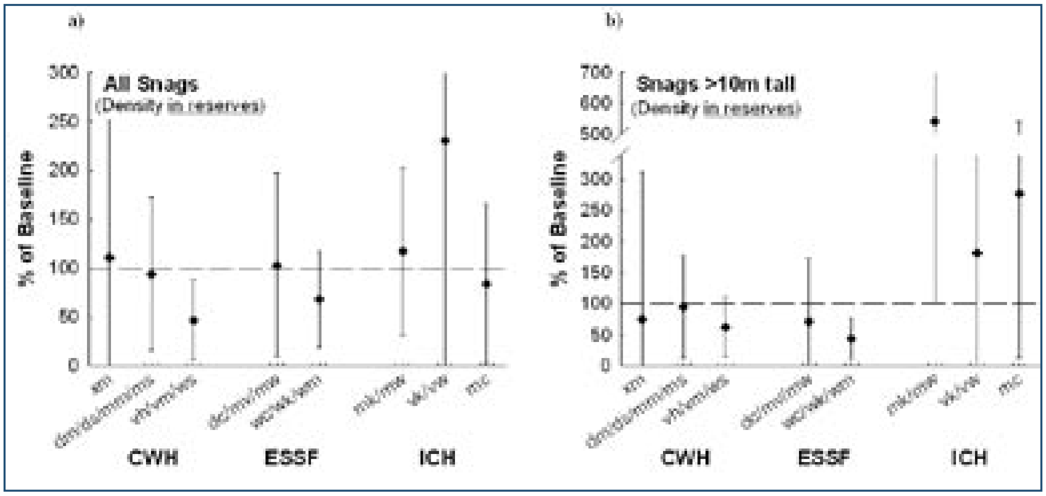

Figure 2. ***Density of (a) all snags, and (b) snags >10 m tall, in WTP reserves, expressed as a percentage of densities in baseline sites. Error bars are (rough) 95% confidence intervals. Note break in scale on the y-axis in (b).***

All stems and snags by size class and wildlife tree class

The size distribution of stems retained in WTP reserves was considerably different from baseline sites in the CWHxm (see Figure 3a). Small and moderately large diameter stems were at the same densities, while mid-sized stems were much more common in WTP reserves, and very large stems were rare. This may reflect the location of WTP reserves where the trees are somewhat smaller than average (though at higher densities). However, much harvesting in the CWHxm is in mature, second-growth forest, whereas at least some of the baseline sites were in old growth. This difference in age classes between the WTPs and baseline sites may explain the observed difference in size distribution. Baseline sites could have been summarized separately by age class, except this information was not available for many baseline sites in this variant, and would have further reduced the sample sizes. In contrast to the overall stems, large diameter snags were not at lower densities in the WTP reserves. Averaging the variability in the three smaller size classes, there was no apparent difference in size distributions of snags between the WTP reserves and the baseline sites in CWHxm, nor did hard (wildlife tree classes 3–5) versus soft (classes 6+) snags differ.

Results for CWHvh/vm/ws (not shown) showed the same pattern for size distributions as CWHxm, but with generally lower overall percentages.

In the CWHdm/ds/mm/ms grouping of subzones, the density of stems in the largest size class was lower in WTP reserves than baseline sites, while the four smaller size classes had similar densities in WTP reserves and baseline sites. Snags showed the same general pattern, except for anomalously high (though variable) densities in the 20–30 cm class.

Assuming that the baseline sites are representative of pre-harvest conditions in the stands sampled by the WTP project, under-representation of the largest stems in WTP reserves across the CWH is a concern for longer-term recruitment of large snags and CWD. Large trees and snags could be identified as anchor structures to look for when laying out WTPs in these subzones.

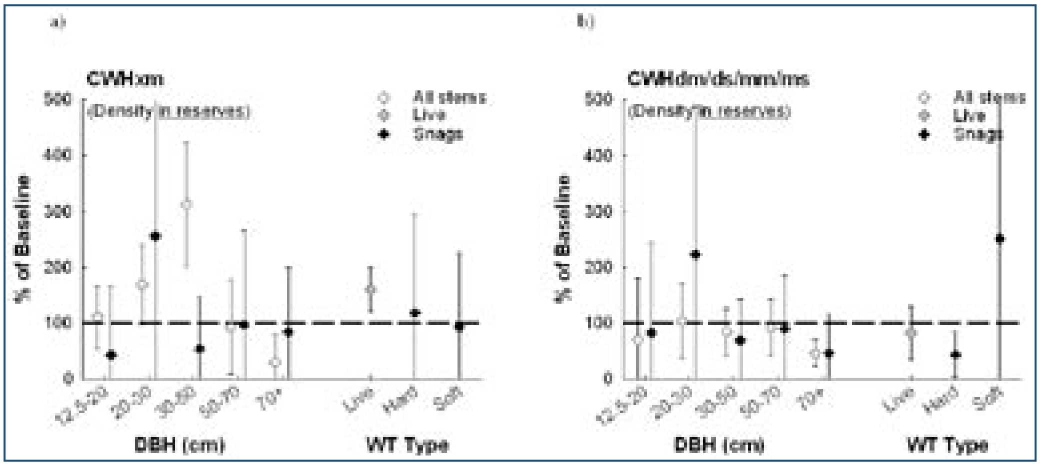

Figure 3. ***Density in WTP reserves of all stems and snags by size class only, and live trees, hard snags and soft snags, expressed as a percentage of densities in baseline sites for (a) CWHxm subzone, and (b) CWHdm/ds/mm/ms subzone grouping. Error bars are (rough) 95% confidence intervals. CWHvh/vm/ws (not shown) showed similar patterns to CWHxm across size classes, but with lower overall percentages.***

WTP reserves in the drier ESSF subzones showed a continuous decrease in retention of stems with increasing size relative to baselines (see Figure 4a). Snags, on the other hand, showed a more comparable size distribution in WTP reserves and baseline sites. (The lack of any stems >70 cm dbh in WTP reserves in these subzones is not a real concern, because such large trees are extremely rare in dry ESSF, although they did occur in some baseline sites.)

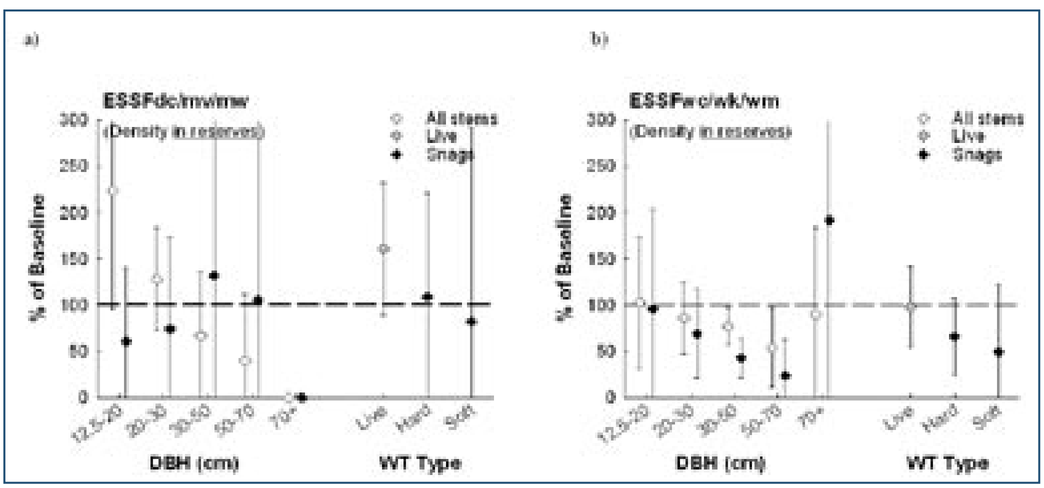

Figure 4. ***Density in WTP reserves of all stems and snags by size class only, and live trees, hard snags and soft snags expressed as a percentage of densities in baseline sites for (a) ESSFdc/mv/mw subzone grouping, and (b) ESSFwc/wk/wm subzone grouping. Error bars are (rough) 95% confidence intervals.***

In the wetter ESSF subzone, the density of stems in WTP reserves relative to baselines also decreased with increasing size (see Figure 4b). (Again, the relatively high values for stems >70 cm may not be very meaningful, as stems this large are very rare). Comparisons of densities by species (see Figure 6b) show that the declining relative retention of larger stems does not reflect a reluctance to include spruce (which is typically larger and more valuable) in WTP reserves. It may instead be due to locating WTP reserves in sites that are inoperable or have poor growth, such as rocky areas or wetlands.

Hard versus soft snags were retained in WTP reserves at similar relative densities compared to baselines (i.e., neither type was favoured over the other). Encouraging the retention of some WTP reserves with more moderately large trees should be a focus in the ESSF because of their long-term importance for snag and CWD recruitment. Greater retention of snags in general, especially moderate to moderately large snags, could be a further focus in WTP reserves in the wetter ESSF subzones.

