



Kamloops Forest Region Stand Structure Modelling Project Report

Walt Klenner, 9 May, 2001

Summary

We reviewed Prognosis BC and TASS with respect to their potential use in modelling the stand structure attributes that are important in evaluating habitat suitability for wildlife and biodiversity. Both models have received considerable testing and calibration in BC, and represent mature models from the perspective of growth and yield estimation. Using these models to estimate the likely changes in key stand structure attributes important to wildlife across a range of management systems is not unreasonable, but will require considerable work. Four main shortcomings were noted in the 2000-01 pilot project that will need to be considered in the future:

1. Unbiased information on stand structure at the 2+ ha scale is virtually non-existent for almost all forest types in BC. Without suitable initiation and model verification data, the entire basis for undertaking stand structure modelling is suspect and needs to be addressed before further work is done.
2. Stand parameters important to growth and yield modelling are reported, but do not correlate well with the stand structure attributes necessary to evaluate habitat condition (e.g. snags, downed wood abundance and dispersion, size and permanence of gaps, etc.). Database queries or interfaces will need to be developed to extract direct or indirect information for the Prognosis BC and TASS databases, and to present these in a suitable manner.
3. TASS and Prognosis BC differ in their basic design but should be viewed as complementary. TASS allows spatial characteristics of stand structure (e.g. the dispersion of snags, patch size of gaps, etc.) to be calculated, while Prognosis BC is non-spatial at the individual tree level. Where spatial data are important, TASS or a similar spatially explicit model will likely need to be used. Constraints of the use of TASS may arise if stand structure modelling becomes more extensive and TASS is not more widely available to users. The less demanding data requirements of Prognosis BC are an asset where spatial indicators are not required.

4. Neither TASS or Prognosis BC are successional models that incorporate natural regeneration or ongoing insect or disease mortality into model runs. Non-stand replacing natural disturbances need to be considered if unbiased estimates of likely stand structure conditions are to be developed. Although disturbances and natural regeneration events are not currently automated run procedures in either model, they can be applied manually as “thinnings” or “plantings”. This is especially critical if long-term projections (e.g. > 50 years) are to be undertaken. Parameter estimates will need to be developed for the key natural disturbance events and the frequency of natural regeneration events.

Introduction

The stand structure modelling project was initiated in September 2000 and represents an initial attempt to review some of the issues that relate to habitat supply modelling at the stand structure level. The project was initiated by W. Klenner and I. Cameron, and a meeting was held in November to discuss project direction with an advisory committee consisting of C. Bealle-Statland, M. Eng, E. Hamilton, J. Stone and Barry Snowden. Due to other commitments, three other people who were requested to participate in the project (A. Arsenault, K. Lertzman, L. MacLauchlan) could not attend.

Stand structure modelling can help anticipate the long-term consequences of different management systems on stand structures important to the maintenance of species or habitat diversity. Many of the key determinants of forest stand development (e.g. competition for light, moisture, nutrients, etc.) are synthesized in stand development models, and can be used to help predict the long-term outcome of treatments where empirical data on stand condition are not available. Several client groups or activities were identified that would benefit from stand structure modelling at the stand prescription or landscape unit planning stage. These include:

- Wildlife species models and habitat suitability models that respond to stand structure and which would complement TEM.
- The Landscape Unit planning process and the development of seral stage targets based on stand structure composition. Also, modifications to the mature and OG seral targets may need to evaluate the contrast in stand structure conditions between managed and natural stands.
- Landscape level (LU or larger) models that intend to advance beyond simple time since disturbance relationships.
- Silvicultural DSS tools to help operational staff visualize the short and long-term implications of silvicultural prescriptions on stand structure.
- Non-habitat models such as visual and water supply that respond to residual and projected stand structure.

- Timber supply review “information packages”.
- Guidance on procedures that represent “best management practices”.

An extensive, complex and often variable list of stand attributes are used by the diverse flora and fauna found in forest ecosystems. Some species or taxa are often very host specific (e.g. insects that feed on one plant species), while others are habitat generalists that are found across a wide array of habitat types and stand structure conditions. Current stand development models do not adequately address the complex and often uncertain development of grass, forb or shrub vegetation development following disturbance, hence we focussed primarily on tree-based stand attributes. The following list of stand structure indicators was developed to reflect key attributes that could be used to describe a forest, in the context of a limited ability to model all aspects of an ecosystem. These indicators would either provide a direct estimate of the level of some habitat attribute (e.g. snags or CWD), or be used to derive an estimate of the suitability/capability of the stand for correlated attributes such as the relative abundance or vigor of shrubs, grass forbs or arboreal lichens. For example, the ground disturbance history, tree density, the size and dispersion of gaps, and the time since last disturbance could be used to estimate the likely vigour or abundance of the understory plant community. The following stand attributes represent a preliminary list of indicators that are should be reported directly, or which could be derived from the variables currently reported.

- a) Tree species composition.
- b) Tree size distribution (measured and/or modelled as a continuous variable but presented in the following size class categories: < 7.5, 7.5-15, 15-20, 20-30, 30-50, 50-100, > 100 [cm d.b.h.]).
- c) Gross and net merchantable stem volume (m^3/ha) by species and size (dbh) category, and other timber volume indicators as necessary.
- d) Tree vigor or condition (e.g. classes 1-9; live, declining, recently dead, etc.) by species and size category.
- e) CWD by species, size category and decay class (e.g. measured and/or modelled as a continuous age of decay variable but presented as classes 1-5, or hard, soft, and debris). A measure of CWD dispersion would also be useful to differentiate between high volumes in few piles vs. high volumes scattered across the stand.
- f) Stand density, represented as both average density and spatial measures such as contagion, dispersion and gap size frequency. It may be best to report gap size information as the proportion of the stand area that receives 0-20% shading, 21-40%, 40-60%, etc.
- g) Canopy characteristics (e.g. depth, live crown, live crown to total height ratio, layers, crown closure).

Several additional stand characteristics need to be tracked, including the time since the last stand replacing disturbance, the nature and timing of the last 3 canopy modifying disturbances, and the nature and severity of the last 3 forest floor disturbances.

The scope of the habitat structure modelling project in 2000-01 was to address the following four issues:

1. Develop four habitat management issues to provide an application context for the evaluation of candidate stand structure models. The habitat issues will also be used to screen silvicultural prescriptions, to model the short and long-term implications of alternative prescriptions on stand structure, and to identify the likelihood that the silvicultural systems being examined can maintain or develop the necessary habitat structures.
2. Prepare a qualitative assessment of the most suitable model or models with respect to their ability to realistically project the stand structure consequences of several alternative silvicultural systems in relation to the four “case study” habitat management issues developed for the Kamloops Forest Region. Included in the model suitability analysis will be a recommended procedure for applying one or more of the “most suitable” models to situations that are beyond their application experience, or the model(s) are being applied in habitats where calibration or verification efforts have been less than comprehensive. A qualitative assessment will be made on the lack in precision and/or potential bias in the stand structure projections that may arise when applying the recommended models to the identified case studies. Where possible, the level of risk in providing erroneous or very misleading results (especially high bias) will be assessed based on the resolution of the information required, model architecture and the level of calibration of the model to the ecosystem being examined.
3. Compile a catalogue of habitat structure data that has been collected with emphasis on data from the IDFxh and ESSFwc biogeoclimatic zones in the Kamloops Forest Region. The data will be used to provide initial habitat condition information for models such as Prognosis or TASS, and verification data for the stand structure projections for cases where silvicultural systems comparable to those being modelled have been applied and measured. A comprehensive list of researchers and agencies will be contacted and the location and availability of the data recorded. A brief “metadata” description will be developed for data collection project describing the objectives of the project, methods used, the type of data collected and habitat structures measured, where the dataset is being maintained and if it is available for use in initiating model runs or for verifying model outputs. Where habitat data are directly applicable to the stand structure – habitat management issues identified for this project, a copy of the data will be requested and disclaimer provided to ensure the researcher that the data will only be used for model initiation or verification. This work will build on previous initiatives (e.g. Andy MacKinnon’s information on CWD) to compile a “directory” of habitat structure data,

and will attempt to locate information relating to the stand structure attributes listed in the stand structure modelling proposal. Although the focus will be on the IDFxh and ESSFwc subzones in the Kamloops Forest Region, the location of other habitat structure data will be recorded to increase the utility of this project to other modelling or verification initiatives.

4. Develop first approximation stand structure attribute estimates using the model(s) identified in #2, the initiation data collected in #3 and 3-5 silvicultural system options. The options will reflect (a) the dominant current practice(s), (b) a more intensive, incremental silvicultural approach, and (c) a system developed to address the particular habitat issue. An attempt will be made to address all four habitat management issues but due to time constraints and likely unforeseen problems, issue #3 (cavity nesting birds in the IDF) will be addressed first, followed by #1 (caribou), #4 (open IDF forest conditions) and #2 (mule deer winter range). Graphs, figures and tables will be developed for each habitat issues being addressed to illustrate patterns in the estimated abundance of stand structure attributes in relation to the silvicultural systems being tested. Some post-processing of model output data is anticipated to summarize the stem map data generated by spatially explicit tree models. For example, to convert stem maps or cylindrical shading projections of stem maps to gaps size of % are shading results, a GIS routine will likely need to be developed.

Results

Activity 1, Habitat Management Issues. Following discussions with MoF, MoELP and forest industry staff in several of the districts in the Kamloops Forest Region, four sample habitat management issues were developed. These were chosen because the desired structural features of the stand are not necessarily determined by stand age, and can be strongly influenced by the stand treatment chosen. Hence, they represent issues where conventional or innovative silvicultural systems may be applied to manage for an acceptable habitat condition in the context of ongoing timber extraction.

Habitat Issue #1: Managing for timber extraction and mountain caribou habitat in the Clearwater Forest District.

Across some of their range in the Kamloops Forest Region, mountain caribou require areas within the ESSFwc2 biogeoclimatic zone for critical early winter habitat (October to January). In areas of the Clearwater Forest District that are characterized by relatively gentle terrain, soft, deep snow often prevents caribou from using higher elevation habitats (e.g. ESSFv or Alpine Tundra) in early winter. However, once the snow becomes compacted in January, caribou generally move to higher elevations outside the timber harvesting landbase. Caribou traditionally use mature and old-growth forests in the ESSFwc2 for early winter range. There is increasing pressure to harvest much of the remaining old forest using either clear-cut or partial-cut harvesting

systems, thereby converting the stands to either early seral habitat with little residual stand structure, or uneven aged stands with varying stand structure depending on the harvesting system applied.

Caribou prefer to feed on lichens of the genus *Bryoria* (dark brown or black arboreal hair lichens) over species in the genus *Alectoria* (light green hair lichen) in the North Thompson area. There is some evidence to suggest that certain types of harvesting may lead to an increase in either the abundance or availability of *Bryoria*. On many of the larger trees in mature and old-growth stands, the lower portion of the stem (e.g. lower 10m) supports a greater biomass of *Alectoria* lichens, while the more exposed upper portion (above 10m) supports more *Bryoria*. Observations of lichen abundance in the more open ESSFv forests or in the sparsely-treed alpine tundra suggest that the abundance of *Bryoria* lichens on each stem, and the ratio of *Bryoria* to *Alectoria* lichens is higher in these open stands. Open stands promote better ventilation, and the associated microclimate changes appear to favor the growth of *Bryoria* lichens lower in the canopy where they are accessible to caribou. In these stands, caribou are able to feed directly on *Bryoria* lichens instead of relying on lichens from windthrown trees or lichen fragments that have fallen from branches higher in the canopy. Hence, it appears plausible that partial cut harvesting systems in these stands may enhance forage availability for caribou if certain habitat features are maintained, allowing for a balance between timber extraction and the maintenance of viable caribou populations.

To manage these mature ESSFwc2 forests for lichen production and mountain caribou, current evidence suggests that it is important to maintain the following habitat features within stands on an ongoing basis:

1. Old trees. Relatively old trees that are greater than 150 years old. Lichen biomass increases slowly and tree age is one of the best indicators of lichen abundance.
2. Snags. The presence of snags that form a stable substrate for lichens. Large (e.g. > cm d.b.h.) and old snags (standing for more than 20 years after tree mortality) are an ideal substrate for lichens since stem growth, bark and foliar sloughing no longer occur that would shed growing lichens. Snags are therefore an important habitat feature if a high lichen biomass and availability is to be supported. In addition to the *Bryoria* and *Alectoria* lichens, many other genera of lichens are dependant on snags for substrate.
3. Overall stand density. High density stands (e.g. > 5000 stems/ha) appear to be used less often for foraging by caribou than lower density stands (e.g. < 1500 stems/ha).
4. Deep crowns. Trees provide an attachment substrate for lichens. Deep crowns provide more attachment sites, but dead branches appear to support the highest

lichen biomass. Therefore, a deep crown with numerous dead branches on the lower 1/3 of the tree represents an ideal condition for lichen growth and caribou foraging.

