Eden Grove Old Growth by TJ Watt, n.d., Ancient Forest Alliance

Economic Valuation of Old Growth Forests on Vancouver Island

Phase 2 – Port Renfrew Pilot Study

May 3, 2021

Prepared for:

Ancient Forest Alliance

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FINAL REPORT

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Summary of Results

We assessed the net economic benefit to society of standing old-growth forests in the portion of the Arrowsmith-South Island Timber Supply Area (TSA) occurring within a 35km buffer around Port Renfrew. We found that this net economic benefit is higher when the trees are left standing than if they are logged. To establish this finding, we compared current timber harvest practices with 19 old growth protection scenarios ranging from minimal old growth protection (30%) to full old growth protection (100%) over a 100-year period. For the full protection scenario, we found that society would be better off by $97 million (2018 CAD, net present value) if trees older than 140 years were fully protected, and $90 million if trees older than 250 years were fully protected. Our modelled scenarios consider economic benefits from multiple ecosystem services provided by old growth forests, including timber harvest, carbon storage/sequestration, tourism, recreation, non-timber forest products, Coho salmon habitat, real estate values, and education/research opportunities. Of these services, we found that the main drivers of economic benefit are carbon sequestration, timber harvest, and recreation/tourism.

Increasing old growth protection would, of course, decrease the ability to harvest the full annual allowable cut in the study area and would result in smaller, less valuable trees being harvested more frequently from the remaining timber harvest land base. At 50% old growth protection, about 84% of the annual allowable cut in the study area would be achievable over the 100-year time horizon, while at 100% old growth protection, 69% of this harvest would be possible. Under the latter scenario, there would be a $16 million loss in net benefits to society, 7 fewer full-time equivalent (FTE) jobs would be generated, and the forest sector’s contribution to provincial GDP would decrease by $247 thousand annually. These reductions would be easily compensated for by gains in other ecosystem services. Due to current harvest practices, the study land base is now a net carbon source. Increasing old growth protection would reduce this source status by 569,250 tonnes of carbon over the next 100 years, for a net economic benefit to society of nearly $46 million from carbon storage alone. Tourism and recreation benefits would contribute and additional $11 million over the same time horizon. The tourism sector would also contribute 7 more FTE jobs, and a $162 thousand increase in annual contributions to the provincial GDP. Additionally, our assessment does not account for other jobs that might be created in the forest sector from a shift to alternative harvesting practices or value-added manufacturing.

The net economic benefits from these and the other ecosystem services we evaluate are incomplete estimates of the total economic value (TEV) of old growth forests in the study area. Our results do not include several services supplied by these forests such as cultural value, health and well-being, and fish production services other than commercial harvest of Coho salmon (i.e., recreational and subsistence fishing; nutrient cycling; other fish species). We did not include these services either due to a lack of required data (cultural value, health and well-being) or the need to conduct more extensive modelling outside the scope of this project (fish production services). We err conservatively in our model assumptions and provide sensitivity analyses to capture more and less conservative assumptions across key parameter values (e.g., log prices, harvest costs, price of carbon). Nevertheless, as with most assessments of economic benefits from ecosystem services, our results should be interpreted as underestimates of TEV. A key point is that even these underestimates suggest significant economic benefit to society from protecting old growth forests in the TSA near Port Renfrew.

1 Introduction

Historically, forest management decisions on Vancouver Island have been driven by the economic value of timber, which has contributed to the widespread harvest of old growth forests. Logging these forests helps maintain timber harvest benefits but can result in an overall reduction in societal welfare when other forest benefits are foregone. Timber harvest strategies often overlook these additional ecosystem services ancient forests provide (see Figure 1), effectively devaluing the contribution, or total economic value (TEV), of those services to society. With this pilot study, the Ancient Forest Alliance (AFA) has launched a unique exploration of potential modelling approaches and economic valuation methods that can be harnessed to better communicate the value of old growth forests on Vancouver Island. The information presented here is a critical step in a broader effort to help communities and governments make more informed decisions about forest management that consider a wider range of economic benefits supplied by intact old growth forests. To our knowledge, this effort is the first of its kind on Vancouver Island and the recommendations we present are designed to support subsequent implementation of an Island-wide valuation of old growth forests.