In the ICHmk/mw subzone grouping, retention densities by size class of all stems and snags alone were either similar to or above densities in baseline sites (see Figure 5a). Hard and soft snags were also at baseline densities. These results do not suggest any particular weak points for retention in these subzones. However, this grouping had the lowest overall retention area (11.5%, compared to 15–17% in the ESSF groupings, and 22–42% in the CWH – although all these values are above recommended targets of 7–10% retention). Further improvement in retention in these subzones would best come simply from reserving more area. (Recognizing that there are many other specific aspects of the retention that have not been examined here).

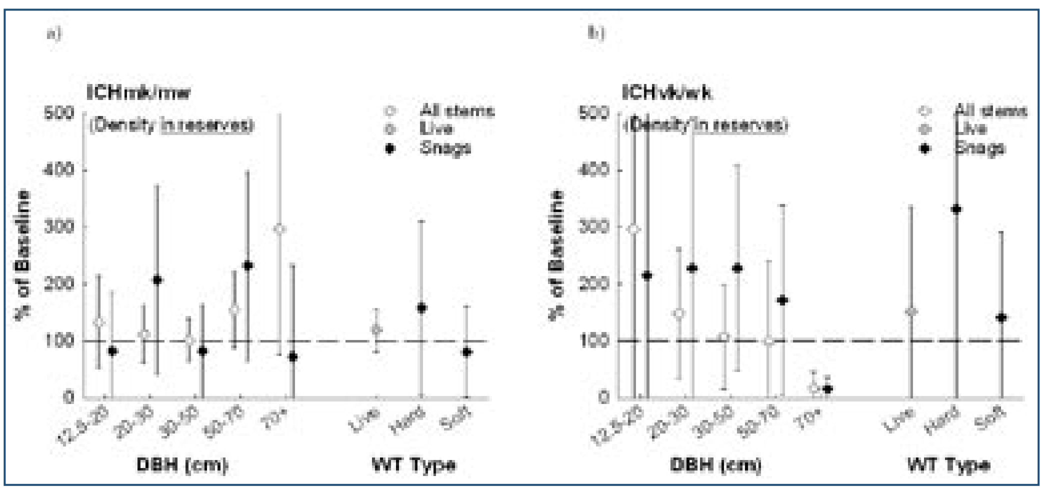

Figure 5. ***Density in WTP reserves of all stems and snags by size class only, and live trees, hard snags and soft snags expressed as a percentage of densities in baseline sites for (a) ICHmk/mw subzone grouping, and (b) ICHvk/wk subzone grouping. Error bars are (rough) 95% confidence intervals.***

In the ICHvk/wk grouping, densities of stems and snags in the first four size classes in WTP reserves are at or considerably above baseline levels (see Figure 5b). However, all stems and snags in the largest size class are much less common in WTP reserves than in the baseline sites. As with the CWHxm, this may reflect differences in the age classes of the WTPs and baseline sites, or it may be due to choosing WTP reserves that do not contain the largest trees and snags. If the latter is true, retention of more stems >70 cm diameter could be a focus for improvement in these subzones.

Results are not shown for the ICHmc subzone because they were highly variable, and some size classes of snags did not occur at all in the limited number of baseline datasets.

Species densities

The densities of different species in WTP reserves relative to baselines showed widely varying patterns across the eight subzone groupings. In a few groupings, the species distribution in WTP reserves was similar to that in baselines, while there were large differences in other groupings. Three examples are shown in Figure 6. In all cases, confidence intervals for the individual species are extremely wide. This reflects the variability in species composition between individual stands, and possibly selection for different types of WTP reserves. The wide confidence intervals are a reminder of how much sampling is required to obtain precise estimates for more specifically defined structures, especially when many ecosystems are being monitored. A further caution is that comparisons of species composition in WTP reserves versus baseline sites would be very sensitive to differences in the types of stands sampled in the MOF WTP monitoring and the baseline studies. Comparisons of stands matched by leading species would reduce this concern. Pre- versus post-harvest measurements would be optimal.

In the example for the CWHvh/vm/ws grouping (see Figure 6a), retention somewhat favoured cedar and spruce, and slightly avoided hembal for all stems. Cedar snags were very rare, and the other two conifer groups were at densities lower than baselines. The huge difference, however, was in deciduous stems and snags, which were retained at densities far higher than found in the baseline sites. Deciduous is often favoured for retention, for ecological and economic reasons, but this difference is so great that it must also reflect differences in the site types sampled in the WTP and baseline projects. In particular, riparian areas are prominent among WTP reserves, but are typically avoided in plots meant to establish forest baseline values. In any case, retention could be improved in these subzones by a greater emphasis on retaining more conifer snags, especially cedar. With its high resistance to decay, cedar is particularly important as a source of large snags that last well into the harvest rotation. However, hemlock and true fir snags can form more suitable, if shorter-persisting, structures for many cavity dwellers.

The ESSFdc/mv/mw example (see Figure 6b) shows only pine snags under-represented in the WTP reserves compared to baselines. This is probably only a minor weakness. The ICHmk/mw example (see Figure 6c) shows some emphasis on retaining hemlock, true firs and pines among all stems, and some under-representation of deciduous stems. This may again reflect differences in the site types sampled. Snag types showed greater differences, with few cedar, many hemlock, and no deciduous snags. Increasing deciduous retention may not be a large issue in these ecosystems where deciduous species are abundant in earlier seral stands. Improving retention of cedar snags would be a useful goal. (Again, this assumes that the baseline stands are similar ages to the surveyed WTP stands. Cedar snags are particularly associated with older stands in ICH, which may explain the much lower numbers in the WTPs compared to the ICH baselines.)

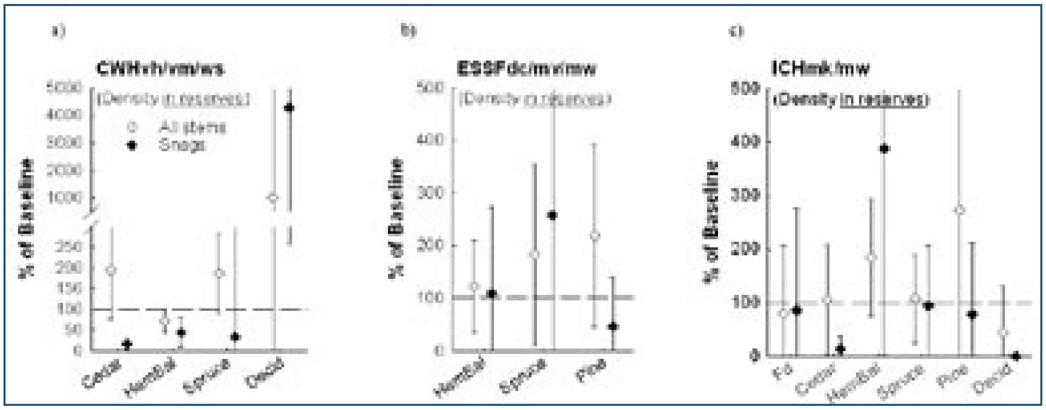

Figure 6. Densities of all stems and snags in WTP reserves, expressed as a percentage of baseline levels, for the main species in three subzone groupings. Error bars are (rough) 95% confidence intervals.

Patch versus dispersed retention

[In addition to the other caveats mentioned above regarding large sampling error and the assumption that baseline and WTP sites are of the same stand type, this comparison also has the limitation that dispersed retention was not the intended main form of retention in many of the blocks surveyed in the MOF WTP effectiveness monitoring project. A more balanced comparison of the different management options would be to compare the patch retention blocks to blocks that only had dispersed retention, matched by forest type.]

(Also note that in this comparison, densities for the patch retention sites are calculated across the whole cutblock, not just in the WTP reserves themselves. This is to allow an "apples-to-apples" comparison with dispersed retention, where retention densities are necessarily expressed across the entire cutblock.)

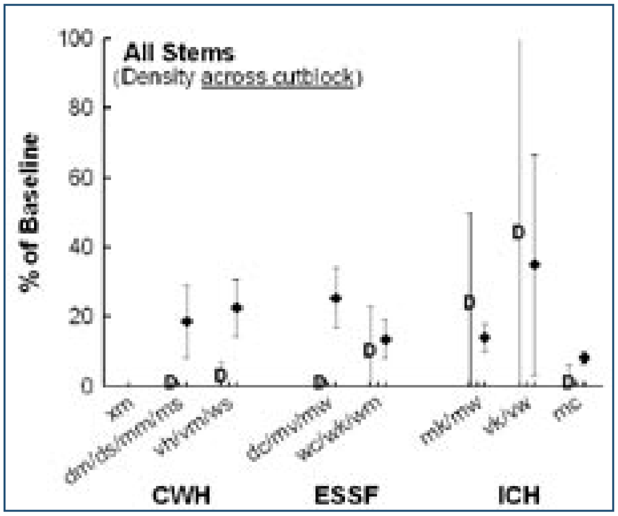

Figure 7. Densities of all stems in dispersed (D) versus patch (♦) retention, expressed as a percentage of the baseline densities. For these comparisons, densities in patch retention are expressed across the whole cutblock (not just in the WTP reserves) to allow equal comparison with the dispersed retention. Error bars are (rough) 95% confidence intervals. No dispersed retention was sampled in CWHxm.