5. A mosaic of small gaps and openings ranging from single tree gaps, gaps that represent groups of trees of approximately 0.01 ha, and larger openings up to 1.0 ha. The small openings mimic the gaps and patchy nature of higher elevation stands, provide for better ventilation and drying in the stand, and allow more light to penetrate the stand. Some or all of the microclimate changes associated with these gaps may contribute to the increased proportion or abundance of *Bryoria* lichens on individual stems. The information on gap size and distribution will also be used to provide input to the development of a berry (e.g. *Vaccinium* sp.) abundance model.
6. Gross and net merchantable stem volume by species and d.b.h. Timber production is an important issue in these stands and needs to be considered in choosing a silvicultural system.

To evaluate the suitability of several silvicultural options for maintaining caribou habitat and to balance this initiative with timber extraction, the long-term abundance of the above six habitat attributes needs to be demonstrated. The relationship between stand structure, or stand structure and snow density and hardness will be explored further in other projects that deal with the ecological relationships of lichens and stand conditions. Other features such as active roads, patch size and the interspersed stands are important to caribou but can be dealt with by landscape models.

Habitat Issue #2: Managing for mule deer winter range in Douglas-fir forests.

Maintaining mule deer winter range is one of the wildlife issues identified in higher level (LRMP) plans in the Kamloops Forest Region. In the Merritt, Vernon and Penticton Forest Districts, there is considerable mule deer winter range in the IDFdk1 and dk2 biogeoclimatic zones. In most years, mule deer move down from ESSF and MS habitats to the IDFdk and IDFxh zones to escape the deep snow that would hinder their movement, preventing them from accessing forage and exposing them to predators. Mule deer prefer areas with large trees in the overstory with deep, interlocking canopies that will intercept snow. In deep snow conditions when grass, forbs and shrubs are not available, mule deer browse on Douglas-fir branches. Litterfall in the form of broken branches from large and relatively old (greater than 120 years) trees provide the most nutritious forage, and also a substrate for lichens which are fed on when other foods are not available.

Interior Douglas-fir forests in the IDFdk subzone are critical to maintaining mule deer populations. Current evidence suggests that it is important to maintain the following habitat features within stands on an ongoing basis:

1. Deep interlocking crowns. Deep and preferably interlocking crowns that will intercept much of the snow and decrease ground snow depth are an important feature of mule deer winter range. The stand should be maintained with a crown closure of 65% or greater from trees greater than 25m in height.
2. Canopy gaps. Small canopy gaps from 0.01 to 1.0 ha, with most (>80%) less than 0.1 ha, provide for a fine scale interspersion of cover and forage, reducing the energetic costs of moving between the two habitat types.
3. Large old trees. Large old trees greater than 25m in height and over 140 years of age provide better forage, form a substrate for lichens and contribute more to litterfall than small trees.
4. Species composition. Douglas-fir is the preferred tree species on mule deer winter range, and Douglas fir should represent greater than 80% of the mature trees in the stand.
5. Gross and net merchantable stem volume by species and d.b.h. Timber production is an important issue in these stands and needs to be considered in choosing a silvicultural system.

To evaluate the suitability of several silvicultural options for maintaining cavity-nesting bird habitat and to balance this initiative with timber extraction, the long-term abundance of the above three habitat attributes needs to be demonstrated.

Habitat Issue #3: Managing for cavity-nesting birds in low elevation Douglas-fir forests.

Cavity-nesting birds are one of the obvious beneficiaries of declining trees and snags in a forest. Low elevation forests in the Kamloops Forest District (IDFxh2) support a diverse assemblage of primary (excavate cavities) and secondary (use existing cavities) cavity nesters. Species such as red-breasted nuthatches or mountain chickadees use relatively small (i.e. < 15 cm d.b.h.) snags or partially decayed trees to excavate their nest in, while pileated woodpeckers require much larger (e.g. > 35 cm d.b.h.) stems. Red-breasted nuthatches appear to use broadleaves and conifers almost equally, but most other cavity nesting birds show a strong preference for trembling aspen that are either healthy or beginning to decline (e.g. insect damage, heart rot, etc.). Once the cavities have been abandoned by primary cavity-nesting species, secondary cavity nesting birds (e.g. flamulated owls, common goldeneye, tree swallows, etc.) will use the sites for roosting and nesting. These species are unable to excavate their own nests,

and hence are dependant on viable populations of primary cavity-nesters for their nesting requirements.

In addition to their use of larger stems for nests, woodpeckers such as the three-toed and pileated are year-round residents that depend on live stems that are experiencing an insect attack or dead conifers and broadleaves for their foraging requirements. From late spring to early autumn, most cavity-nesting birds feed on foliar or flying insects that are gleaned from trees or hawked from perches. Pileated woodpeckers, and to a lesser extent three-toed and hairy woodpeckers, use downed wood extensively during the snow-free season. Large (e.g. > 50 cm d.b.h.), partially decayed (decay class 3) downed wood is most important for pileated woodpeckers, while the smaller woodpeckers feed on downed wood between 15 and 30 cm in diameter. The abundance of carpenter ants in the diet of pileated woodpeckers, and the strong association between carpenter ants and recently dead, partially decayed stems or downed wood suggests that snags and downed wood are critical habitat features. Unlike nesting habitat requirements that are likely met with one or two preferred stems per ha, foraging habitat requirements appear to necessitate the maintenance of large territories (often in excess of 150 ha) which large numbers of dead and dying trees. Not all of these appear to provide suitable foraging habitat at all times since forage within a patch and then move over 500m to a different foraging site, bypassing many declining stems or snags on the way to the new foraging location. The most important foraging habitat requirement appears to be large diameter (> 50 cm d.b.h.) declining conifers (decay class 2, following the 9 stage classification in Cline et al. 1980)). These declining stems receive high and often extended use by most species, particularly pileated, hairy and three-toed woodpeckers.

Interior Douglas-fir forests are critical to maintaining viable cavity-nesting bird populations. The moderate overwinter climate reduces energetic requirements, the relatively brief period of snow and lesser amount of snow facilitates foraging lower on the trunk of trees and on downed wood, and the abundance of broadleaf trees provides critical nesting and foraging habitat. To manage IDFxh2 forests for the nesting and foraging requirements of cavity nesting birds, current evidence suggests that it is important to maintain the following habitat features within stands on an ongoing basis:

1. Declining trees and snags. Declining broadleaves and conifers create nesting and foraging habitat. The diverse range of cavity-nesting species is directly linked to the different tree types and sizes used by an individual species, but a critical and limiting habitat feature is large broadleaf (>40 cm d.b.h.) and conifer (> 50 cm d.b.h.) trees that are declining or dead.
2. Downed wood. Downed wood represents critical foraging habitat for pileated woodpeckers in summer. The firm to partially decayed classes of downed wood (1-3) and the larger piece sizes (> 50 cm diameter) appear to be most important.

3. Gross and net merchantable stem volume by species and d.b.h. Timber production is an important issue in these stands and needs to be considered in choosing a silvicultural system.

To evaluate the suitability of several silvicultural options for maintaining cavity-nesting bird habitat and to balance this initiative with timber extraction, the long-term abundance of the above three habitat attributes needs to be demonstrated.

Habitat Issue #4: Managing for open forest condition in dry Douglas-fir forests.

Historically, some dry-belt Douglas-fir forests in the IDFxh2 biogeoclimatic zone were maintained in a fire climax condition by frequent low severity fires, either through a combination of topography and weather patterns (i.e. lightning-caused ignitions) or ignitions by First Nations peoples. These frequent low severity fires are thought to have favored a more open stand condition than now exists. There is currently much interest in managing some of the low elevation Ponderosa pine and Interior Douglas-fir biogeoclimatic zone in a more open condition, since a more vigorous grass, forb and shrub understory would likely exist in these stands if competition with overstory trees for moisture and light was reduced. Numerous native herbivores and domestic livestock would likely benefit from a more vigorous understory, and this condition may also facilitate managing for low or moderate severity fires rather than stand replacing fires. To provide herbivores that would benefit from the open stand conditions with other life history requirements, several other stand structure features will need to be maintained. Large live and declining trees that are suitable for primary and secondary cavity nesting birds, dense thickets for security or thermal cover, deep and interlocking crowns for snow interception and downed wood for small mammals are important features to consider.

Several approaches have been proposed to achieve and maintain an open forest condition in IDFxh2 forests. Prescribed fire, innovative silvicultural prescriptions and a combination of silviculture and fire have been suggested as candidate tools. Each approach has associated costs and risks, some of which will not be known for decades. The attractiveness of the silviculture approach lies in the relatively high certainty of achieving target stand structure results following an intervention, but the ability to maintain desired conditions over time is poorly known. It is important to maintain the following habitat features within stands on an ongoing basis:

1. A high proportion of the stand with little or no tree canopy to intercept light. For example, a minimum of 50% of the stand with less than 20% shading, and no more than 20% with high levels (e.g. > 60% light interception) of shading.

2. Tree species composition. Open forest conditions would favor shade intolerant species such as Ponderosa pine and this species should form a significant component (20-40%) of the stand.
3. Declining trees and snags. Declining broadleaves and conifers create nesting and foraging habitat for cavity nesting birds, and a continuing supply of declining (e.g. insect infestation, heart rot, etc.) or dead trees in a range of size classes, including large (> 50 cm d.b.h.) trees is necessary.
4. Dense thickets that provide thermal and security cover. Dense thickets (e.g. > 5000 stems/ha) of layer 3 and 4 trees (1-10m height) should occupy about 10% of the stand area on an ongoing basis.
4. Downed wood. Downed wood represents critical foraging habitat for pileated woodpeckers in summer. The firm to partially decayed classes of downed wood (class 1-3) and the larger piece sizes (> 50 cm diameter) appear to be most important.
5. Large, live trees with deep crowns and interlocking branches that would intercept snow should cover about 30% of the area .
6. Gross and net merchantable stem volume by species and d.b.h. Timber production is an important issue in these stands and needs to be considered in choosing a silvicultural system.

To evaluate the suitability of several silvicultural options for maintaining open stand conditions and to balance this initiative with timber extraction, the long-term abundance of the above six habitat attributes needs to be demonstrated. The relationship between stand structure and grass, forb or shrub biomass and species composition will be explored further in other projects that address the ecological relationship between understory features and stand structure.

Activity 2. Qualitative assessment of stand development models.

The main focus of this component of the study was to prepare a qualitative assessment of currently available stand development models regarding their present ability to report on the stand structure indicators important to evaluating habitat suitability (e.g. tree species composition, diameter distribution of live and dead stems, decay class of dead stems, downed wood, etc.). We focussed on two stand models that were developed in BC (TASS [Tree And Stand Simulator, BC Ministry of Forests]) or which has been adapted to BC (Prognosis BC, US Forest Service). Another stand development model, SORTIE, was not tested because of time constraints and the lack of calibration to the IDF and ESSF ecosystems that were the focal habitat types for this project.

From the beginning, it was apparent that several key ingredients that are required to conduct an assessment of model capabilities were missing. A reliable qualitative assessment would require suitable model initiation data, model versions calibrated to the forest types being evaluated in this project, a consistent and comparable set of reporting indicators and verification data that model outputs could be compared to. These features would facilitate an evaluation of precision or bias in each of the model predictions. Differences in the initiation data requirements of TASS and Prognosis BC, combined with differences in the indicators being reported, and the lack of verification data led us to abandon this approach and place more emphasis on assessing the likely utility of the two models to report on habitat indicators, and the refinements that would enhance this capability. As both Prognosis BC and TASS are mature (i.e. have been developed and tested for over a decade) growth and yield models that likely capture the basic aspects of stand growth, our work focussed on assessing the suitability of these models for predicting changing levels of the stand structure features identified above.

Prognosis BC

The Prognosis BC model is not spatially explicit at the tree level within a stand, and requires a tree list of the initial stand conditions. The species, height, diameter, and base to live crown for each tree should be available, but if base to live crown is not available it can be synthesized. Similarly, Prognosis BC can run from diameter distribution data if the average height for each diameter class is known. No spatial information is necessary to run PROGNOSIS, but the model requires the aspect, elevation, and Daubenmire Habitat Type for the area to which the tree list applies. Daubenmire habitat types have been cross-mapped to site series. In acquiring data on the initial stand conditions for the habitat types (IDFxh1, IDFdK1, ESSF wc2) on which to conduct trial runs of the Prognosis BC model, we encountered several problems:

- 1) Many stand plots do not record stems ≤ 12.5 cm DBH. Where data on smaller stems do exist, they are often collected as counts in sub-plots, and they are usually not spatially referenced. The absence of small stems means that we only follow the larger trees in our projections, ignoring an important source of recruitment and, quite often, the majority of stems in a stand.
- 2) Dead trees and downed wood are often ignored when stand data are collected. When these data are available, the decay classes of the snags and downed wood are usually missing. Without these data it is impossible to know the present distribution of snags and downed wood in a stand, and their persistence over a projection cannot be calculated without decay class information.

In addition, several other challenges need to be addressed:

- 1) The BC variant of Prognosis is still evolving, and reliability is low for many BEC-site series combinations in the Kamloops Region.
- 2) Aside from a root disease extension and harvesting, there are currently no external mortality sources (e.g., bark beetles) for trees in a stand.