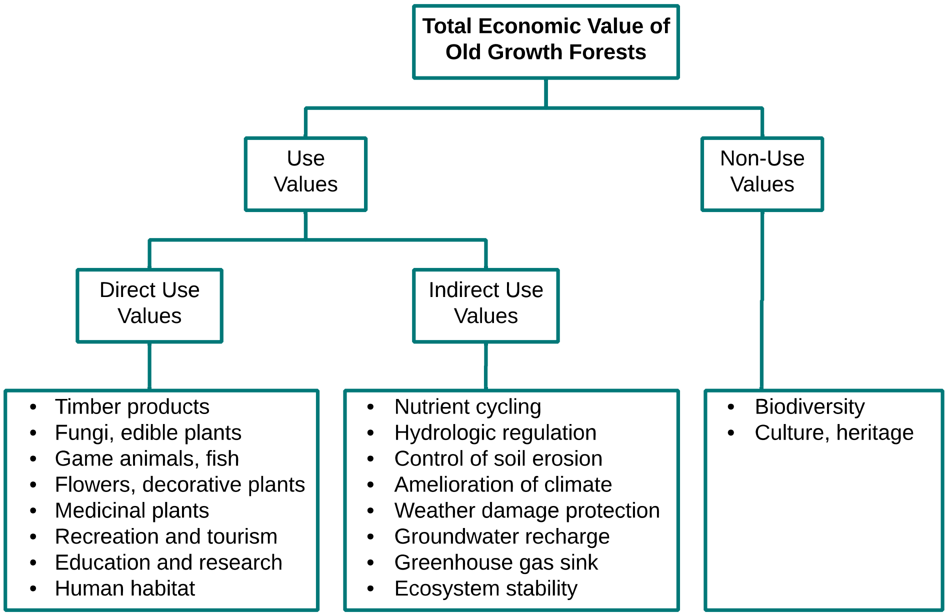

Figure 1. Total economic value of old growth forests. Adapted from Knowler et al. 2003.

Figure 2 shows all old growth stands (>140 yrs) remaining on Vancouver Island according to the BC Vegetation Resources Inventory (VRI) published online 2017-02-06 and last modified 2019-02-20 (Data BC 2019; Sandvoss et al. 2005) and Sentinel-2 imagery, with logging updates and data gaps for Tree Farm Licenses and private lands addressed via Landsat (1972-2019), SPOT (2006), NRCAN time series (1985-2015), Baseline Thematic Mapping (BTM), and 1957 forest cover maps (prepared for the Ancient Forest Alliance by David Leversee in spring 2020). These stands are primarily situated within protected areas, currently active logging areas, and inactive logging areas.