The dispersed retention sampled in the CWH, drier ESSF, and ICHmc contained far lower densities of stems than the patch retention (see Figure 7). The dispersed retention sampled in these ecosystems contained a negligible density of trees compared to baselines. In contrast, in the wetter ESSF and the two main groupings in the ICH, dispersed retention had very similar densities to patch retention.

The same pattern was seen in snags, and snags >10 m tall, across the seven groupings with both retention types (see Figures 8a and b), except that dispersed retention in wetter ESSF had fewer snags than patch retention. The relatively high retention of snags in dispersed retention in ICH, including tall snags, is surprising given safety requirements to fall dangerous trees.

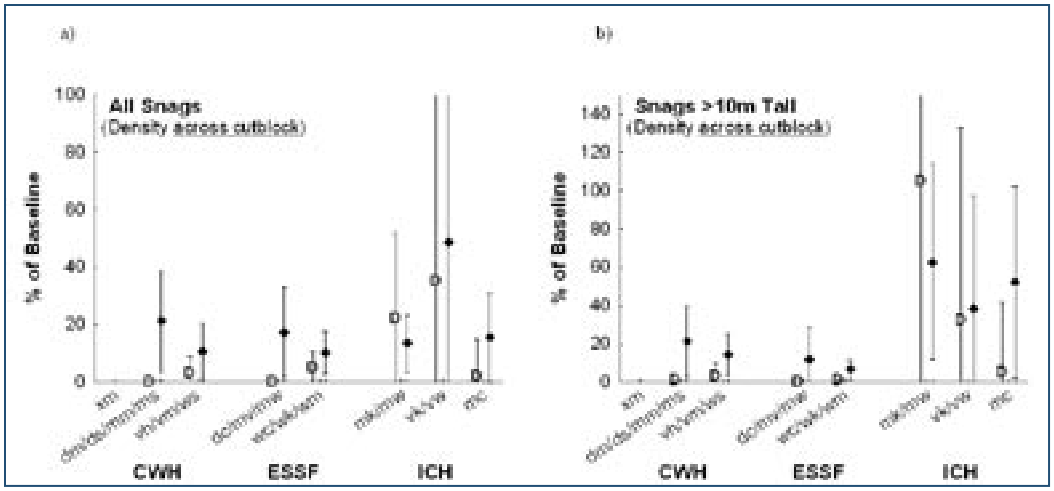

Figure 8. ***Densities of (a) all snags and (b) snags >10 m tall in dispersed (D) versus patch (♦) retention, expressed as a percentage of the baseline densities. For these comparisons, densities in patch retention are expressed across the whole cutblock (not just in the WTP reserves) to allow equal comparison with the dispersed retention. Error bars are (rough) 95% confidence intervals. No dispersed retention was sampled in CWHxm.***

Summary of weak points in retention

In this summary, "weak points" are variables for which the WTP reserves have the lowest values relative to the baselines. Again, there are other ways to define weak points that are not discussed here (e.g., comparing WTP values to regulatory targets or to known requirements of wildlife species or other values). For the few basic variables compared between WTPs and baselines in this project, the main weak points in current WTP retention for each subzone grouping are as follows:

CWHxm: Low densities of the largest trees (>70 cm dbh).

CWHdm/ds/mm/ms: Few trees or snags >70 cm dbh. [Note: if the harvested stands in these two drier CWH groupings contain few of these largest trees to begin with, then reasonable densities of stems in the 50–70 cm diameter class are being retained in WTPs. Pre-harvest values would be required to confirm this.]

CWHvh/vm/ws: Relatively low overall densities of snags, including conifer snags.

ESSFdc/mv/mw: Few moderately large trees.

ESSFwc/wk/wm: Low densities of tall snags (and generally low snag densities overall), as well as few moderately large and soft snags.

ICHmk/mw: Cedar snags and deciduous stems were the only elements examined that are relatively under-represented in WTP reserves; however, the main issue in this grouping is the lowest overall amount of area in WTP reserves.

ICHvk/wk: Stems >70 cm dbh are at very low densities in WTP reserves (assuming these types of stems are present in the stands being harvested in these ecosystems).

ICHmc: Low overall live tree densities (but the sparse available data suggests that this may be because particularly large trees are being retained).

With these weak points, the WTP densities expressed as a percentage of the baseline values are substantially less than 100%. This means that reported percent retention in WTPs overstates the percent retention of these particular elements. For example, in the CWHvh/vm/ws grouping, overall area retained in WTPs was 22.9% of the cutblock area. However, all snags had densities in the WTP reserves of only 47% of baseline levels. Therefore, overall retention of snags across the cutblock was only 10.8% (47% of 22.9%). In this case, the value is still above general policy targets (~7–10%), but this may not be the case for other elements in other ecosystems.

One “administrative” way of evaluating the results of WTP versus baseline comparisons would be to determine which particular elements do not meet these overall percent retention targets. Doing this would require careful consideration of the confidence intervals of the estimates, particularly for rarer elements, as well as thinking about what scale the targets are meant to apply to — across the whole ecosystem type, within landscape units, within individual cutblocks? — as well as designing monitoring and evaluation appropriately. In addition, guiding principles for wildlife tree retention that favour uncommon species and rare elements may lead to WTP reserves with lower levels of common elements (e.g., dominant species), or higher densities of small snags. An administrative evaluation would have to make allowances for some expected under-representation of common elements.

These weak points, and others that might be identified in a more thorough examination of the data, could be recommended as focus points for efforts to improve management in the different ecosystems. Subsequent monitoring could specifically examine these elements in more recent cutblocks to see if practices are improving where improvements are most needed. This might be one way of providing guidance for “extensive” monitoring, done as a quick check of effectiveness across many cutblocks. However, the results reported here have several caveats and limitations discussed in the next section. Focusing on these weak points should certainly not curtail more intensive monitoring of a wide range of habitat structures, even those that this preliminary comparison suggests are being well maintained in WTPs.

Limitations and Suggestions

The main assumption underlying these comparisons is that the baseline sites represent pre-harvest conditions in the blocks that were monitored in the MOF WTP effectiveness monitoring project. The wide variety of studies that produced the baseline values used in this project cast some doubt on this assumption. Potential differences include different geographical areas, different forest types within a BEC subzone, different age classes, and different disturbance histories. Age may be a particularly important issue in some subzones where considerable harvesting occurs in second growth, either naturally (e.g., Nelson region) or following historical logging (e.g., drier CWH). Some baseline studies specifically focused on old-growth stands (e.g., Deb MacKillop's work, the UBC/WLAP benchmark monitoring on Vancouver Island), or may have been biased towards older stands by choosing particular land designations for baseline sites (e.g., deer winter ranges for some of Weyerhaeuser's benchmark sites). Careful matching of WTP sites with local baseline sites in similar forest types and age classes would help reduce this concern.

However, perfect matching of harvested and baseline sites is likely not possible relying solely on existing baseline studies. Even with locally matched sites, stands chosen for harvest would be expected to differ from stands not chosen for harvest. The best way to get around this concern regarding the representativeness of baseline sites is to supplement baseline data with pre- and post-harvest monitoring of cutblocks. Pre-harvest measurements should sample the whole block, not just proposed WTPs, to assess whether the WTPs are capturing a representative sample of the pre-harvest block. Some pre-harvest monitoring was initiated in the MOF WTP effectiveness monitoring project. Another potentially large source of pre-harvest data for managed stands worthy of investigation is cruise plots. Limitations that would have to be overcome in order to use cruise information include the relatively low sampling effort per block, particularly for rarer snag types, and the use of timber-grading rather than ecological decay classifications for snags.

The WTP monitoring results only indicate snag values immediately after harvest. However, one of the main values of WTPs is as a source of future recruitment of snags and other habitat attributes. Some WTP reserves may have been established with the expectation that they would be good sources of future snags, even if they currently have few snags. A more thorough evaluation of WTPs would require projecting snag levels through the harvest rotation, and comparing these with baseline values or stands undergoing succession after natural disturbances. Along with information on retained snags, snag projections require information on retained live trees, and rates of tree mortality, snag decay and snag fall.

A number of issues arose during the analysis of the baseline data, which were not resolved for this project. These issues, and some suggestions for future work, include:

Encouraging a central deadwood database

- Collating and using existing baseline data to make comparisons is efficient, especially with habitat structures where there has been widespread monitoring. The collation and processing of existing baseline data done for this project (1175 baseline sites) cost approximately the same as doing comparable field surveys for five sites. Continued efforts to establish a more complete central database of existing habitat structure measurements in the province should certainly be a priority.