- 3) Regeneration has not been calibrated for the BC variant. Regeneration in the current version can be done by manually entering values.
- 4) Prognosis is calibrated for 10 year growth intervals and a 50 year projection length. Using the Prognosis BC model to project stand conditions beyond this period (i.e. using it to estimate successional changes) may compromise results. Biases introduced by shortening growth intervals and extending the projection length need to be explored.
- 5) Snags are not considered directly in the model and were derived indirectly from the mortality of stems over time. This leads to a bias in the estimate of snags in the stand in the early years of the simulation (Figure 1).

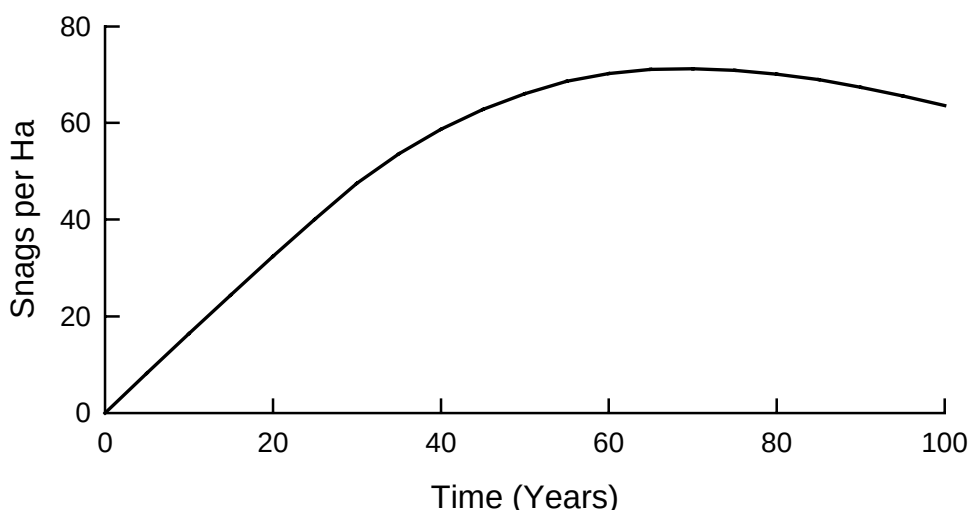


Figure 1. Estimated snag densities 100 years after a patch cut in the IDFdk1 stand (mortality is from self-thinning).

- 6) Snags and downed wood cannot be analysed with the BC variant (a post-processing snag model does exist for the US variant). To follow the decay of snags over time, we created queries that calculated the stems per ha lost between 5 year reporting intervals. Snags can be summarized by species and diameter class, if required (e.g., 2.05 Douglas-fir snags/ ha were created in year 10 of the simulation).

Using values for subalpine fir snag annual fall rates from Huggard (1999), we created a spreadsheet model in Excel97 that takes the output from the Access query and automatically calculates the density of each snag cohort over time. Fallen snags become downed wood, which are tracked over time as well. The following table shows part of the snag model. Each row follows the persistence of snags that fall within a year; each column total provides the density of snags in the stand over time.

Years Dead/ Ha	Yr0	Yr5	Yr10	Yr15	Yr20	Yr25	Yr30	Yr35	Yr40	Yr45	Yr50
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0	0											
5	2.761	0	2.76	2.73	2.71	2.69	2.59	2.51	2.07	1.71	1.4	1.17
10	2.519			2.51	2.49	2.47	2.45	2.37	2.29	1.89	1.6	1.29
15	2.506				2.50	2.48	2.46	2.44	2.35	2.27	1.9	1.55
20	2.57					2.57	2.55	2.52	2.5	2.42	2.3	1.93
25	2.531						2.53	2.51	2.49	2.46	2.4	2.3
30	2.495							2.49	2.47	2.45	2.4	2.34
35	2.485								2.48	2.46	2.4	2.42
40	2.482									2.48	2.5	2.44
45	2.489										2.5	2.47
50	2.368											2.37
Total			2.76	5.25	7.71	10.2	12.6	14.8	16.7	18.2	19	20.3
Snags												

Table 1. A sample of the snag spreadsheet model.

There is a real lack of data available for building species-specific snag and downed wood models. Huggard (1999) provides the most detailed information on annual fall rates by decay class, but there are several assumptions of his methodology that restrict their general application. A thorough literature search is required to find any potential sources for model calibration.

- 7) Prognosis has a well-developed graphical interface, but we needed greater flexibility for our analyses. We created an MS Access97 database to use as an analysis "shell" for processing Prognosis runs. To use this shell, we import key tables from *FVS_GAME.mdb*, the database where Prognosis stores run information. Queries are then run to process the data, always taking care to account for the "weighting" given trees in a stand. We created templates in SigmaPlot for automatically graphing the results.

We illustrate the outcome of using Prognosis BC to project and report on the consequences of several management options on stand structure (Figs. 2 – 7). Five treatments were developed for and IDFxh1 and and ESSF wc2 stand: (1) all stems in a 50x50m patchcut were removed, (2) all trees greater than 32.5 cm dbh were cut, (3) all trees less than 32.5 cm were cut, (4) no harvesting was imposed, and a "J" curve (some harvesting in each diameter class) type of harvest imposed on the stand. An effort was made to standardize the volume of timber harvested in all treatments except the control (uncut) to facilitate comparisons. Figures 2a,b are graphs of variables that form part of the standard output from Prognosis BC, while Figure 3 illustrates changes in the snag and down wood levels in relation to the treatments using the process described in point #6 above. Figures 4a and 4b illustrate changes in the diameter class distribution of live

stems in relation to treatment at year 0 and year 20, Figure 4c illustrates conditions at year 100. Comparable results that were developed for an ESSF wc2 stand (using the Prognosis BC model for the ESSF wc4 variant) are illustrated in figures 5a,b, 6, 7a,b,c.

Figures 2a,b and 5a,b represent a subset of the standard Prognosis BC reporting variables. These were relatively easy to obtain from the Prognosis database, but do not match well with the stand structure indicators that are necessary to evaluate wildlife habitat. These can be derived from the Prognosis BC database (Figs. 3, 4a,b,c, 6, 7a,b,c), but the process is difficult and needs further refinement and automation. Figure 2a also illustrates how the non-spatial nature of Prognosis BC may give confusing results for some indicators. The patch-cut and “J curve” treatments always show identical trends, a result that reflects the relatively uniform nature of the initial stand. The patch-cut treatment removed all trees in the patch, creating a large gap. The “J curve” treatment achieved a similar result by removing the same volume, again from all diameter classes in the stand, but uniformly distributed across the block. For non-spatial features such as overall stand basal area or trees per ha. this may not be an issue. However, if an inference about the understory conditions in a stand is important, the “gappiness” of a stand will likely need to be considered.

A further issue that was encountered during these trial runs was the volume of graphs and tables that can easily be generated, and no efficient mechanism is in place to process or present the results efficiently. The many graphs and figures generated from multiple runs of one scenario in different stands, and the many indicators that can be developed will require a more efficient process for presenting and managing the information.

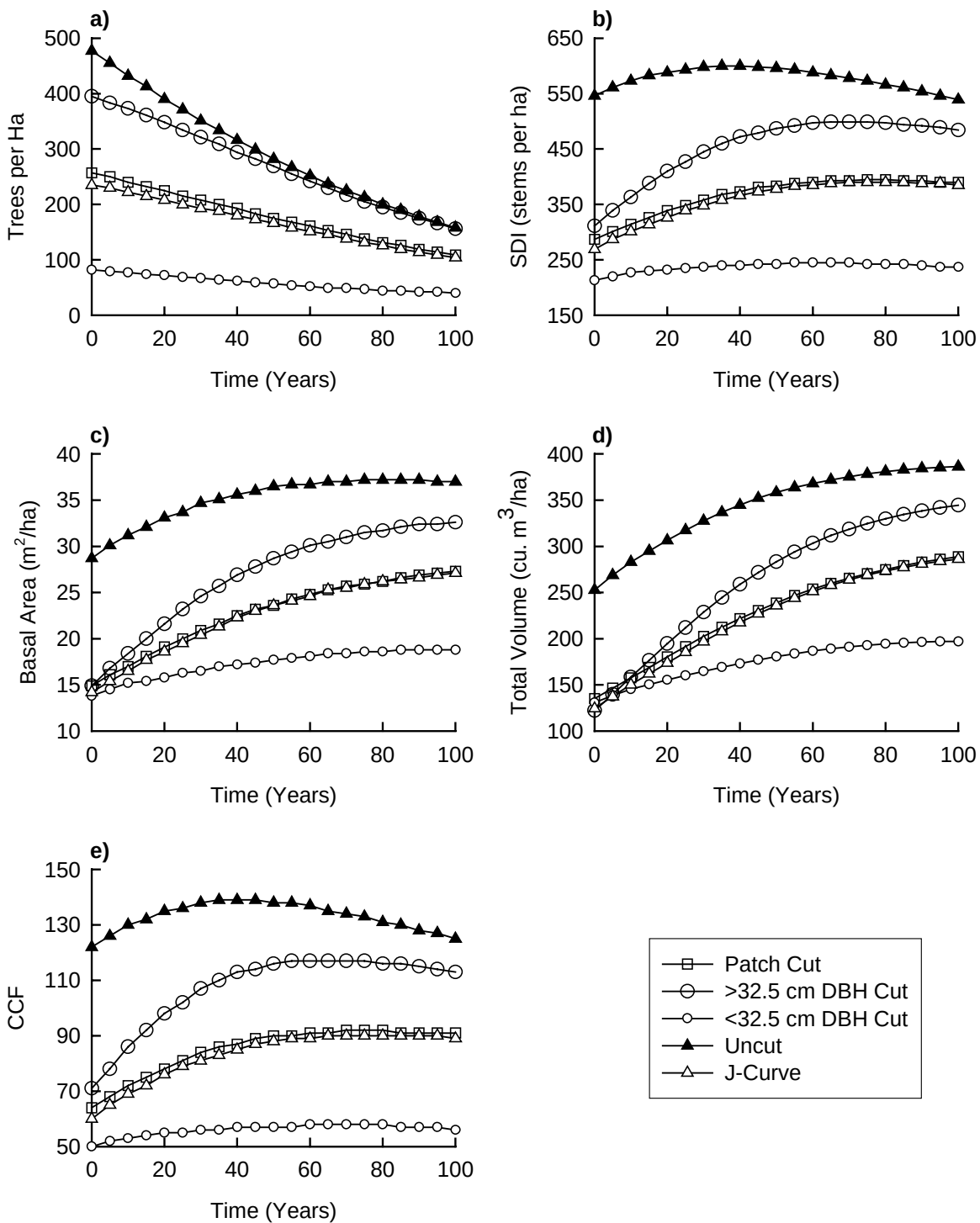


Figure 2a. Output from 100 year Prognosis runs with 5 year intervals for an IDFdk1 stand. Time begins immediately after the cutting treatment (i.e., treatments were done in VISTAS and imported to Prognosis to grow).

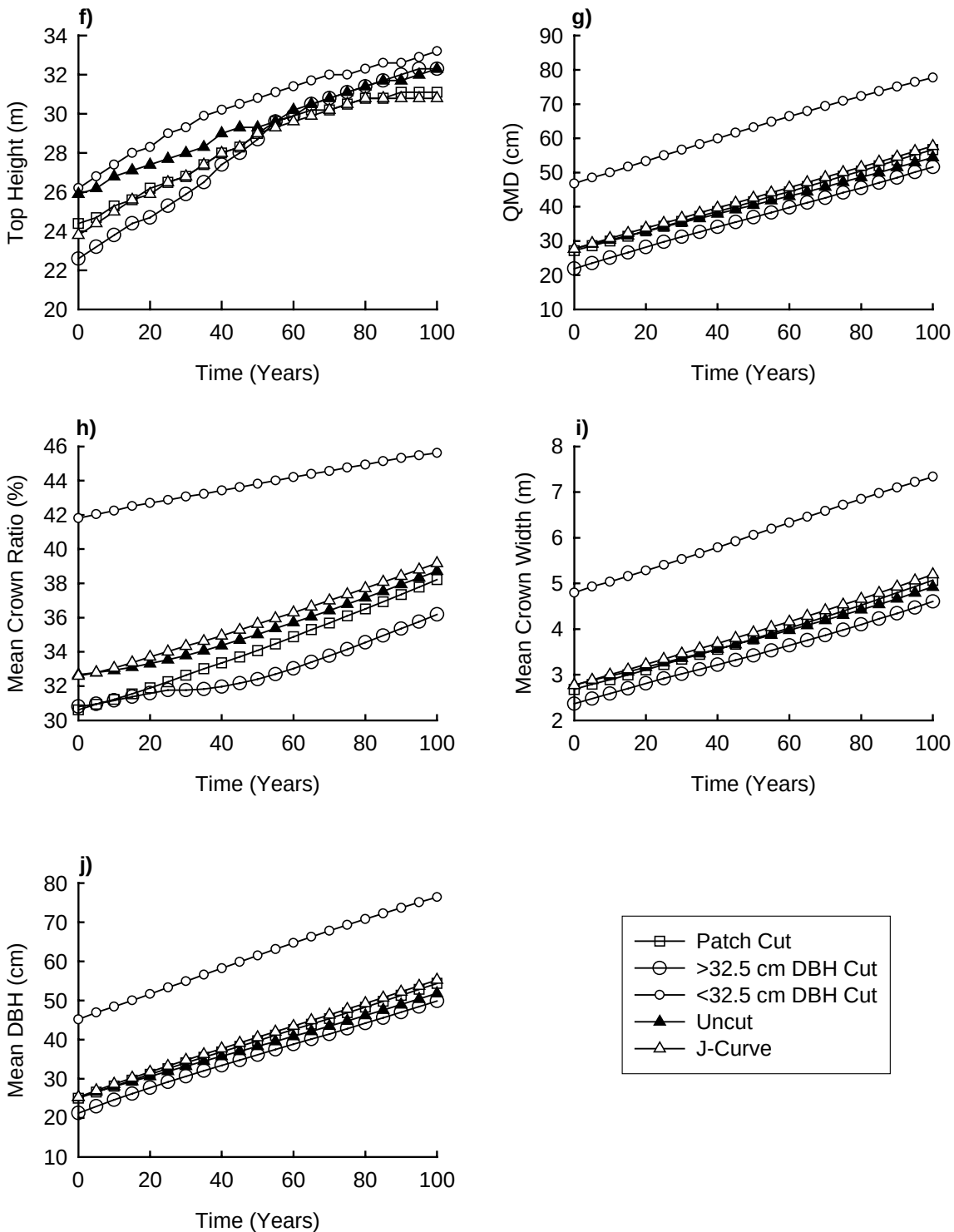


Figure 2b. Output from 100 year Prognosis runs with 5 year intervals in the IDFdk1. Time begins immediately after the cutting treatment (i.e., treatments were done in VISTAs and imported to Prognosis to grow). I have calculated the last 3 variables (not done as part of standard output in Prognosis).