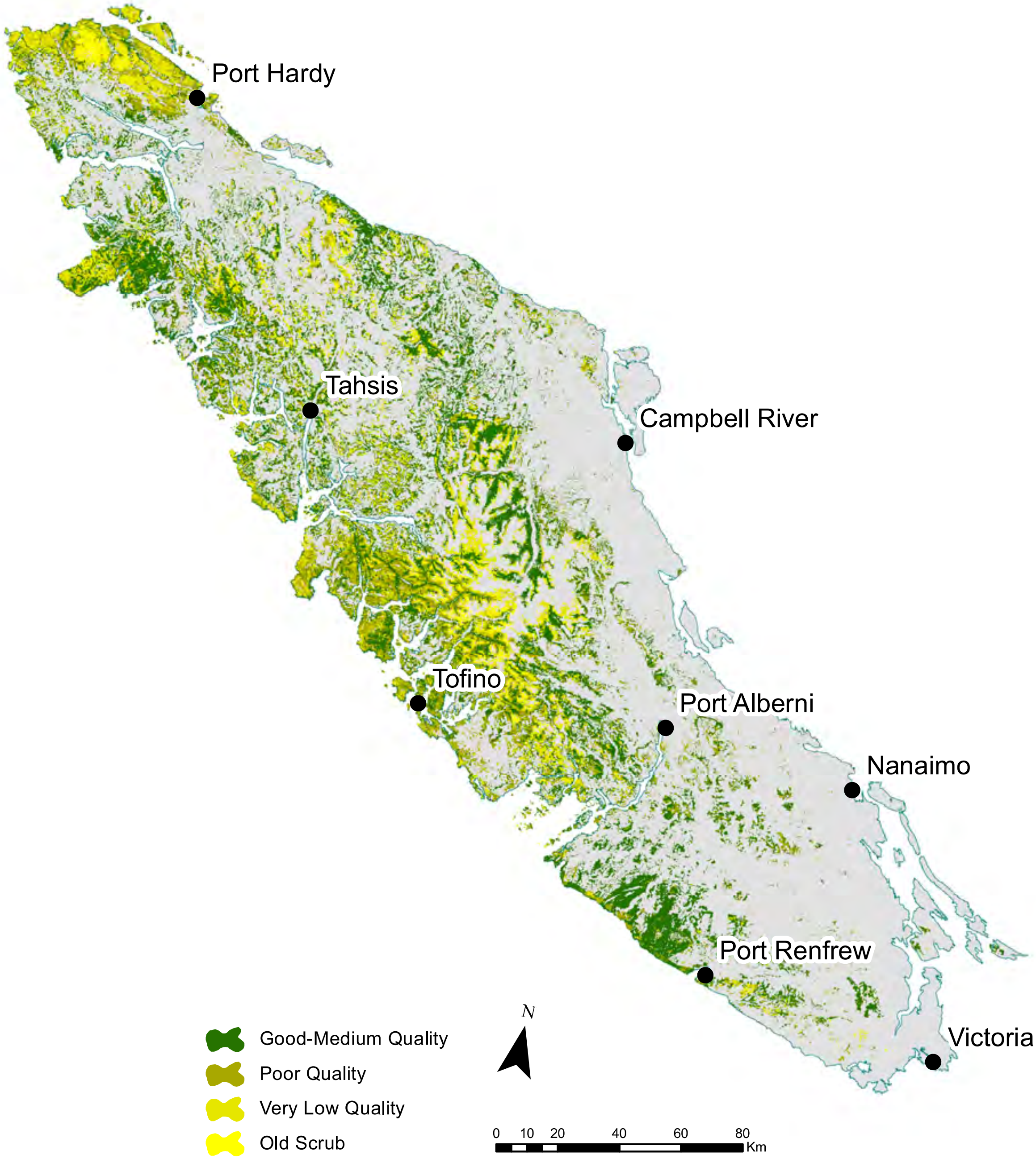

Figure 2. Old growth stands remaining on Vancouver Island according to the BC Vegetation Resources Inventory (VRI) published online 2017-02-06 and last modified 2019-02-20 (Data BC 2019; Sandvoss et al. 2005) and Sentinel-2 imagery, with logging updates and data gaps for Tree Farm Licenses and private lands addressed via Landsat (1972-2019), SPOT (2006), NRCAN time series (1985-2015), Baseline Thematic Mapping (BTM), and 1957 forest cover maps. Data are for conifer stands classified as >140 years. Stand quality classifications are based on VRI Site Index values. Projection: NAD 1983 BC Albers. Data prepared for the Ancient Forest Alliance by David Leversee in spring 2020. Map produced by ESSA.

The stands in Figure 2 are classified by stand quality using VRI Site Index data, a measure of site productivity estimated using stand height and age. Index classification thresholds shown in Table 1.

Table 1. VRI Site Index thresholds used for stand classifications in Figure 2.

Leading Species	Good-Medium	Poor	Very Low
Fir	≥20.1	10.1-20.0	5.1-10.0
Cedar	≥15.1	10.1-15.0	5.1-10.0
Hemlock-Balsam	≥12.6	10.1-12.5	5.1-10.0
Spruce	≥15.1	10.1-15.0	5.1-10.0
Pine	NA	≥10.1	5.1-10.0
Deciduous	≥0.1 (minimal >140 years on Vancouver Island)		
Non-forest / old scrub (all conifers)	0.1-5.0		

Source: Prepared for the Ancient Forest Alliance by David Leversee in spring 2020.