- Because different users have different questions requiring different types of summaries, a queriable database would be the best format for compiled data. Even within the current project to provide baseline comparisons, there are innumerable ways of summarizing the results that might be of interest for a particular user, including different ways of grouping ecosystems, size classes, species, wildlife tree classes, heights and all their interactions (e.g., "How well are we retaining class 5 or 6 Douglas-fir snags >50 cm dbh and <10 m tall as prime foraging habitat for pileated woodpeckers in dry CWH on Vancouver Island?"). In addition, various summary variables may be most appropriate for different purposes (e.g., density, basal area, volume, percent of stands above some threshold, etc.), along with different statistics of variability (e.g., standard deviations, standard errors, coefficient of variations, percentiles, etc.). No summary compilation, such as the Excel spreadsheets provided with this project, can cover all possible combinations of potentially useful summaries. Raw data is required to address these multiple purposes.
- Establishing a broad usable database based on the original plot data would require getting consent from the data collectors to make their data available in this manner. However, almost all the data used in this project were collected with public funding, and should be made available after publication by the data collectors.

Analysis issues

- One issue encountered, but not well resolved in this project, was how to do statistical summaries of existing datasets that used widely different sampling designs. A basic problem was what to consider as the sample unit, when some studies lightly sample many stands, and others intensively sample blocks within one general location. The weighting used in this project was clearly a crude way of dealing with this issue. However, there is unlikely to be a very rigorous statistical answer to this issue because the set of sites available in a collation of existing datasets certainly cannot be considered a formal random sample of the population of stands to which inferences are being made. It would also make little sense to treat each data source as one sample (with the individual sites within a project as subsamples) because there are widely varying sampling efforts among the existing projects, and a primary goal is to be able to assess variation among stands (not among projects).
- A related unresolved issue previously discussed is the problem that variation among stands is confounded with the sampling error within stands. This is a large issue when using existing datasets where the sampling effort per stand varied considerably (at least 20-fold, based on the number of stems recorded per site in different projects). It leads to exaggeration of between-stand standard deviations, and hence reduced estimates of how many standard deviations different WTP results are from the baseline means. This problem could be reduced by partitioning the subsampling and sample variance components for baseline studies that use multiple subsamples. However, this would have to be done for each of the varying sampling designs in the existing datasets and for each habitat element of interest, and would not be possible for those that did not

use or record subsamples within sites. This is one of several problems that make the range of natural variability paradigm difficult to use empirically.

- The wide confidence intervals on many of the comparisons demonstrate that much effort is needed to obtain precise estimates of most habitat structures. This problem is exacerbated for provincial-scale monitoring that has a mandate to cover many regions and ecosystem types. Assuming a huge monitoring program is not possible, one suggestion is to focus the WTP monitoring on a few fairly narrowly defined ecosystem types, perhaps one per region, or one typical of coastal forest, dry Interior, wet Interior, montane and subboreal types. Choosing particular forest types within these classes that have good existing baseline data, or coordinating with other habitat monitoring projects to provide these baseline data, would also be necessary for truly convincing comparisons. Maintaining long-term research sites at representative locations could also be part of this strategy. Otherwise, natural variability and sampling uncertainty will ensure that only very large differences in very broad types of habitat elements (e.g., "all snags") will be detectable with confidence.
- One partial solution to the conflict between wanting data from many ecosystem types and needing large enough samples to be able to conclude anything with any certainty is to use the data itself to determine the best way of combining the different ecosystem types or keeping them separate. This involves statistical approaches that compare the trade-off between increased precision from greater sample sizes when ecosystem types are lumped, versus decreased precision from combining ecosystem types with different mean values. Selection of models using information criteria (Burnham and Anderson 1999) is one way of finding the most efficient way of combining samples for summaries given the available data. This would probably be an improvement on the fairly arbitrary decision to use the eight subzone groupings in this project. The more rigorous statistical analysis, however, would be difficult because it would need to examine both the WTP and the baseline datasets. It would also likely produce different optimal ways of combining ecosystems for different habitat elements, which would make data summary and presentation more complex.
- Even with focused sampling effort, and matched baseline sites, rare habitat elements will always be a problem to measure with any precision in general habitat sampling, even using prism or nested plots. These rare elements are, unfortunately, the elements that are most often of ecological interest. Probably the only way around this issue is to identify a specific set of elements representing the range of particular structures of ecological interest, and to develop specific sampling methods to handle these efficiently. An example might be using low-level aerial photographs or broad transects rapidly covered on the ground to survey large cedar snags, or large well-decayed logs, etc. Ecological concerns about the adequacy of habitat retention in WTP reserves will always be unsatisfied if specific efforts are not made to sample at least some rare elements adequately.

References

BC Ministry of Forests. 2001. Mensuration data from the provincial ecology program. For. Sci. Prog., BC Ministry of Forests, Working Paper 62/2001. Victoria, BC.

Beasley, B., R. Scott, D. Edwards, C. Jacobsen, M. Moeges and K. McNutt. 2002. Monitoring and demonstrating the scientific panel recommendations for sustainable forest management in Clayoquot Sound. Unpublished report for the Long Beach Model Forest Society and Iisaak Forest Resources Ltd.

Bradford, P., W. Bergerud, N. Densmore, E. Hamilton, A. Prasad and R. Thompson. 2003. Evaluation of wildlife tree retention for cutblocks harvested between 1996–2001 under the Forest Practices Code. BC Ministry of Forests and BC Ministry of Water, Land and Air Protection, Victoria, BC.

Braumandl, T. and R. Holt. 2000. Refining definitions of old growth to aid in locating old-growth forest reserves. In Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). SIFERP, Kamloops, BC, pp. 41–44.

Burnham, K.P. and D.R. Anderson. 1998. Model Selection and Inference: A Practical Information-Theoretic Approach. Springer-Verlag, New York, NY. 353 pp.

Cline, S.P., A.B. Berg and H.M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. Journal of Wildlife Management 44:773–786.

Coates, D, A. Banner, J. D. Steventon, P. LePage and P. Bartemucci. 1997. The Date Creek silvicultural systems study in the Interior Cedar–Hemlock forests of northwestern British Columbia: overview and treatment summaries. BC Ministry of Forests Land Management Handbook 38, Victoria, BC.

DeLong, S.C., J.M Arocena and H.B. Massicotte. 2003. Structural characteristics of wet montane forests in east-central British Columbia. Forestry Chronicle 79:342–351.

Flanagan, P.T., P. Morgan and R.L. Everett. 2002. Snag recruitment in subalpine forests of the North Cascades, Washington State. USDA For. Serv. PSW-GTR-181.

Harris, R.B. 1999. Abundance and characteristics of snags in western Montana forests. Gen. Tech. Rep. RMRS-GTR-31. Ogden, UT, USDA For. Serv. 19p.

Harrison, M., C. DeLong and P. Burton. 2002. A comparison of ecological characteristics of stands in differing age classes in the ICHwk3, ESSFwk2, ICHmm and ESSFmm: Development of an index to assess old growth features. Prepared for Robson Valley EFMPP. (Website no longer accessible).

Hennon, P.E. and M.H. McClellan. 2003. Tree mortality and forest structure in the temperate rain forests of southeast Alaska. Canadian Journal of Forest Research 33:1621–1634.

Holt, R.F. and D.J. MacKillop. 2002a. Defining old-growth forests in the ESSFdk BEC subzone in the Nelson Forest Region. Unpublished report for Slocan Forest Products, Tembec Industries, Louisianna Pacific Engineered Wood Products, and Ministry of Forests Nelson Forest Region.

Holt, R.F. and D.J. MacKillop. 2002b. Defining old-growth forests in the ICHwk1 BEC variant in the Nelson Forest Region. Unpublished report for the Revelstoke Community Forest Corporation, Downie Street Sawmills and Pope and Talbot.

Huggard, D.J. 2000. Developing wildlife-habitat models for management of high-elevation forest. PhD Thesis, Univ. BC, Vancouver, BC.

______. 2002. Use of habitat features, edges and harvest treatments by spruce grouse in subalpine forest. Forest Ecology and Management 175:531–544.

ICBEMP (Interior Columbia Basin Ecosystem Management Project). 2000. Appendix 12: Requirements for snags and downed wood, in ICBEMP supplemental draft environmental impact statement.

Jull, M.J. and S.K. Stevenson (eds). 2001. The Lucille Mountain Study: 8-year results of a silvicultural systems trial in the Engelmann Spruce-Subalpine Fir Zone. BC Ministry of Forests Working Paper 59, Victoria, BC.