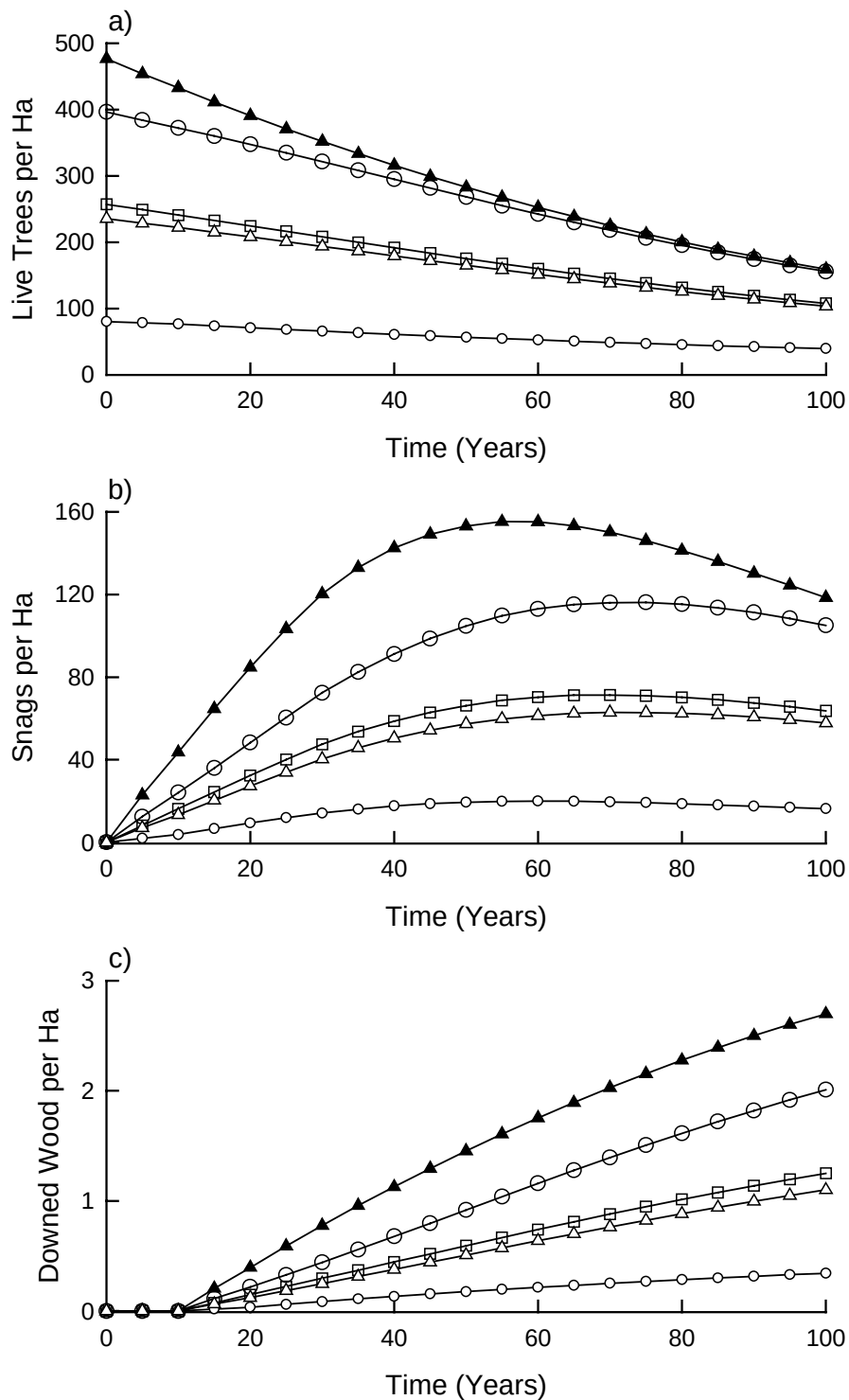


Figure 3. Live trees, snags and downed wood by treatment (symbols as in Fig. 1) for a stand in the IDFdk1. Remember, these do not account for snags or downed wood at year 0, and once a snag falls, it begins to decay at class 1, when it might in reality start at class 3.

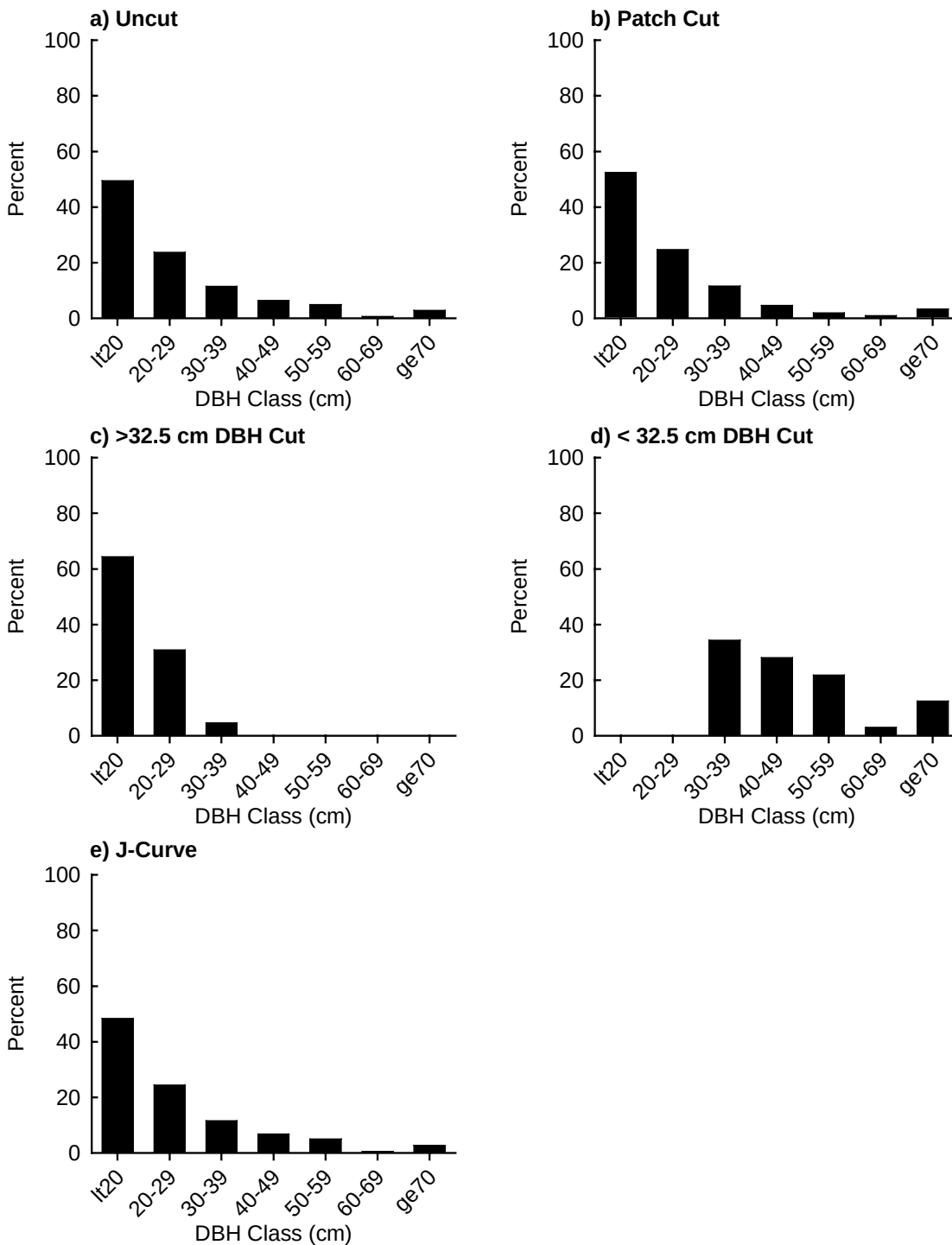


Figure 4a. DBH class distribution of Douglas-fir by treatment at Year 0 for a stand in the IDFdk1.

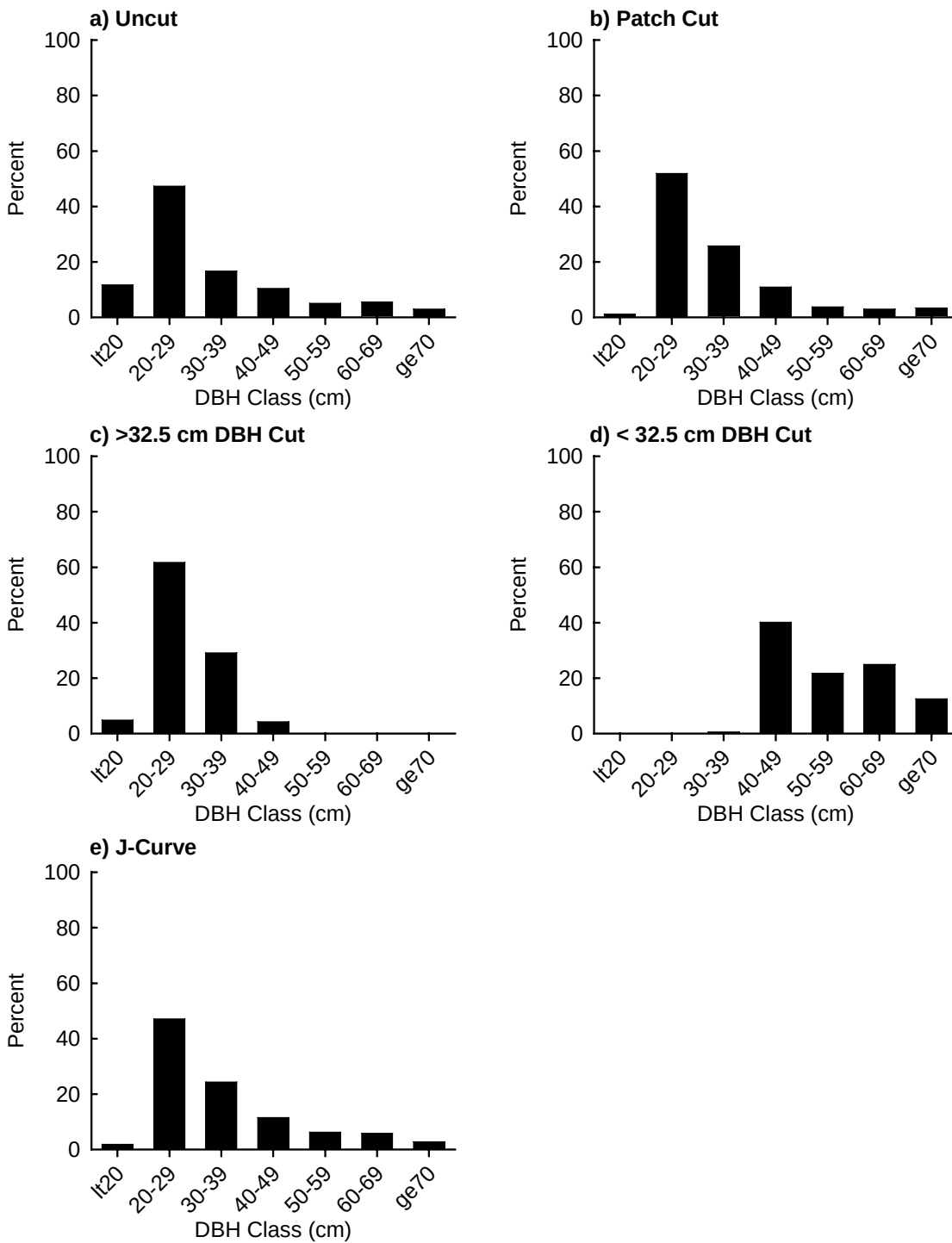


Figure 4b. DBH class distribution of Douglas-fir by treatment at Year 20 for a stand in the IDFd1.