An important distinction in conducting economic assessments is the difference between welfare-based approaches and economic impact approaches. Welfare approaches like that applied in the main body of this report are concerned with economic efficiency, or the allocation of resources that generates the greatest *net* benefits for society (IEAB 2005). Alternatively, economic impact approaches are concerned with the distribution throughout a region's economy of investments toward a management action or policy program. Economic impact analysts trace direct expenditures ('direct effects'; e.g., fees for guided tours to old growth forests), to associated expenditures ('indirect effects'; e.g., accommodations and food services), and resulting changes in personal income and household spending ('induced effects'; e.g., salary increases) (IEAB 2005; Joseph 2013). Economic impact analyses (EconIA) calculate these indirect and induced effects by applying multipliers from input-output models to direct expenditures (Joseph 2013).

Results from EconIA studies are frequently reported in the media as changes in GDP, jobs or personal income (e.g., "logging area x will result in 100 full-time equivalent jobs"). The two approaches can complement one another if used appropriately, but unlike welfare-based approaches, EconIA does not estimate *net* benefits, and therefore is not capable of fully assessing if a project or action is in the broader public interest (Joseph 2013). EconIA results cannot be added or subtracted from welfare-based results and do not readily account for opportunity costs. For example, considered alone, local job creation from timber harvests may be meaningful for a regional economy but detrimental to non-harvest benefits like recreation and tourism. For natural resource-based projects, a sometimes perverse feature of EconIAs is the fact that greater expenditures per unit of output will always result in a more 'beneficial' project, a potentially misleading outcome where negative external impacts like environmental costs (e.g., pollution, biodiversity loss) are relevant (Joseph 2013), or where inputs used in timber harvesting have alternative uses.

Since the purpose of the proposed pilot study is to assess broader benefits to society from old growth protection, we perform a cost-benefit analysis that incorporates both market and non-market valuation methods. This approach is consistent with the methodology applied by Knowler and Dust (2008) for valuing old growth forests in the Fraser Timber Supply Area. However, since results like changes in GDP, jobs, or personal income from recreation-based tourism and timber harvest may be informative, **we also supply a supplementary EconIA for these two sectors in Appendix D**.

For a defined study area, cost-benefit analysis (CBA) uses discounted net benefits (benefits minus costs) to compare estimated welfare derived from different management alternatives relative to a baseline or ‘business as usual’ timber harvest scenario (Treasury Board Secretariat 2007, US EPA 2010). The basic steps of CBA are: (1) identify alternative management scenarios, (2) identify who is impacted, (3) inventory potential impacts, (4) quantitatively predict impacts over time, (5) monetize any non-monetary impacts, (6) discount future benefits and costs, (7) compute net present values (NPV) for each alternative scenario, (8) perform sensitivity analyses, and (9) make a recommendation (Boardman et al. 2011 in Joseph 2013). Following these steps permits a comparison across management alternatives and can support decision makers in selecting options that will supply the greatest benefits to society.

To perform CBA, the effects of each old growth management alternative on timber harvests and revenues must first be modeled over an established time horizon using a timber supply model. Modelled outputs can then be used to assess the effects on non-harvest ecosystem services by linking each scenario’s resulting units of remaining old growth (e.g., area, volume) to per unit dollar values associated with these services. During a preliminary assessment and scoping study completed in July 2019 (Phase 1), we identified modelling approaches and economic valuation methods to measure changes in societal welfare from a) timber harvest, b) tourism and recreation, c) carbon storage/sequestration, d) non-timber forest products, e) drinking water quality, f) salmon habitat, g) real estate, and h) education and research. This report implements those methods using Port Renfrew as a pilot case study.

Table 2 shows recommendations from the Phase 1 report and their status for the purposes of this study (Phase 2).

In the chapters that follow, we review our methods (Chapter 2), and results (Chapter 3) for a suite of alternate scenarios. We then provide guidance for developing community narratives that imagine how the people and forest ecosystems around Port Renfrew would be affected (Chapter 4). We conclude with suggested next steps for Phase 3 of this project (Chapter 5). Four appendices also provide: a short primer on valuation methods for non-market ecosystem services (Appendix A), a discussion of the role of discounting future benefits and costs in economic evaluations (Appendix B), sensitivity analyses of our results (Appendix C), and an economic impact assessment (Appendix D).