Rogers, B. 2003. Annotated bibliography of scientific and operational knowledge regarding the management of snags in northern British Columbia. Appendix 2 of "Strategic plan for identifying and maintaining snags in managed forests stands in the Prince George TSA," Univ. of Northern BC Mixedwood Ecology and Management Program (Canfor, Prince George).

Spies, T.A., J.F. Franklin and T.B. Thomas. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology 69:1689–1702.

Thomas, J.W., R.G. Anderson, C. Maser, and E.L. Bull. 1979. Snags. Pages 60–77 in Thomas, J.W., editor. Wildlife Habitats in Managed Forest in the Blue Mountains of Oregon and Washington. U.S.D.A. Forest Service Agriculture Handbook 553.

Waters, L. and H. Quesnel. 2000. Case study: Patch cutting in old-growth forests to maintain caribou habitat, 1997–99 research results. Extension Note 54, Nelson Forest Region, Ministry of Forests. (Formerly available from this region's website).

Wilhere, G.F. 2003. Simulations of snag dynamics in an industrial Douglas-fir forest. For. Ecol. and Manage. 174:521–539.

Appendix 1. Miscellaneous Snag Density Studies

Several published studies containing information on snag densities from mature or old unmanaged stands in CWH, ESSF, ICH or similar U.S. ecosystems are summarized below. Riparian studies and studies of habitat features preferred by some animal species are excluded. Several other studies measured snags, but did not present basic information on their densities (preferring instead statistical p-values, convoluted multivariate metrics, or other derived values). Others reported only biomass or volume.

Comparisons of published values with results of the MOF WTP effectiveness monitoring or the baseline studies were made using the most similar ecosystem types or interpolations when reported size classes differed from those in this study.

1. **Beasley et al. (2002)** reported various values for snags in CWHvh in the Clayoquot Sound area, including average diameters, heights, and species composition. Pre-harvest density values from replicates of four silvicultural system treatments were taken from figures in the report:

Snags >30 cm dbh (/ha)

	Mean	SD	n
Control	73.3	26.7	4
Dispersed	86.7	17.3	3
Adjacent retention	73.3	23.1	3
Patch Cut	80.0	34.6	3
Combined	77.9	23.4	13

Class 3 snags (/ha)

	Mean	SD	n
Control	3.1	5.4	4
Dispersed	2.3	2.7	3
Adjacent retention	5.8	5.3	3
Patch Cut	10.8	4.0	3
Combined	5.6	5.2	13

The values for snags >30 cm in this study are approximately double the 41.4/ha for the baseline sites, and four times the values of 20.0/ha found in the WTP reserves. This seems reasonable for the old west-coast rainforests in Clayoquot Sound. Class 3 snags were much more common in the baseline studies (~22/ha) but rarer in the WTP reserves (~2.3/ha). The differences may reflect observer variability in the fairly arbitrary distinction between class 3 and class 4 snags.

2. **Hennon and McClellan (2003)** in hemlock-dominated coastal rainforests in southeast Alaska (equivalent to wetter mainland CWH), found the following snag densities (/ha):

Species	25–45 cm	>45 cm
Hemlock	15.1 (SD 2.9)	29.1 (SD 9.9)
Cedar (+others)	11.3 (SD 3.5)	17.4 (SD 2.9)
All	26.3 (SD 0.8)	46.5 (SD 7.3)

Baseline values were consistently double the densities for the 25–45 cm class in this study, but less than half the densities for the >45 cm class. This is probably due to the large cedars in the coastal rainforests of Hennon and McClellan's sites. The WTP reserves had similar densities in the 25–45 cm class, except for a lack of cedar, but had even lower densities than the baseline values for the >45 cm snags.

3. **Cline et al. (1980)** reported densities of snags >9 cm of 18.3/ha in 200+ Douglas-fir stands in western Oregon (similar to CWHxm or mm): 81% were Douglas-fir, 12% other conifers, and 8% hardwoods. Baseline and WTP reserve values were far higher (82.4/ha and 74.1/ha, respectively), with a lower proportion of Douglas-fir and more deciduous in the WTP reserves.

4. **Spies et al. (1988)** provided snag densities in a variety of size classes for coastal Douglas-fir forests:

Location	Age		<50 cm	>50 cm	>5 m tall	>50 cm, >5 m tall	>50 cm, >15 m tall	All (>10 cm)
Washington	90–190	Mean	118	17	77	8	3.5	135
Cascades		SD	66	8	43	4	4	74
	250–900	Mean	37	36	34	18	8	73
		SD	24	15	15	10	4	29
Coast Range	80–120	Mean	115	17	80	7	1	132
		SD	135	18	90	9	2	129
	200–525	Mean	23	17	22	10	4	41
		SD	13	13	8	8	4	17

Baseline values were very similar for the large diameter and tall snags in this study, but lower (34/ha) for the <50 cm size (though Spies et al. may have used a lower minimum diameter). WTP reserves had moderately lower densities than Spies et al. for all snag types.

5. **Wilhere (2003)** reported regulatory requirements for retention on harvested blocks in Washington and Oregon west of the Cascade crest (~CWH):
   - Washington: 7.4/ha "Wildlife reserve trees" >30.5 cm and >3 m tall, and 4.9 live trees/ha >25.4 cm and 9.1 m tall.
   - Oregon: 4.9/ha snags or live trees >27.9 cm and >9.1 m tall.

   Assuming "wildlife reserve trees" include live trees, cutblocks using WTP reserves would easily meet the targets in this study (~65 "wildlife reserve trees"/ha across the cutblock, and the same density of the taller live trees). Even dispersed retention, which had very low retention in this ecosystem, would almost meet the targets, with 4.1/ha. If the "wildlife reserve trees" only include snags, then cutblocks using WTP reserves would not meet the targets (~2.7/ha).

6. **DeLong et al. (2003)** contains some information on snag densities in wet montane (ESSFwk2 and wc3):

Stand age	15–25 cm	>25 cm	n
<70 years	222 (SD 177)	253 (SD 129)	5
70–140 years	64 (SD 23)	158 (SD 150)	5
>140 years	52 (SD 23)	62 (SD 58)	5

Values for the baseline stands are very similar to DeLong et al.'s >140 year stands (48/ha for 15–25 cm snags and 75/ha for >25 cm snags). WTP reserves had somewhat lower values for the smaller snags (36/ha) and considerably lower for the larger snags (37/ha).

7. **Braumandl and Holt (2000)** discriminated between old growth, old-growth recruitment, and non-recruitment (not suitable to recruit old growth) stands in ICHdw and ICHmw2 using a variety of stand structures, including two sizes of snags. Old-growth stands had >18 snags >50 cm dbh per hectare, while recruitment stands had 11–18 large snags/ha. Old-growth stands also had <44 snags 10–25 cm per hectare, while recruitment stands had 44–78 of these snags/ha. Non-recruitment stands had <11 large snags/ha and >78 small snags/ha. By these measures, the mean ICHmk/mw baseline stand and the mean WTP reserve would both qualify as "non-recruitment," with 4.1 and 7.6 large snags/ha, respectively, and ~80 and ~79 small snags/ha, respectively.

8. **Harris (1999)** summarized a large number of inventory plots in western Montana, by habitat type groups. Snag densities (converted to /ha) were:

Habitat type group	BEC equivalent	n Stands	23–38 cm	38–53 cm	53–66 cm	>66 cm	Total
Warm, moist	ICH	102	32.7	9.5	2.2	0.8	45.3
Cool, moist	ESSF	284	34.8	6.0	1.7	0.6	43.2

Baseline sites in ICH had nearly identical snag densities for these different size classes, while ESSF baselines had similar densities for larger snags but more small snags. WTP reserves in both ecosystems tended to have more snags in all but the largest snag class.

9. The Interior Columbia Basin Ecosystem Management Project (**ICBEMP 2000**) reported current densities and "historic range of natural variability" for snags >50 cm by general habitat types and fire regimes. (It is not completely clear how these historical ranges were calculated). Densities (converted to /ha) are far higher than Harris' (1999) results from seemingly similar ecosystems.

Forest type	Fire intensity	BEC equivalent	Historic RoNV	Current
Cold	High	Dry ESSF	20.0	11.4
Cold	Low	Wet ESSF	9.4	10.4
Moist	High	Drier ICH	13.3	7.4
Moist	Low	Wet ICH	10.1	10.1

Baseline sites (averages from the collected baseline datasets) in the two ESSF types and drier ICH (4.2/ha, 4.7/ha and 4.1/ha, respectively) had much lower densities than either the current or "RoNV" values in the ICBEMP study. Harris' (1999) empirical results, from the same general area, were also much lower. WTP reserves were even lower in the ESSF, but similar to the current values in drier ICH. In contrast, large snag densities in the wetter ICH baselines were three times as high as the ICBEMP values, and WTP reserves were twice as high. These large discrepancies between empirical results (WTP and baseline) and calculated values (ICBEMP) could be seen as a warning against uncritically adopting "natural" or "historical" values from other areas as targets.