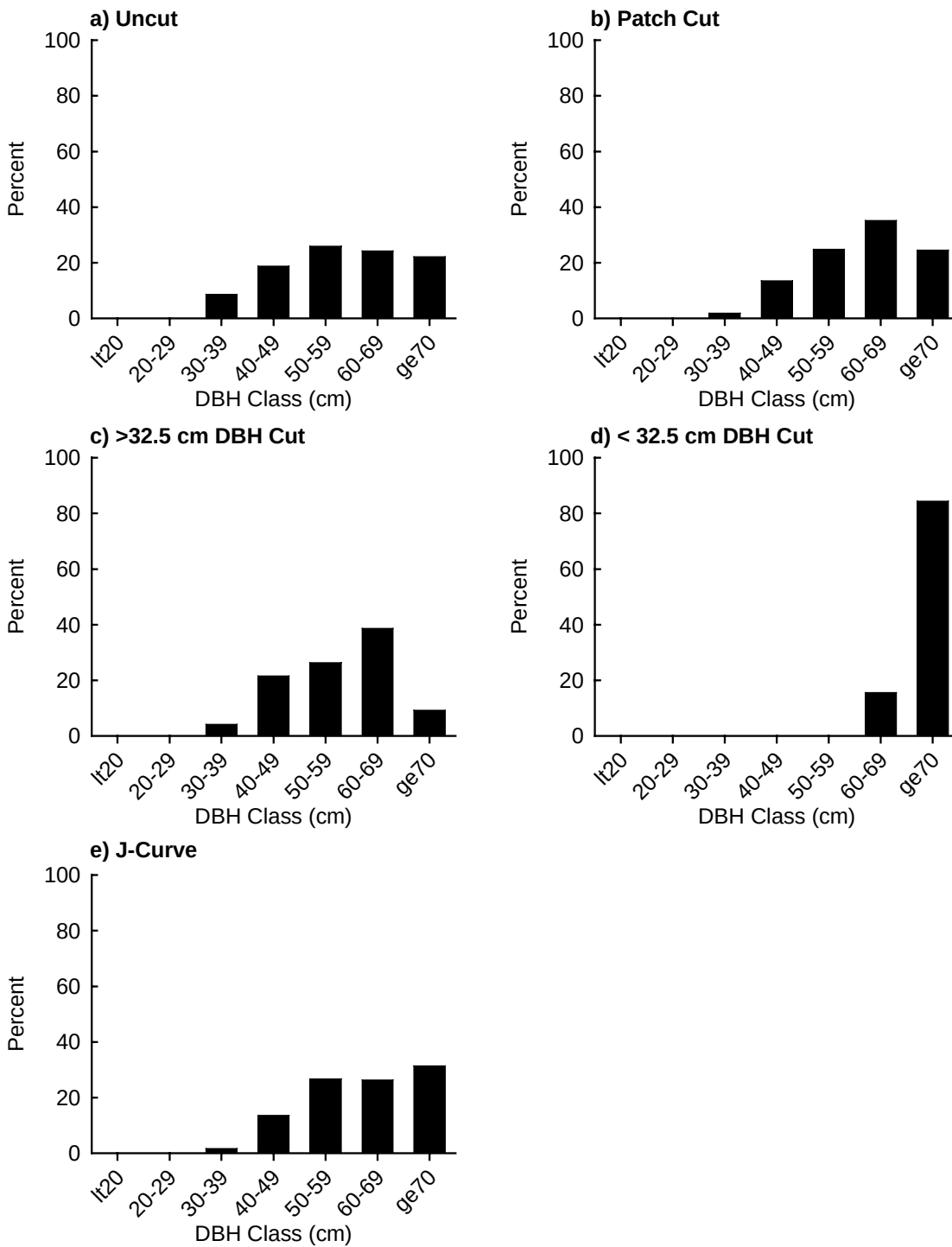


Figure 4c. DBH class distribution of Douglas-fir by treatment at Year 100 for a stand in the IDFdk1.

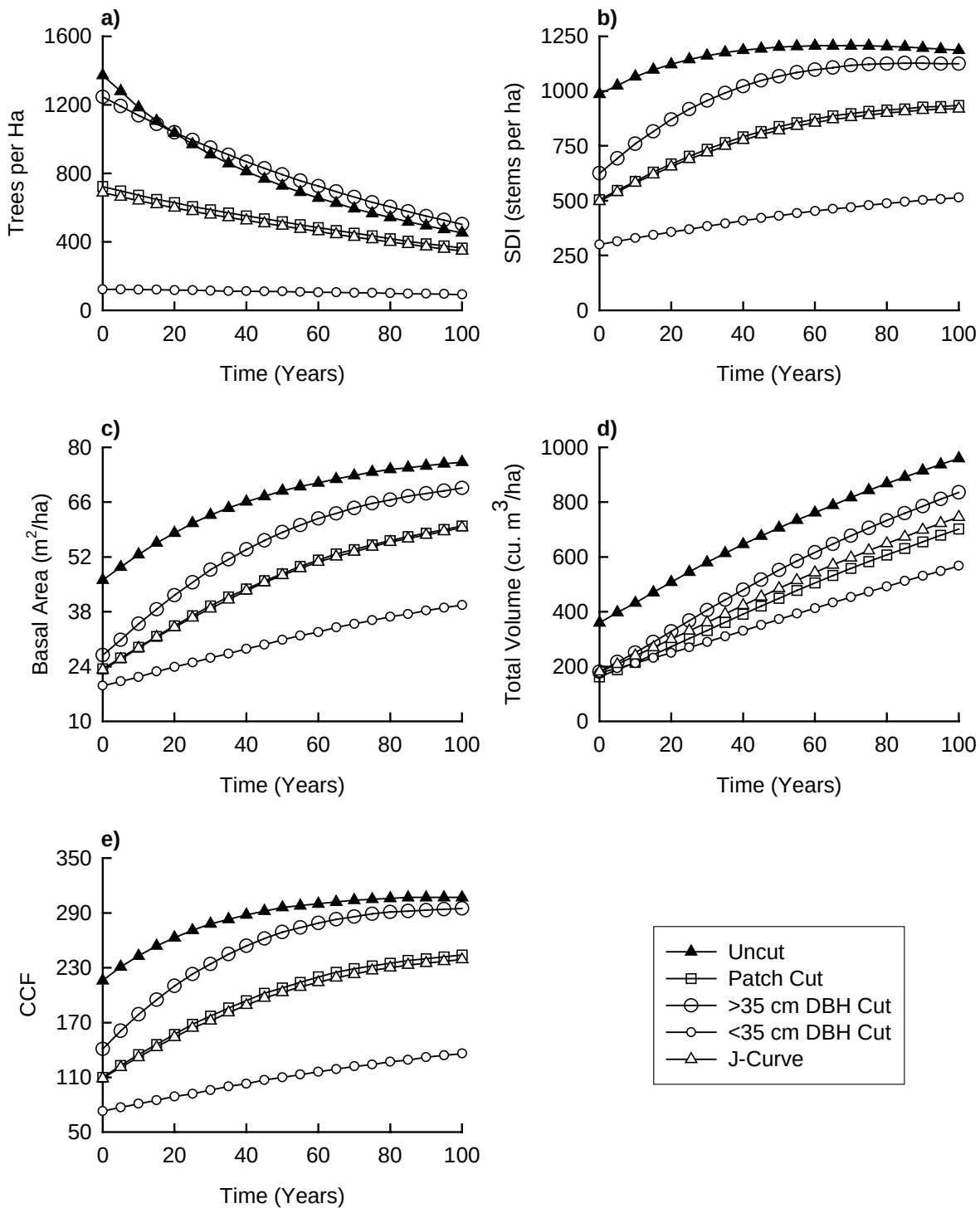


Figure 5a. Output from 100 year Prognosis runs with 5 year intervals for an ESSFwc2 stand. Time begins immediately after the cutting treatment (i.e., treatments were done in VISTAs and imported to Prognosis to grow).

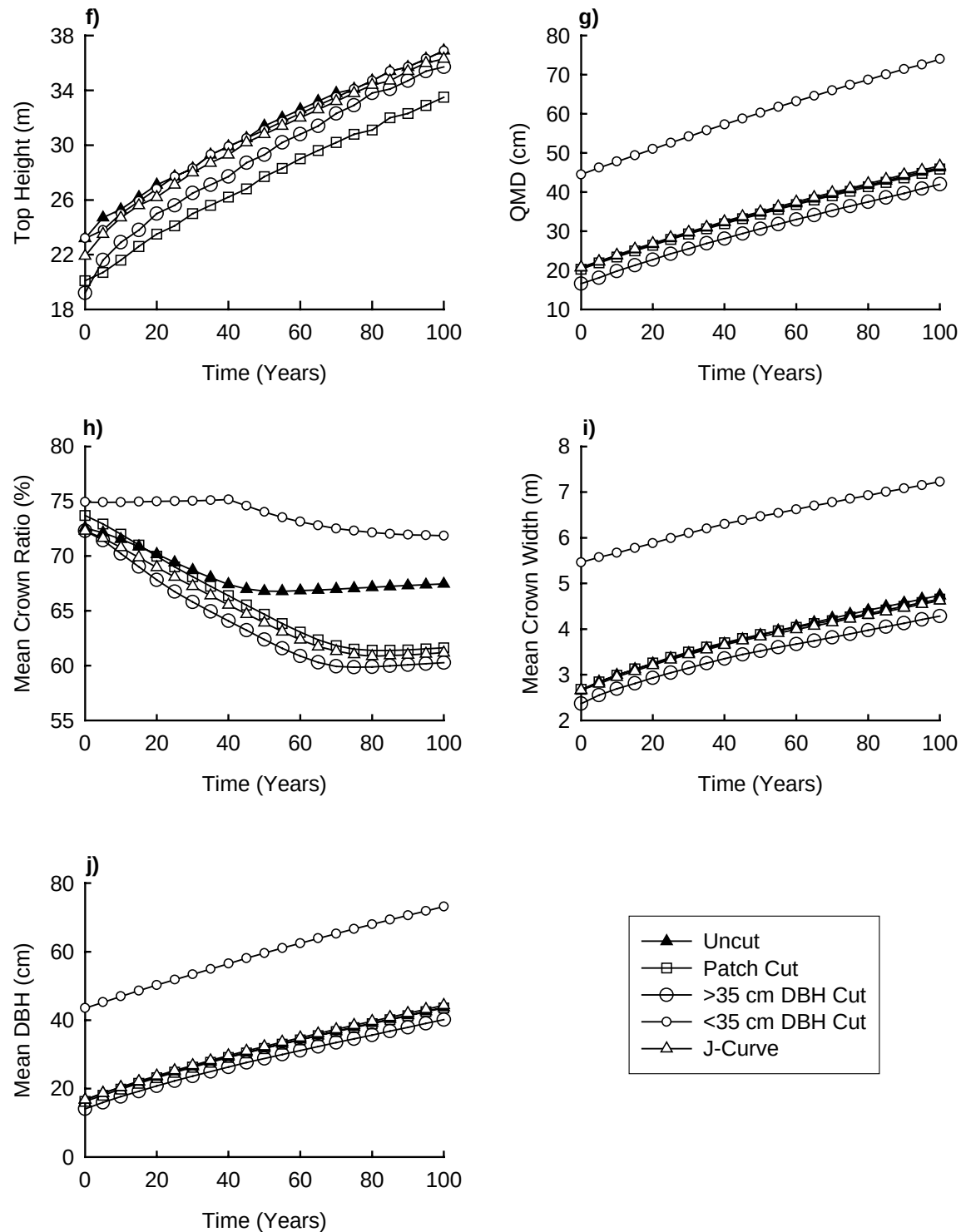


Figure 5b. Output from 100 year Prognosis runs with 5 year intervals for an ESSFwc2 stand. Time begins immediately after the cutting treatment (i.e., treatments were done in VISTAs and imported to Prognosis to grow). I have calculated the last 3 variables (not done as part of standard output in Prognosis).