Table 2. Status of recommendations from Phase 1

Recommendation	Status
Select a pilot study site near Port Renfrew	**Adopted**
Use modelled timber supply data from the Arrowsmith-South Island Timber Supply Review as a baseline timber harvest scenario	**Adopted**
Develop two alternative timber harvest scenarios using the Arrowsmith-South Island Timber Supply Review's harvest levels and growth curves as inputs to the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)	**Adopted**, but added many more scenarios
Model timber harvest, remaining timber, and carbon storage and sequestration volumes using CBM-CFS3	**Adopted**
Apply benefit transfer techniques to modelled outputs for the area/volume of remaining old growth to evaluate the following ecosystem services under each scenario: recreation, non-timber forest products, drinking water quality, habitat, education and research	**Adopted** for all but drinking water quality. Habitat is only coho salmon habitat.
Transfer tourist expenditure data and combine with data about tourist visitation to old growth sites at pilot location for evaluation of the tourism ecosystem service (may require primary data collection)	**Adopted** for tourism-based producer surplus only.
Apply market prices to modelled outputs for volume of old growth timber harvested and volume of remaining old growth to evaluate the following ecosystem services under each scenario: timber harvest, carbon storage and sequestration	**Adopted**
Address significant data gaps by partnering with a university graduate student (e.g., from Simon Fraser University's Department of Resource and Environmental Management) to collect primary data using contingent valuation surveys, choice experiment surveys, and/or other methods as required	**Adopted** by AFA, in progress with SFU
Consider strengthening partnerships with other ENGOs and First Nations to leverage funds, capacity and expertise to support an Island-wide valuation effort	**In progress**, AFA

2 Methods

2.1 Site Selection

Our pilot site selection was constrained to areas where intact old growth forests still exist on Vancouver Island. Whereas all forested area on Vancouver Island before European colonization (2,873,000 ha) was once old growth, subject only to natural and very limited human disturbance, only 39% (1,119,000 ha) of that total area is currently old growth, only 19% (550,000 ha) is of productive quality, and only 8% (218,000 ha) is at low to medium elevations with the biggest trees, highest carbon storage per hectare, and highest biodiversity[1] (see Figure 2). About 70% (777,125 ha) of remaining old growth (all productivity types) is in publicly owned and managed forests, with roughly 32% (250,000 ha) of that area still available for harvest.[2] While we also evaluated other criteria (see Morton et al. 2019), our site selection focused on publicly owned and managed forest lands primarily due to the expected difficulty of obtaining timber harvest data from private forest companies. In addition, we did not consider protected areas for the pilot study since these have been withdrawn from the harvesting land base.

Our initial scoping with the Ancient Forest Alliance (AFA) identified three candidate areas of old growth forest on Vancouver Island that might be suitable for a pilot study, all of which are near communities transitioning from resource-based economies: a) Port Renfrew, b) Tahsis, and c) Port Hardy (Figure 3). The Tofino area was excluded for pilot purposes since Clayoquot Sound's unique forest management arrangements are not representative of the rest of Vancouver Island.

Figure 3. Candidate sites for pilot study. Projection: NAD 1983 BC Albers. See Figure 2 caption for data sources.

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[1] Sierra Club BC 2016 (https://sierraclub.bc.ca/white-rhino-map-shows-vancouver-islands-most-endangered-old-growth-rainforests/)

[2] The BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) estimated 44% (840,125 ha) of public forestland was old growth in 2013, 37% (313,000 ha) of which was considered harvestable (FLNRORD 2013). Assuming an average rate of 9,000 ha/yr for old growth harvest on Vancouver Island based on the Sierra Club's old growth harvest rate estimates for 2011 to 2015 (Sierra Club 2016), this results in 777,125ha of old growth in public forest land and 250,000 ha of harvestable old growth.

Based on the recommendations of the Phase 1 report and subsequent discussions with AFA, old growth forests near Port Renfrew were selected as a pilot case study. A key driver of this decision was data availability, however this site also aligns well with AFA's goals, has stronger community support for alternative old growth uses, and offers a relatively large suite of ecosystem services that, if evaluated, will be transferable to areas of the Island where only subsets of these services are relevant.

During data collection for this project, ESSA was able to obtain provincial timber harvest data from the recently completed (2018) Arrowsmith Timber Supply Review (TSR), including growth curves for different stand types, harvest projections, and GIS shapefiles showing the areal extent of publicly owned and managed forests inside the South Island TSA, which includes Port Renfrew.