10. **Flanagan et al. (2002)** recorded 52 snags/ha in old stands in ESSF type forests in the North Cascades of Washington. Baseline sites had double this density (100.5/ha), while WTP reserves were similar (55.7/ha).

11. The **DecAid** program (available at http://wwwnotes.fs.fed.us:81/pnw/DecAID/DecAID.nsf) provides an interface for summarizing a large number of U.S. Forest Service inventory plots by "wildlife habitat types" and stand age (or quadratic mean diameter (QMD) of live trees as a surrogate for age in unmanaged stands). The DecAid database subsumed the datasets used in several other papers (by Ohmann, Mellen and others). These papers are not summarized here.

Values were obtained for three wildlife habitat types:

- Westside Lowland Conifer-Hardwood/Washington Coast (equivalent to CWH);
- Montane Mixed Conifer (equivalent to ESSF); and
- Eastside Mixed Conifer/North Cascades and Rockies (equivalent to ICH).

Summaries were only based on unmanaged forests, in two classes of tree size:

- Small/medium (QMD) live trees 25–50 cm; typical of almost all mature and old stands in ESSF, man mature stands in ICH, and some mature stands in CWH); and
- Large (QMD) live trees >50 cm; rare in ESSF, some mature and most old stands in ICH, many mature and most old stands in CWH.

The available summary information included:

- Histograms of the percent of stands in the area with different densities (15 classes) of snags ≥25.4 cm and ≥50 cm. The values from these histograms were used to calculate the means and standard deviations of densities for these two sizes of snags.
- For snags >25.4 cm, percentages were provided in the following diameter classes: 25.4–49.9 cm, 50–79.9 cm, and ≥80 cm.

Westside Lowland Conifer–Hardwood Forest Washington Coast (~CWH)

	Densities of snags						
	QMD of live: 25–50 cm				QMD of live: >50 cm		
	25.4–50 cm	>50 cm			>25.4 cm		
Mean	30.9	17.4		Mean	41.8		
SD	27.0	18.3		SD	28.0		
	25.4–50 cm	50–80 cm	>80 cm		25.4–50 cm	50–80 cm	>80 cm
% snags	64	33	3	% snags	44	45	11

Baseline densities were lower than DecAid values (~20/ha) for the 25.4–50 cm class, and also for the >50 cm class. WTP reserves were lower than DecAid values for both sizes (~20/ha and 12.2/ha, respectively).

Montane Mixed Conifer (~ESSF)

	Densities of snags						
	QMD of live: 25–50 cm				QMD of live: >50 cm		
	25.4–50 cm	>50 cm			25.4–50 cm	>50 cm	
Mean	38.4	11.6		Mean	15.6	21.5	
SD	30.8	12.9		SD	10.5	14.2	
	25.4–50 cm	50–80 cm	>80 cm		25.4–50 cm	50–80 cm	>80 cm
% snags	78	19	3	% snags	46	36	19

Baseline sites and WTP reserves had double the density of the DecAid values for the 25.4–50 cm class (~66/ha and 65/ha, respectively), but far lower densities for the >50 cm snags (~2.8/ha and 4.2/ha, respectively).

Eastside Mixed Conifer (~ICH)

	Densities of snags						
	QMD of live: 25–50 cm				QMD of live: >50 cm		
	25.4–50 cm	>50 cm			25.4–50 cm	>50 cm	
Mean	19.0	3.0		Mean	11.3	4.3	
SD	26.1	5.4		SD	24.3	9.5	
	25.4–50 cm	50–80 cm	>80 cm		25.4–50 cm	50–80 cm	>80 cm
% snags	86	13	1	% snags	71	23	6

Baseline sites had higher densities than the DecAid values for both size classes (~42/ha and 7.6/ha, respectively), as did WTP reserves (~31/ha and 4.1/ha, respectively).

Appendix 2. Boxplot Comparisons of Baseline Data and WTP Reserves

The data from individual stands in each of the eight baseline BEC groups are plotted as boxplots, and compared with boxplots of the WTP sites. These plots should be useful for comparing the retention in WTP reserves to the range of variability in baseline stands. Note, however, that the range of variability shown in the boxplots includes both the variability among stands and the extra variability from sampling uncertainty within the stands. A few statements about the main comparison results are made after each figure.

The boxplots show the median (thin line), mean (thicker line), 25 and 75 percentiles (bottom and top of box), 10 and 90 percentiles (error bars), and more extreme individual stands.

Some points to note in interpreting these plots are:

- The WTP results are the densities in the patches only, not averaged across the whole cutblock.
- Unlike the results in the main body of the report, data points could not be weighted differently for the various studies. In particular, studies with relatively little sampling effort per stand count equally with studies with more effort per stand. Many of the more extreme values in the boxplots come from those studies with little sampling effort per stand, as they add more sampling uncertainty to the actual variation between stands.
- Because of the lack of weighting, a comparison of the baseline means and the WTP means may give somewhat different values than the weighted comparisons presented in the main body of the report.
- Some studies only reported some of the variables presented below, so the sample sizes in a given BEC group can differ between variables. For example, most of the results for the drier ESSF types did not include measurements of stems <20 cm. The boxplot for stems <20 cm is therefore based on far fewer points than for the stem classes >20 cm.
- The VRI stands were averaged into one point per variant because that study had far lower sampling effort per stand than the other baseline studies. As a result of the low sampling effort per stand, the VRI data contained many zero values, which would have badly skewed the boxplots if individual stands had been used.
- The PEP data could not be included here because values for individual stands were not available.
- Boxplots are missing for some variables for ICHmc because there were few baseline studies in this subzone, and they did not measure all variables.

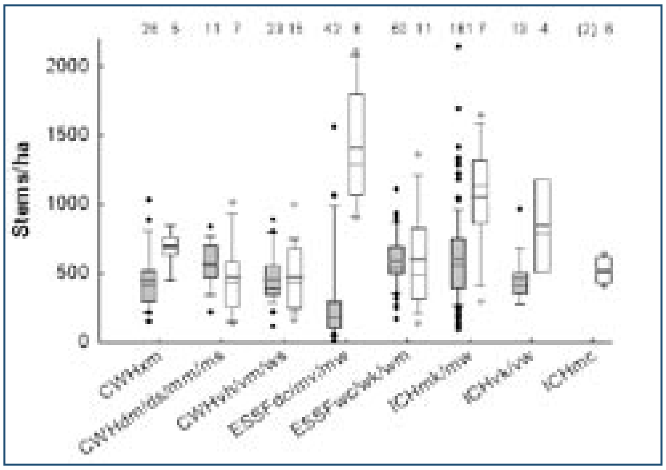

Figure A2-1. ***All stems (live and dead) per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- WTP reserves are generally within the upper half of the baseline range.
- Baseline values for drier ESSF may be anomalous because many of the results for all stems were extrapolated from studies that did not measure live stems <20 cm, and variation between younger pine-dominated ESSF stands and older stands were dominated by spruce.
- There were too few live-stem values for ICHmc to create boxplots.

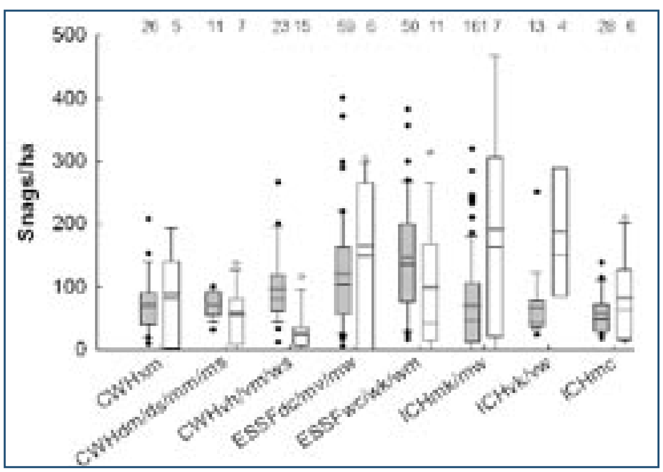

Figure A2-2. ***All snags per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- Snags in WTPs were generally within the baseline range for CWH and ESSF; higher snag retention in WTPs in ICH.
- There may be a greater range of values in the WTPs than in the baselines, but different sampling intensities make interpretation difficult.