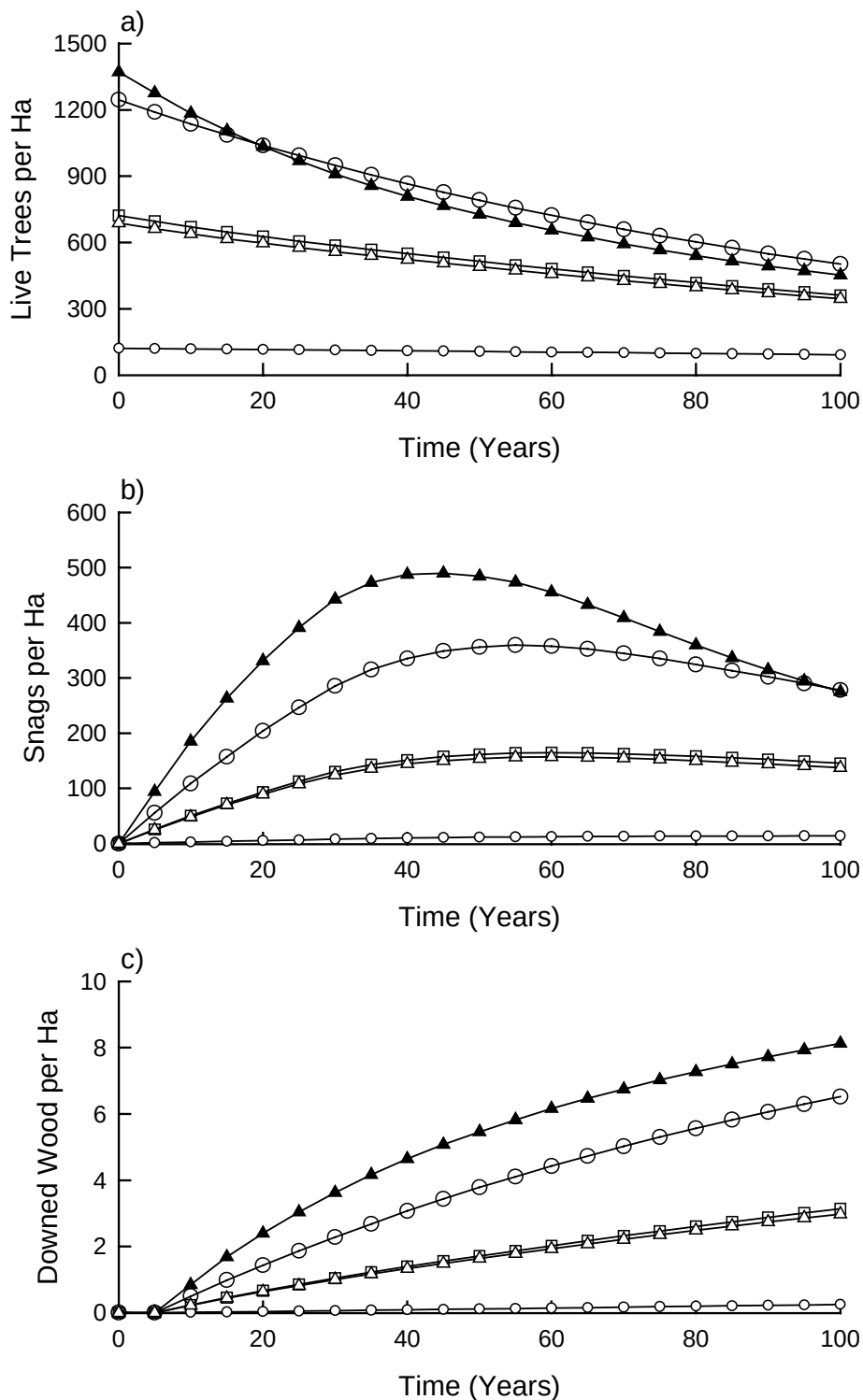


Figure 6. Live trees, snags and downed wood by treatment for an ESSFwc2 stand (symbols as in Fig. 1). Remember, these do not account for snags or downed wood at year 0, and once a snag falls, it begins to decay at class 1, when it might in reality start at class 3.

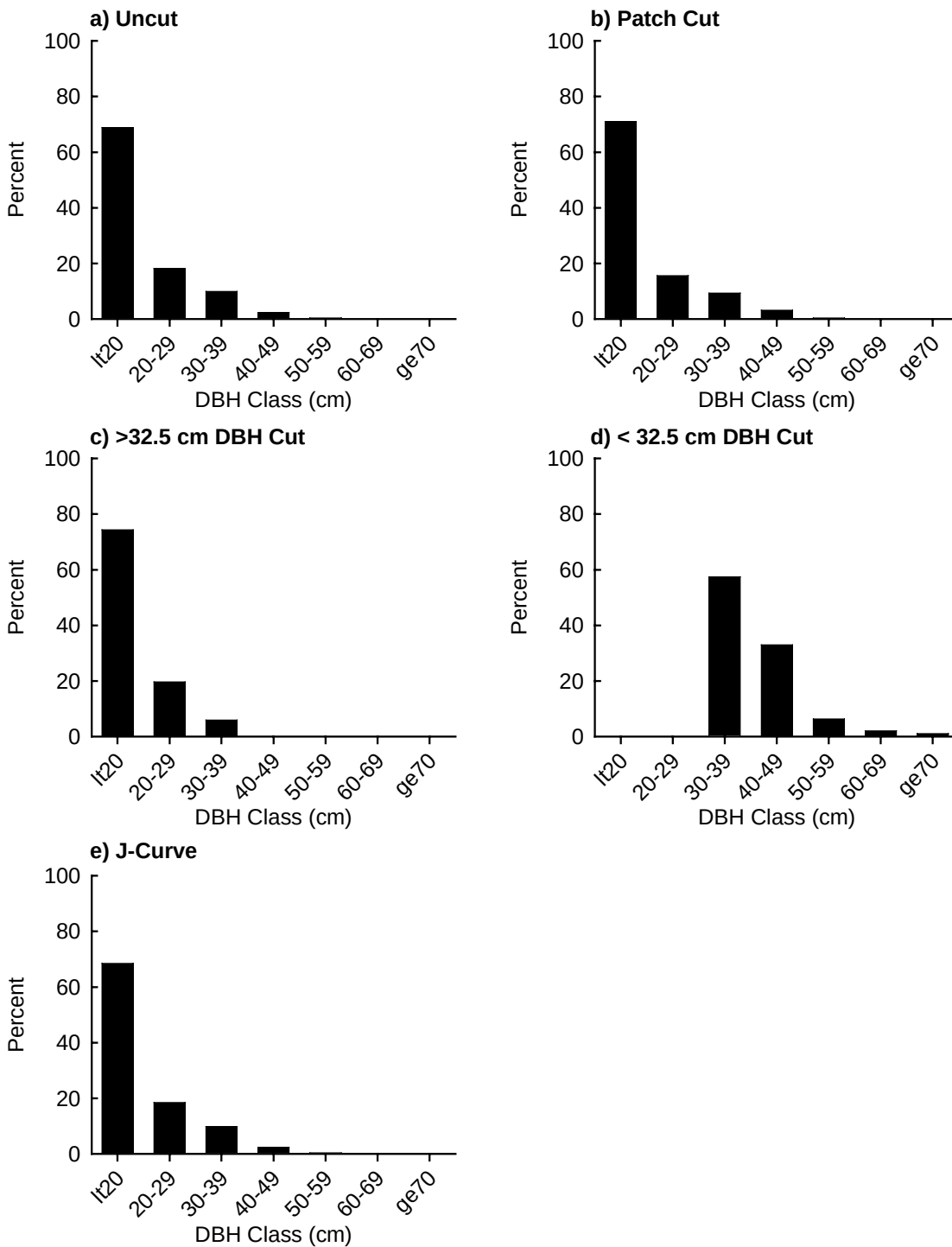


Figure 7a. DBH class distribution by treatment at Year 0 for Subalpine Fir in an ESSFwc2 stand.

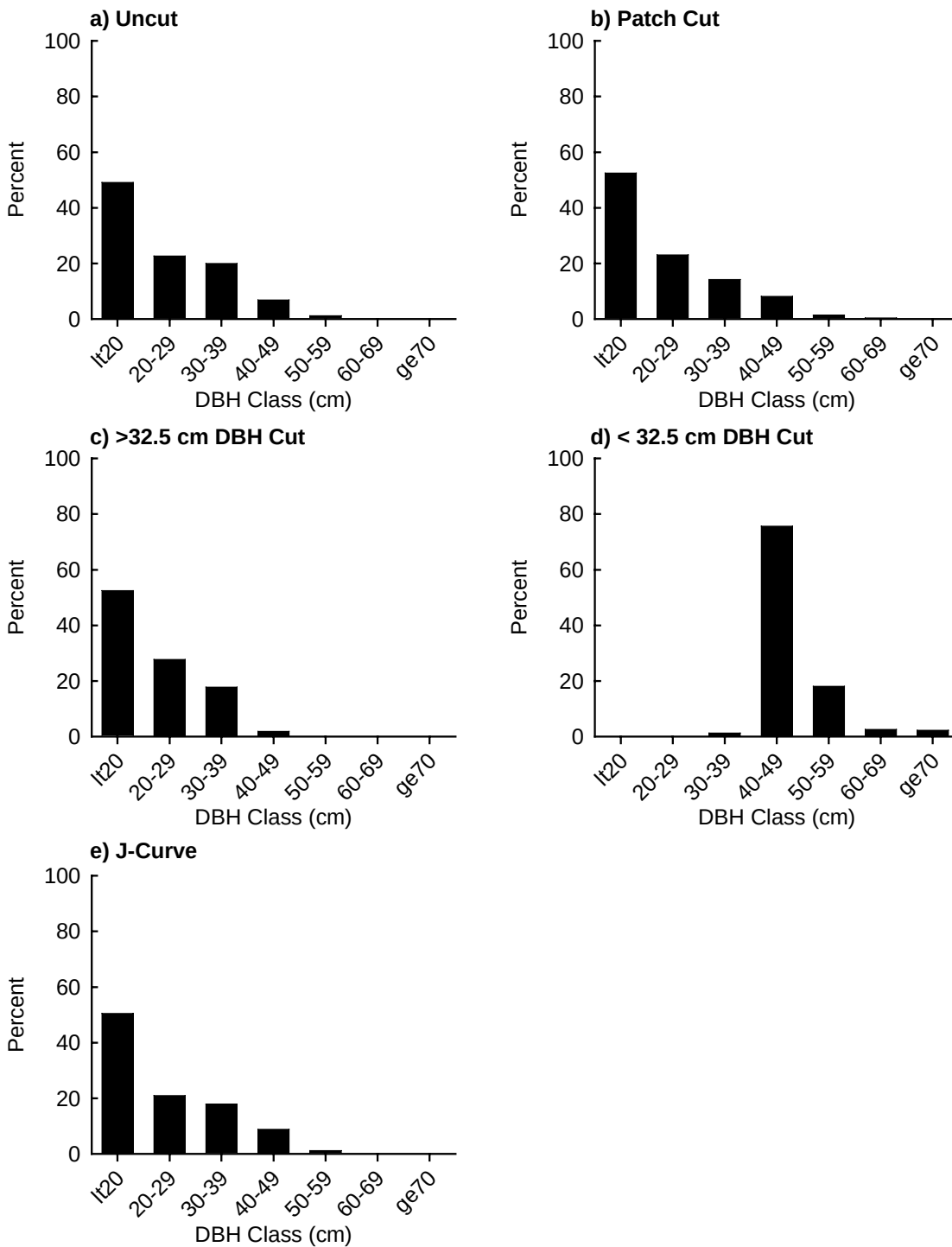


Figure 7b. DBH class distribution by treatment at Year 20 for Subalpine Fir in an ESSF wc2 stand.