2.2 Site Description

Figure 4 below shows a 35km buffer around Port Renfrew, BC, which represents the spatial scope of this study. Located on the southwest coast of Vancouver Island approximately 2 hours west of Victoria with a permanent population of just 144 people (2016 census), Port Renfrew is a key area of interest for the AFA. Eco-tourism is an important part of the local economy given the town's proximity to the provincial capital, its status as the terminus of the renowned West Coast and Juan da Fuca trails, and as a sportfishing destination. For the last decade, the AFA has engaged in advocacy to protect old growth around Port Renfrew, raising the public profile of several unique groves and tall trees in the area (e.g., Avatar Grove, Jurassic Grove, Mossome Grove). These efforts have contributed to the growth of local eco-tourism and the town's embrace of the tourism potential of old growth forests. Port Renfrew now brands itself the 'Tall Tree Capital of Canada'.

The area also encompasses almost all the traditional territory of the Pacheedaht Nation, which include lands and waters along the southwest coast of Vancouver Island between Bonilla Point and Sheringham Point, as well as the main Pacheedaht community near Port Renfrew. The Pacheedaht Nation owns, manages or co-manages forest lands that produce a 140,000 m^3 annual cut of timber and owns/operates two facilities: a log sorting facility for TFL 61 (employs 12 people, including 2 Pacheedaht members), and a sawmill built in 2017 that processes 10,000 m^3 per year into high value specialty cedar products (employs 8 people, including 6 Pacheedaht members). Plans are also underway for a chipping facility. The Pacheedaht initiated a forest conservation strategy in 2005 and are currently in the process of identifying the cedar supply needed to fill traditional use needs over the next 400 years, which is the length of time for a red cedar to mature sufficiently for certain traditional uses (see Natural Resources Canada's "Successful Indigenous-industry Partnerships in the Forest Sector: The People of the Sea Foam" at: https://www.nrcan.gc.ca/our-natural-resources/forests-and-forestry/state-canadas-forests-report/successful-indigenous-industry-partnerships-forest-sector-people-seafoam/21197). They have also recently developed an Integrated Resource Stewardship Plan that includes the identification of special sites, traditional use areas, and conservation areas to guide forestry-related activities in the territory. In addition to Pacheedaht territory, the study area overlaps traditional lands of the Ditidaht, Te'mexw, Hul'qumi'num, and W̱SÁNEĆ Nations (https://native-land.ca).