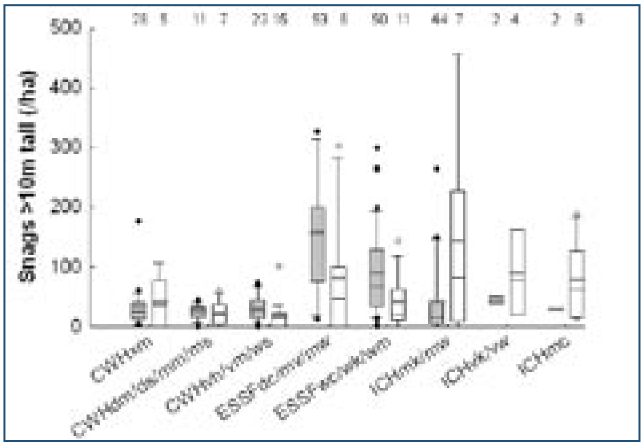

***Figure A2-3.** Tall snags (>10 m tall) per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).*

- As with all snags, snags >10 m tall in WTPs are within the baseline range for CWH, somewhat lower in ESSF, but considerably higher in ICH.
- Again, WTP variability is high, particularly in the ICH and drier ESSF.

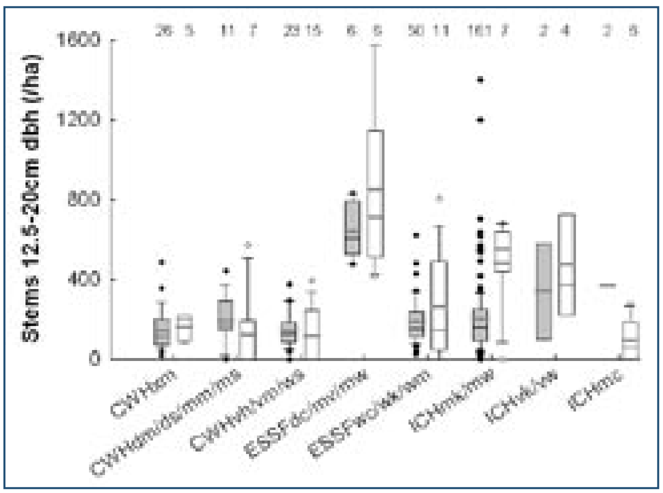

***Figure A2-4.** All stems (live and dead) 12.5 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).*

- Small diameter stems in WTP reserves show a similar range of densities to baseline stands.

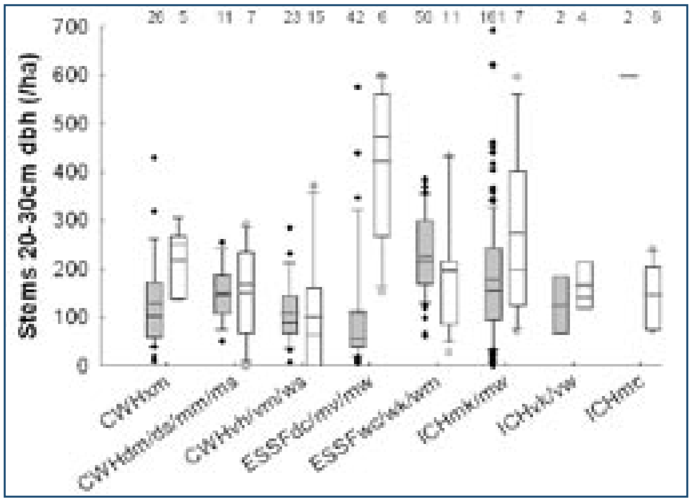

Figure A2-5. ***All stems (live and dead) 20–30 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- WTP reserves retain medium-size stems at levels that are typically in the upper half of the baseline levels.
- The dry ESSF results suggest that the WTP reserves were mainly in mature pine-type sites (with high densities of mid-sized stems), whereas the baseline studies included older spruce sites as well.

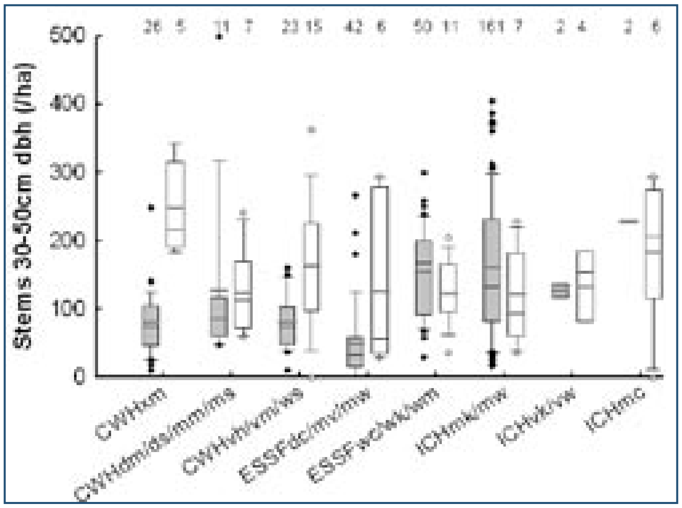

Figure A2-6. ***All stems (live and dead) 30–50 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- WTP reserves appeared to favour this size of stem compared to baselines in CWH and dry ESSF, and have similar densities to baselines in wet ESSF and ICH.

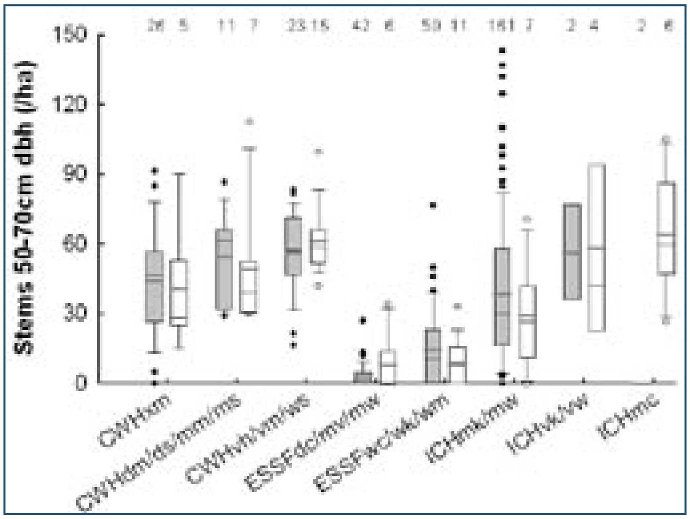

Figure A2-7. ***All stems (live and dead) 50–70 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- These moderately large stems were retained in WTP reserves at a very similar range of densities to the baseline sites in all BEC groups.

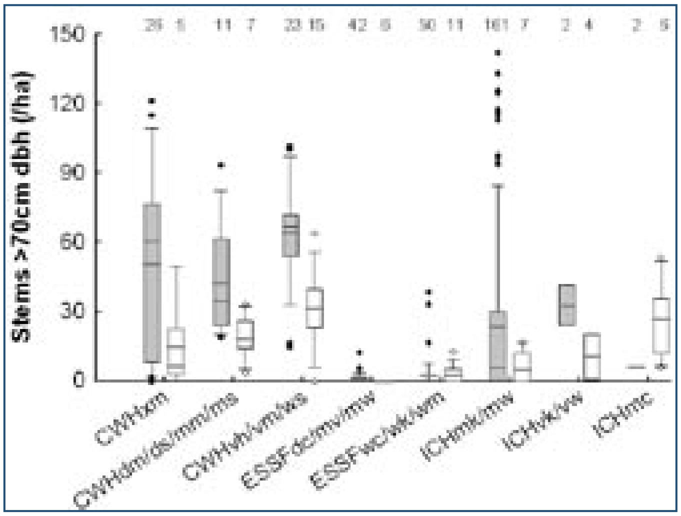

Figure A2-8. ***All stems (live and dead) >70 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- Retention of the very largest stems in WTP reserves was generally at or below the low end of the range of baseline stands.
- The exception was the ESSF, where such large stems are generally rare in all cases.

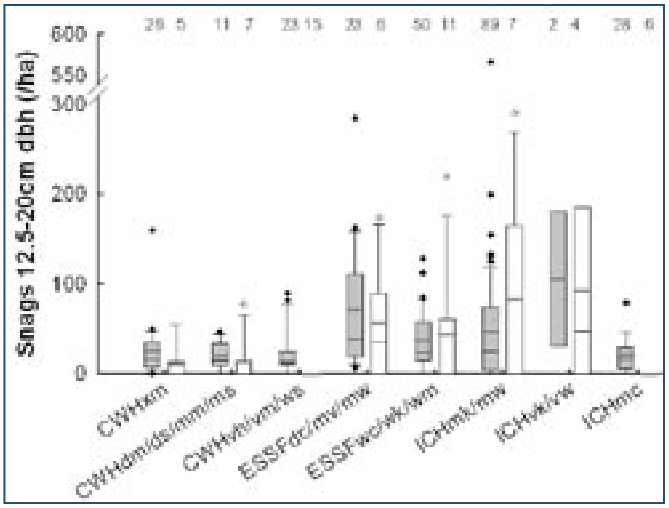

Figure A2-9. ***All snags 12.5–20 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- Retention of small snags in WTP reserves generally matches baseline levels.
- Exceptions occurred in wet CWH and ICHmc where retention levels were lower, but this may simply reflect the chance of sampling. (It is difficult to imagine how WTP location could be intentionally biased away from small, and typically safe, snags).