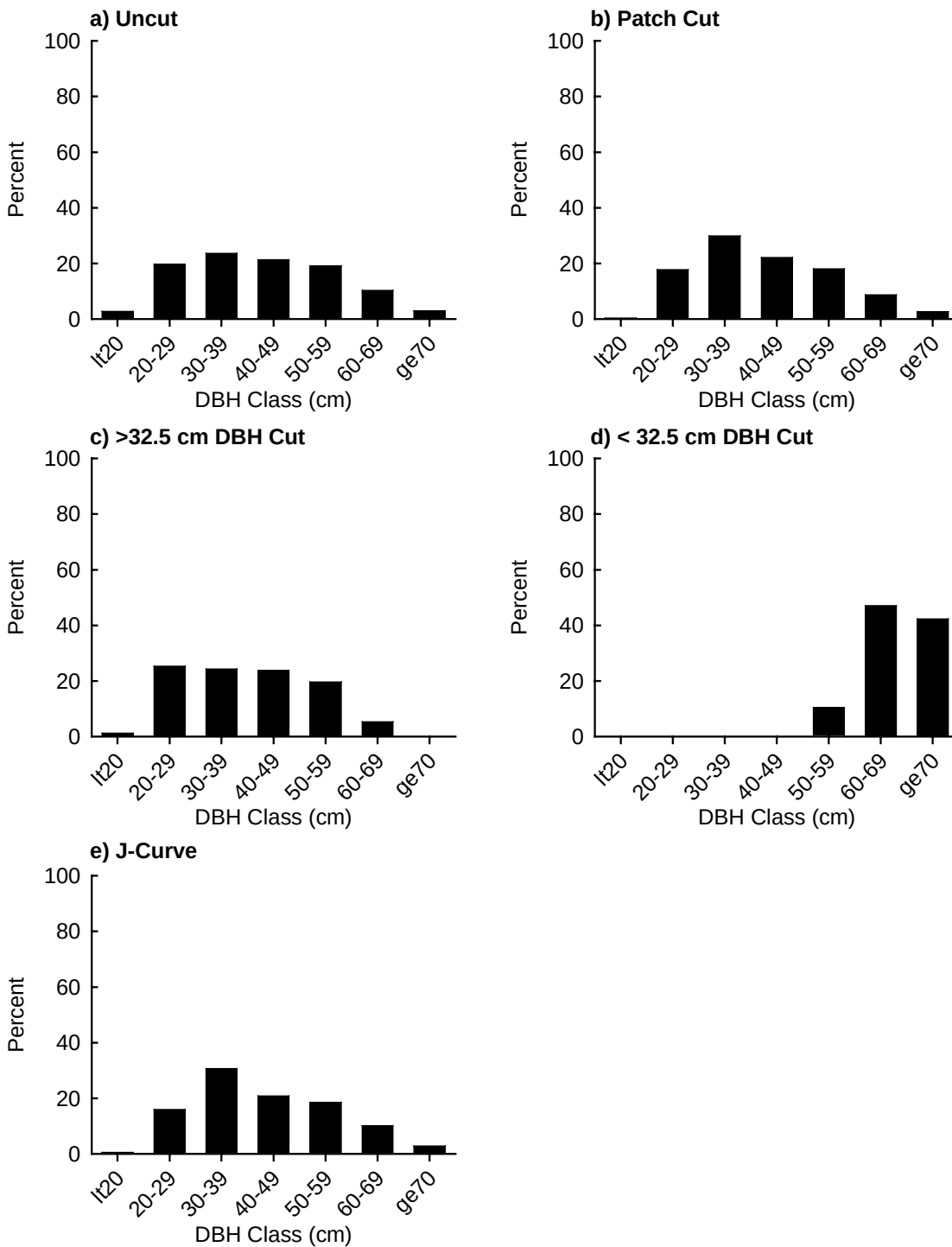


Figure 7c. DBH class distribution by treatment at Year 100 for Subalpine Fir in an ESSF wc2 stand.

TASS

TASS is an individual tree, spatially explicit model that tracks the growth and fate of individual stems in a stand. In Version 2 of the TASS model, the size and distance between stems drives growth and mortality. A more recent version uses ray tracing to develop a percent above canopy light (PACL) map that will be incorporated be used to drive tree growth and mortality once development and testing is complete. To initiate model runs in TASS, we required information on the x,y coordinate of each tree, and the tree species, height, diameter, and base to live crown. Site index is necessary for at least one species, but can be generated if site series is known. Stem map data is ideal for setting initial conditions in TASS. Finding these data proved to be difficult for the IDFxh1, IDFdK1 and ESSF wc2 habitats that we were modelling, and from the search conducted in compiling the habitat data catalog (see below), similar work in other forest types will likely encounter the same difficulties.

Where stem maps for stands are available, several concerns exist.

- Plot sizes are usually too small to allow the application of different harvesting practices. For example, our sample stand data for the IDFdK1 came from a 75 x 75m plot. To apply patch cuts of even modest sizes, we replicated this plot 9 times to create approximately a 5 ha “pseudogenerated” stand.
- Many stand plots do not record stems ≤ 12.5 cm DBH. Where data on smaller stems do exist, they are often collected as counts in sub-plots, and they are usually not spatially referenced. The absence of small stems means that we only follow the larger trees in our projections, ignoring an important source of recruitment and, quite often, the majority of stems in a stand.
- Dead trees and downed wood are often ignored when stand data are collected. When these data are available, the decay classes of the snags and downed wood are usually missing. Without these data it is impossible to know the present distribution of snags and downed wood in a stand, and their persistence over a projection cannot be calculated without decay class information. This leads to results like the following, where snags are apparently at very low densities for the first 40 years.

As with the Prognosis BC model, several other challenges need to be addressed in the TASS model:

- 1) The TASS model has been most widely used to simulate stand growth in even-aged, coastal Douglas-fir stands. Some work on calibration to interior forest types has begun, but will take time before the model has been fully calibrated and tested.
- 2) Stem mortality from insect pests, root disease or other external (i.e. not necessarily associated with tree-tree competition) mortality agents (e.g. windthrow) are not represented in the model. The opportunity exists for manually imposing non-stand replacing stem mortality such as the patchy attack of balsam bark beetle, but the process would benefit from an interface that would facilitate the procedure.

- 3) Natural regeneration has not been incorporated into the model. As with the issue of imposing chronic stem mortality, a mechanism for inserting periodic natural regeneration events would help develop the succession component of the model.
- 4) The lack of a natural regeneration and external mortality component in the model make long-term projections tenuous and may seriously bias the estimates of some structural features during long-term model projections (e.g. > 50 years). For example, the recruitment of snags and downed wood may be much lower than is achieved in a forest environment.
- 5) The current model reporting structure is not conducive to tracking levels of the stand structures important in assessing habitat condition for wildlife and biodiversity. The necessary data to derive these variables exist in the TASS database, but are currently difficult to retrieve. Examples of such variables include decay condition of snags, amount and dispersion of downed wood, the size and permanence of gaps in the tree crowns, and the size distribution of areas with similar ground level light penetration (similar to crown gaps, but reflecting light vs. vertical crown projection).
- 6) TASS is not currently distributed to users and all model runs are processed through the Forest Productivity Decision Support Group, Ministry of Forests, in Victoria. A backlog of runs may develop if stand structure modelling using TASS is pursued on a more extensive scale, and this may limit the utility of this model.

We conducted several tests of TASS output to evaluate the feasibility of deriving spatial information on gaps from the model output. In the first series of tests, we examined the range of gap sizes created by projecting the average crown diameter onto the forest floor to give an indication of the distribution of gaps created by the interlocking crowns. In combination with information on the previous disturbance and time since disturbance, this measure may provide information that could be used to assess the vigor of understory grass, forbs and shrubs. Figures 8-10 illustrate the outcome of some of these tests, and the difficulty we encountered. We used ARCINFO to calculate a patch size distribution but the results were initially confusing since both the crown area and "ground" were represented by only a few small patches (Fig. 9, 10). When viewed closely, many of the linkages that created a continuous crown or ground "patch" were as little as 10 cm wide, yet this created the large patches vs. the many small gaps or tree crowns we anticipated. These tests indicated that it would be difficult to derive a simple statistic of "gappiness", and that other statistics such as the patch – perimeter ratio would need to be developed to adequately describe light conditions in the understory.

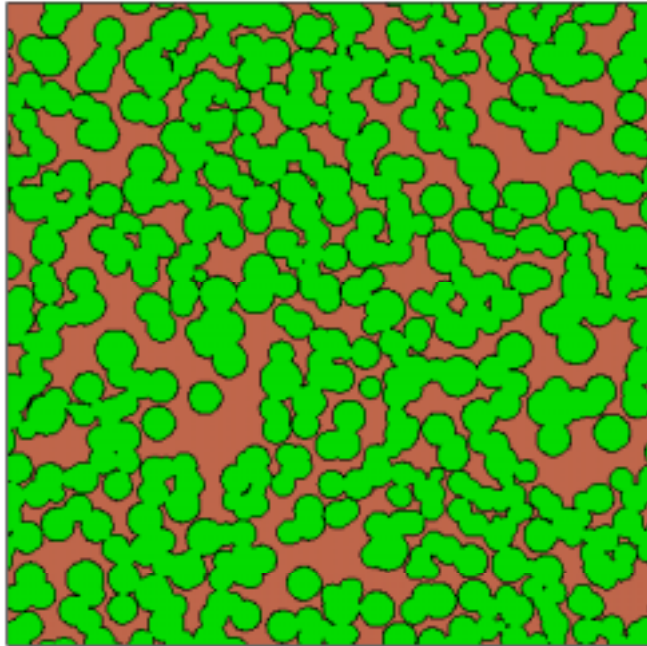
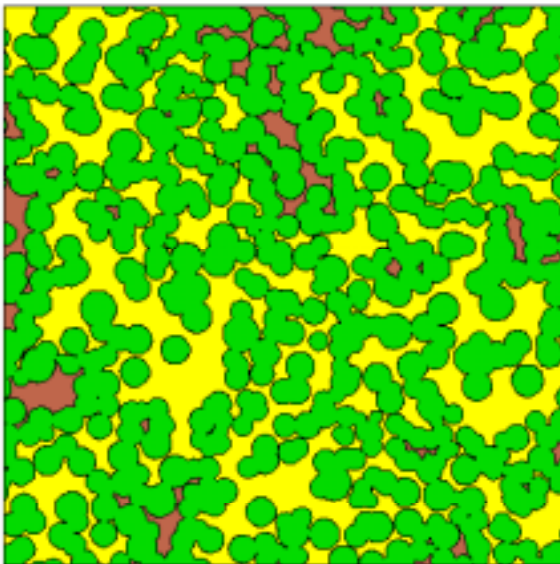


Figure 8. Vertical crown projection in an IDFdk1 stand at age 40 following clearcut and planting of 1500 stems at random spacing.

a) one 3,017 m² non-crown patch



b) one 1,800 m² crown polygon

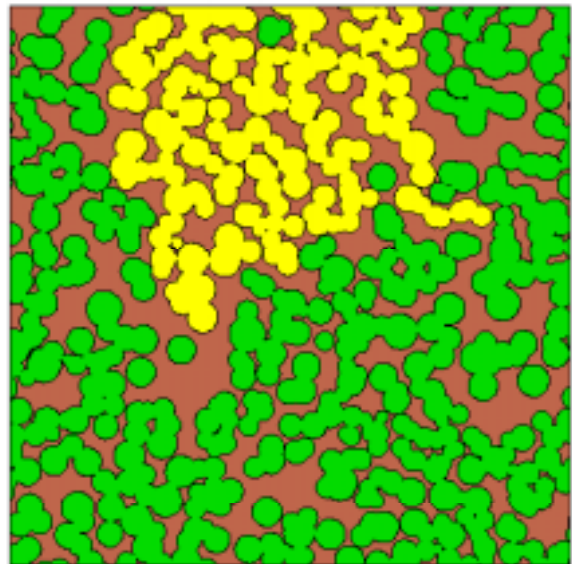


Figure 9. Vertical crown projection in an IDFdk1 stand at age 40 following clearcut and planting of 1500 stems at random spacing. Yellow indicates largest patch. Some of the connecting corridors are only 2 cm wide.

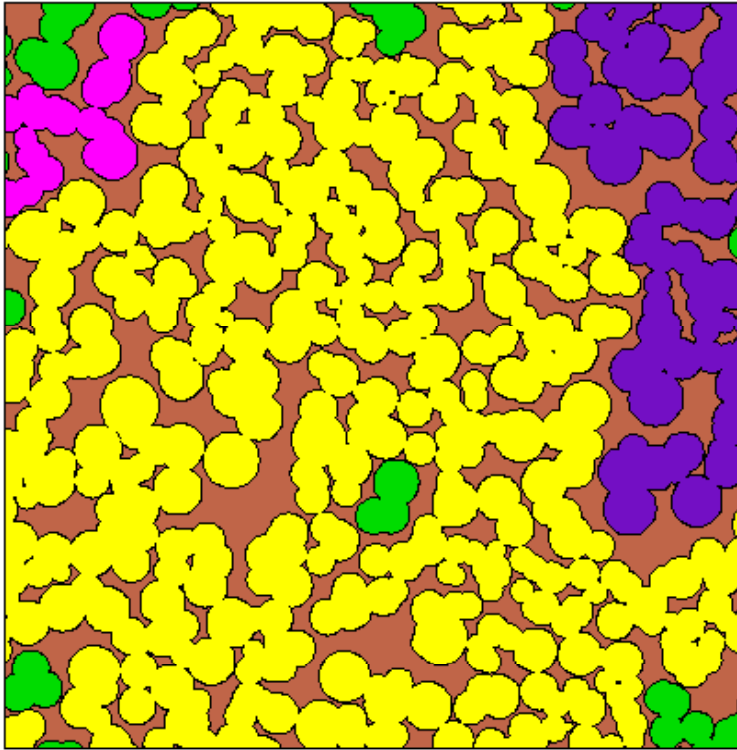


Figure 10. Vertical crown projection in an IDFdk1 stand at age 60 following clearcut and planting of 1500 stems at random spacing . The yellow (5,874 m²), blue (1,038 m²) and purple (225m²) polygons are the 3 largest of the 19 crown polygons.

Instead of pursuing the quantification of gap size further, the ability to directly assess light conditions in relation to stem dispersion and height in the latest version of TASS gave us the opportunity to explore ground-level light conditions directly instead of pursuing the indirect gap-size approach. We examined in detail the relationship between PACL readings, tree height and aspect (north or south side of the opening) and concluded the ground level light sensors in the TASS model appear to be reliable. Light readings in relation to opening size and surrounding stand height for the test patch cuts are presented in Figures 11 – 13, and light readings in a single tree selection partial cut in Figure 14. The PACL values illustrate the interaction between opening size and surrounding stand height; as surrounding stand height increases, larger patches need to be harvested to maintain areas of high light conditions in the opening (> 0.8 PACL). In the single tree selection partial cutting treatment (Figure 14), very few openings large enough to create patches of greater than 0.5 PACL are created, illustrating the possible difficulty of developing a vigorous understory with this type of treatment. An approach to summarizing this information is presented in Figure 15.