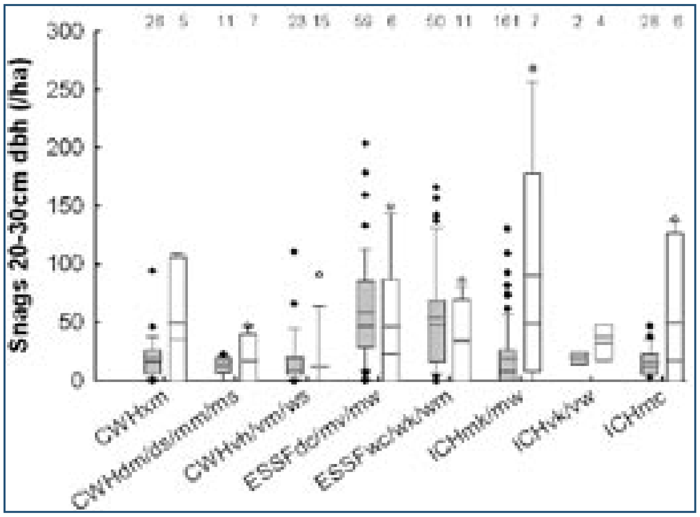

Figure A2-10. ***All snags 20–30 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- Moderately sized snags were retained in WTP reserves at densities typically in the upper range of the baseline stands.
- Variation between WTP reserves was high for this variable, probably due to sampling uncertainty for this fairly specific variable.

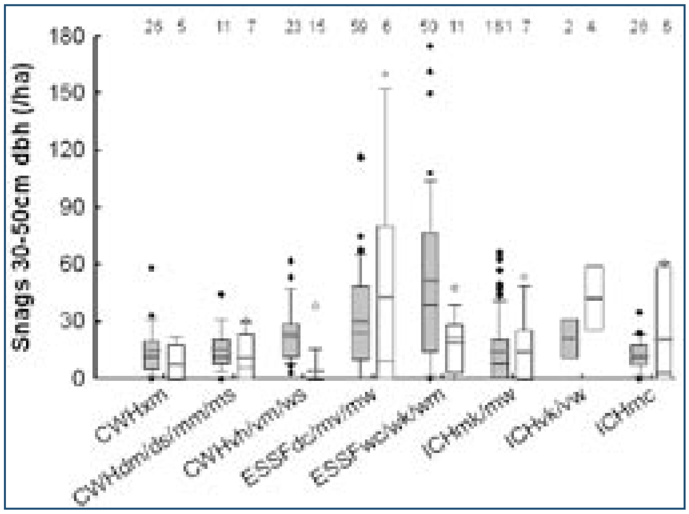

Figure A2-11. ***All snags 30–50 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- Retention of this size of snag was within the main range of the baseline sites for most BEC groups, and somewhat higher than the baseline range in the wetter ICH.

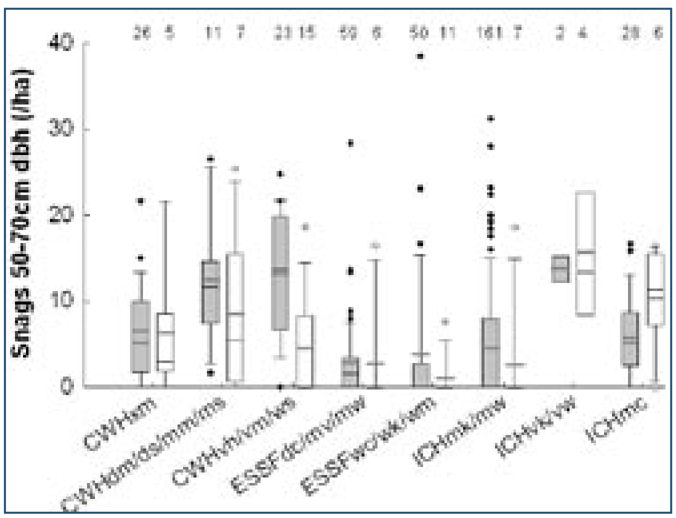

Figure A2-12. ***All snags 50–70 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- Moderately large snags were generally retained in WTP reserves at densities within the range, or in the upper part of the range, of baseline sites.
- An exception was the wetter CWH, where densities were in the lower end of the baseline range.
- In the ESSF and drier ICH, most WTP reserves had no moderately large snags (with limited sampling), which produced the strange-shaped boxplots.

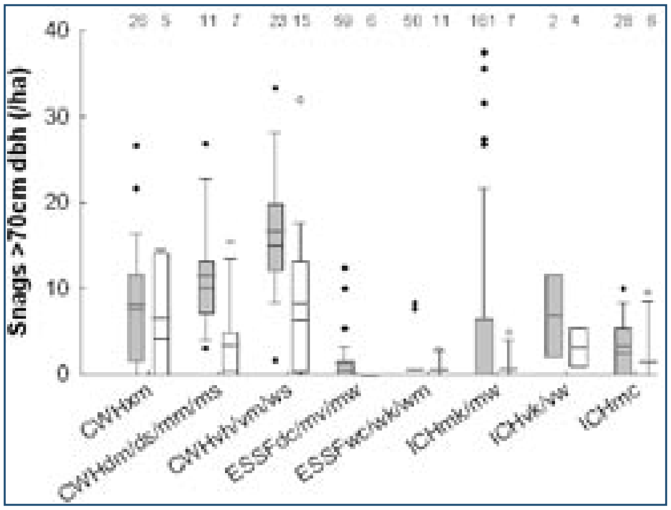

***Figure A2-13.** Snags >70 cm dbh per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).*

- The largest snags were typically retained in WTP reserves near the lower end of the baseline range, except in the CWHxm (and the ESSF types, where these large snags are very rare).
- Except in the CWH baselines, variability of these rare structures is very high, and includes many zero values in both baselines and WTP reserves.

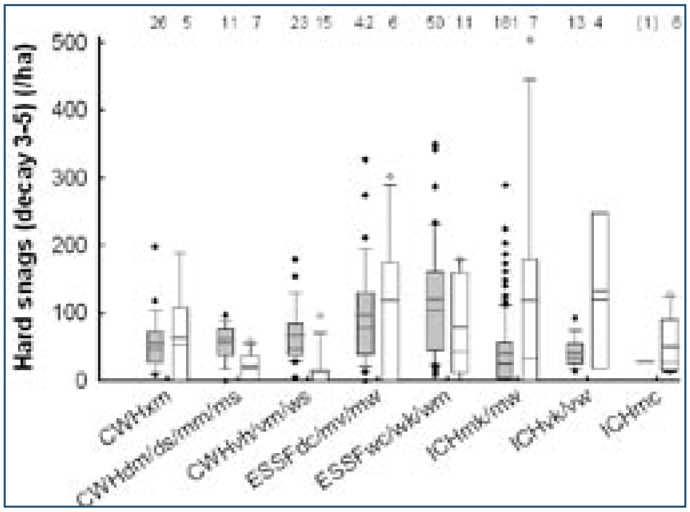

***Figure A2-14.** Hard snags (wildlife tree classes 3–5) per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).*

- Hard snags in WTP reserves in CWH (except CWHxm) were retained at lower levels than the baseline range.
- In contrast, WTP reserves in ICH tended to have more hard snags, but also high variability.
- Retention levels in WTP reserves in ESSF were more typical of the wide range of baseline sites.

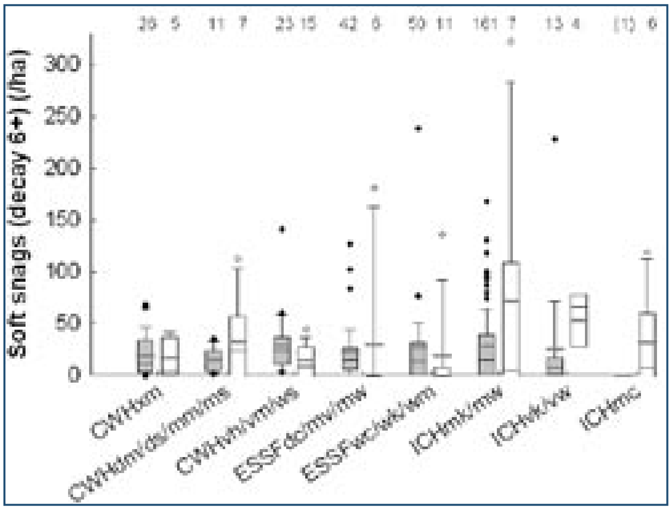

Figure A2-15. ***Soft snags (wildlife tree classes 6–8) per hectare for individual baseline stands (grey boxplots) and WTP reserves (open boxplots).***

- Soft snags (which are often short and hence safe) were typically retained in WTP reserves in the upper part of the baseline range for all BEC groups.