Change in PACL values from 25 to 100 m openings
PACL values for a 5 m tall (20 year old) Interior Douglas-fir stand

a) 25 x 25 m Opening



b) 50 x 50 m Opening



c) 75 x 75 m Opening



d) 100 x 100 m Opening



§ 0 - 0.2
§ 0.2 - 0.4

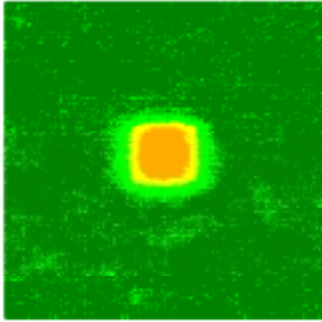
§ 0.4 - 0.6
§ 0.6 - 0.8

§ 0.8 - 1.0

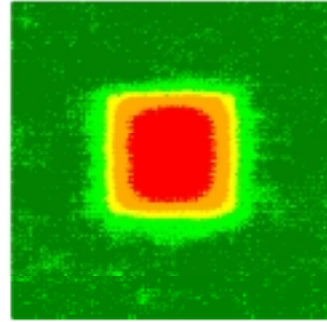
Figure 11. Change in PACL (Percent Above Canopy Light) values across a range of opening sizes (25 to 100 m openings) in a 5 m tall surrounding stand.

Change in PACL values from 25 to 100 m openings
PACL values for a 10 m tall (35 year old) Interior Douglas-fir stand

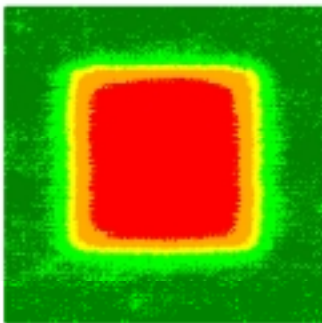
a) 25 x 25 m Opening



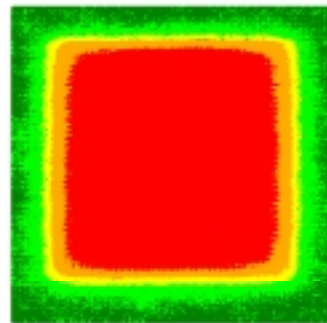
b) 50 x 50 m Opening



c) 75 x 75 m Opening



d) 100 x 100 m Opening



§ 0 - 0.2
§ 0.2 - 0.4

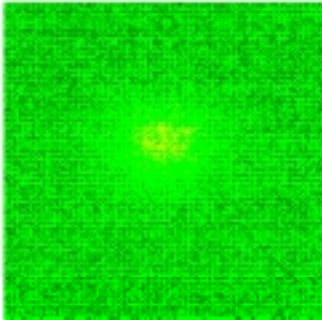
§ 0.4 - 0.6
§ 0.6 - 0.8

§ 0.8 - 1.0

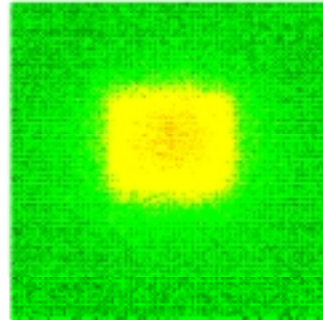
Figure 12. Change in PACL (Percent Above Canopy Light) values across a range of opening sizes (25 to 100 m openings) in a 10 m tall surrounding stand.

Change in PACL values from 25 to 100 m openings
PACL values for a 30 m tall (130 year old) Interior Douglas-fir stand

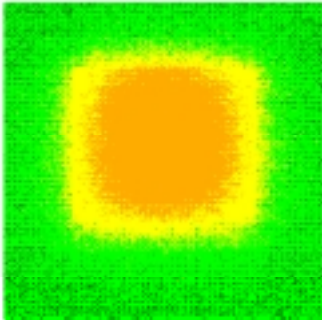
a) 25 x 25 m Opening



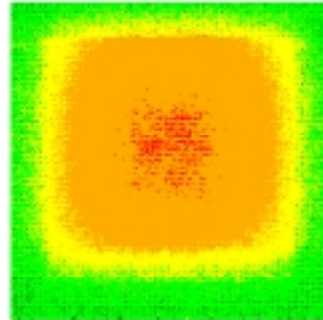
b) 50 x 50 m Opening



c) 75 x 75 m Opening



d) 100 x 100 m Opening



§ 0 - 0.2
§ 0.2 - 0.4

§ 0.4 - 0.6
§ 0.6 - 0.8

§ 0.8 - 1.0

Figure 13. Change in PACL (Percent Above Canopy Light) values across a range of opening sizes (25 to 100 m openings) in a 30 m tall surrounding stand.

PACL values for an IDFdm1 stand immediately following thinning
within a diffuse, single tree selection thinning. 50% of Basal Area removed

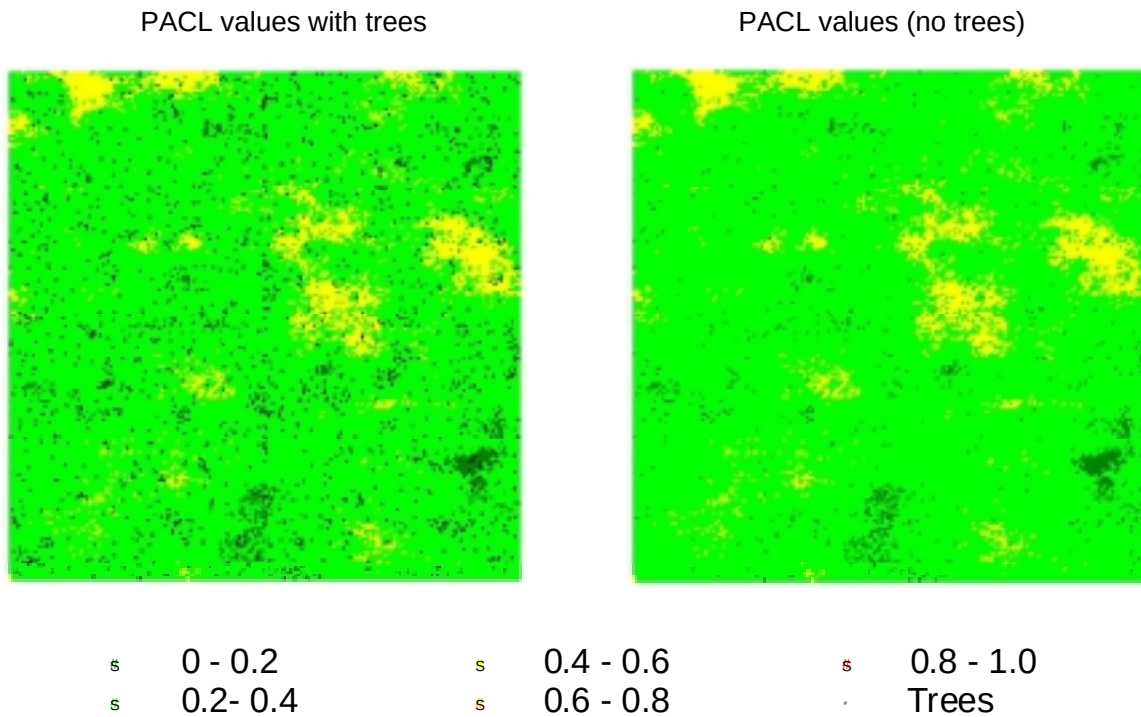


Figure 14. PACL (Percent Above Canopy Light) values in a single tree selection stand immediately following a 50% basal area removal.

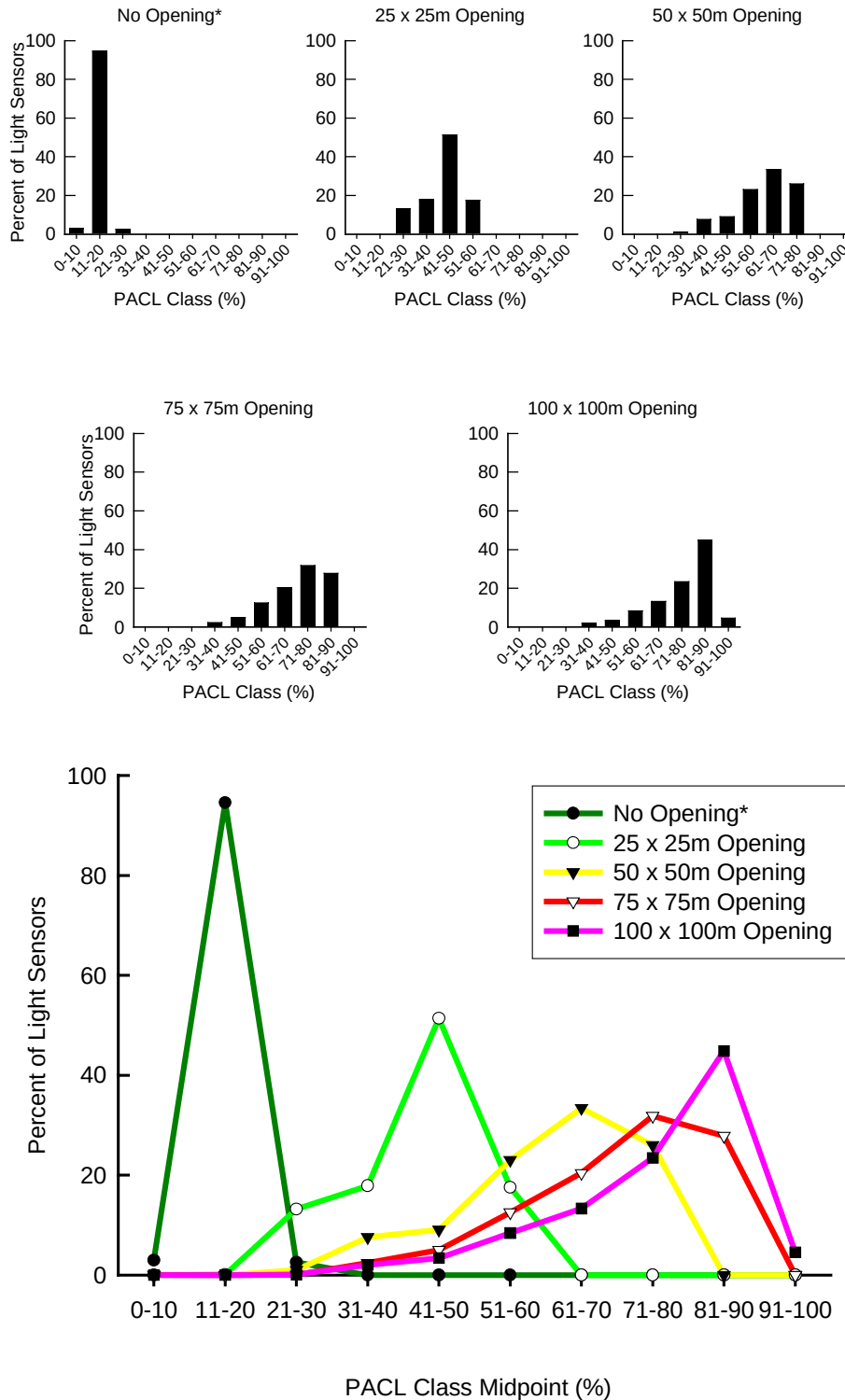


Figure 15. Percent distribution of PACL values for light sensors inside openings for a 60 year old Interior Douglas-fir stand.

The stand conditions illustrated in Figures 11-14 represent the immediate post treatment condition and do not reflect the increased shading that will occur as trees in the treatment area grow and begin to shade the overstory. This is an important issue that will need to be addressed in the future evaluation of prescriptions. The “permanence” of an opening (high PACL values) may be critical to understory plants that require a period of time to develop, or which are most productive in permanent or semi-permanent forest gaps.

Activity 3. Catalogue of habitat structure data.

L. Kremsater compiled a catalogue of the location and type habitat structure data that has been collected with emphasis on data from the IDFxh and ESSFwc biogeoclimatic zones in the Kamloops Forest Region. The draft report verified the issues we encountered in acquiring data to conduct the trial runs described above. Very few unbiased data sets exist that can be used to represent initial stand conditions in the IDFxh1, IDFd1 or the ESSF wc2. There are several limited sources of non-spatial data that could be used to initiate Prognosis BC runs, but only one limited stem map dataset exists for each of the subzone types we were evaluating.

Activity 4. First approximation of stand structure changes in relation to management systems.

Our initial perspective was to develop first approximation estimates using Prognosis BC and TASS of the stand structure consequences of different management systems, and to relate these to the case study wildlife habitat issues. The difficulties encountered in obtaining stand model initiation data, testing the models and in obtaining suitable indicators from the models did not allow us to proceed with this section of the project.