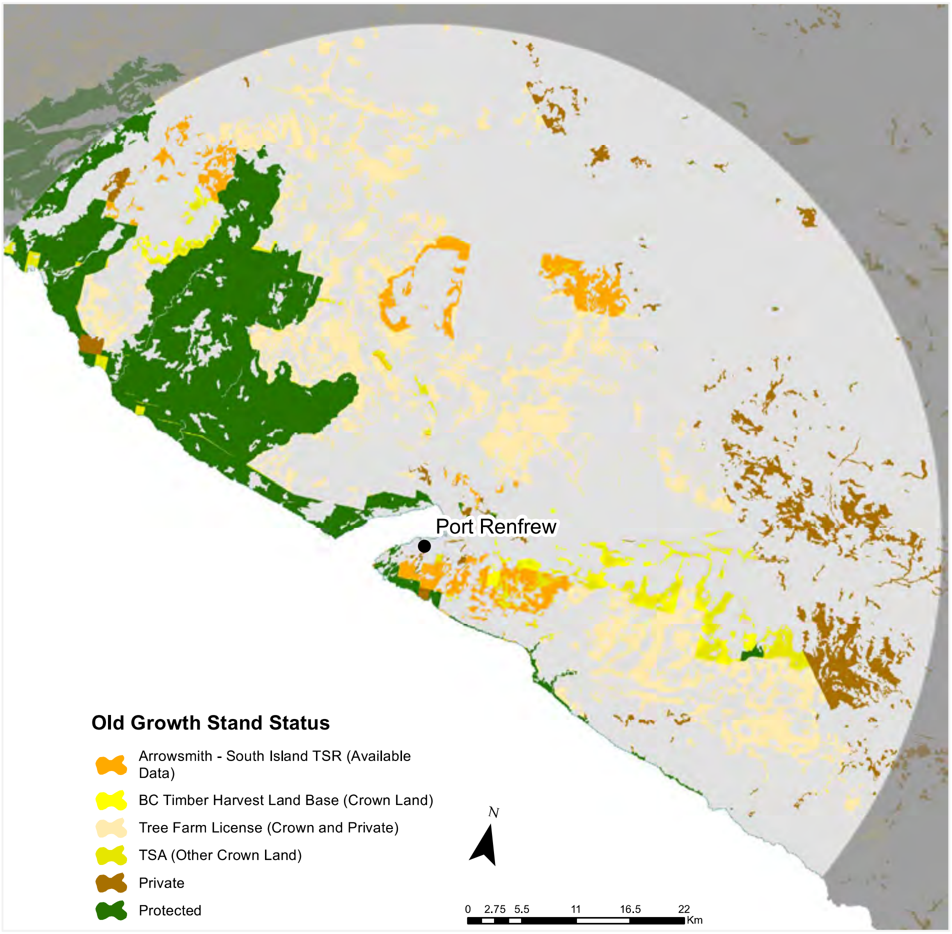

Figure 4. Status of old growth stands >140 years near Port Renfrew. Data BC (2019), Arrowsmith-South Island Timber Supply Review (2016). Projection: NAD 1983 BC Albers

The study area is situated primarily within the Coastal Western Hemlock biogeoclimatic zone (Snetsinger 2011, Nicholls 2018) and is located within BC's South Island Natural Resource District and the Arrowsmith Timber Supply Area (TSA). The community is also bordered by Tree Farm License (TFL) 46 held by the Teal-Jones Group (Snetsinger 2011). Using the total *forested* area currently within a 35km radius around Port Renfrew (i.e., the study area) as a proxy, the total area of historical old growth prior to harvest disturbance would have been over 200,700 ha. According to the provincial VRI data used for this study, about 32% (64,951 ha) of that old growth forest now remains (see Figure 4), 36% (23,599 ha) of which is protected either provincially or federally, 7% (4,729 ha) of which is within the Provincial Timber Supply Area (TSA), and 4% (2,783 ha) of which is both in the TSA and eligible for harvest under the Arrowsmith TSR (the other 3% in the TSA is not currently eligible for harvest). The remaining old growth (54%) is in private lands or other Crown lands for which no harvest data are publicly available. Orange old growth areas in Figure 4 are stands for which TSR model data were acquired by ESSA for this pilot study. Note that younger stands inside TSR data boundaries (not shown in Figure 4) are also included in this study's vegetation inventory, some of which are harvested and some of which grow to achieve old growth status during the 100-year time horizon.

2.3 Timber Harvest Modelling

Timber supply simulation models are an essential tool for non-market valuation of actively logged tree stands. Outputs from these models are needed to establish a baseline timber harvest scenario that can then be compared with alternative management scenarios. While the modelling process can be quite involved and complex[3], most timber supply models assess different timber harvest strategies by performing two key functions: they estimate changes in the area and/or volume of harvestable timber over time due to 1) disturbances, including logging, and 2) tree growth and species succession. Area, volume, and stand composition outputs from these models can be used directly or coupled with other models to perform ecosystem service valuation and to estimate producer surplus from timber harvests. Multiple modelling options are available (see Phase 1 report), including the Forest Service Spatial Analysis Model (FSSAM) used by FLNRORD for Vancouver Island's most recent timber supply review (TSR) in the Arrowsmith Timber Supply Area (MFLNRO 2016; MFLNRORD 2018). For this analysis, FLNRORD provided ESSA with FSSAM growth curves for merchantable timber (m^3/decade), TSA area shapefiles, and overall harvest levels that were used in the Arrowsmith TSR. We applied these data using the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) to simulate carbon volumes and timber harvest volumes for baseline ('business-as-usual') and alternative harvest scenarios. We describe FSSAM and CBM-CFS3 in more detail below.

2.3.1 Forest Service Spatial Analysis Model (FSSAM)

The Forest Service Spatial Analysis Model (FSSAM) is a timber supply simulation model developed in-house by FLNRORD using Java (latest build: JDK version 8u31). FSSAM considers the interactions between forest development, natural disturbance, and management intervention processes to project the impact of forest management strategies on forest structure over time (Di Lucca 2006). Model inputs include GIS-based landbase inventories and harvest parameter values. FSSAM is modular, meaning there are several different sub-models that can be incorporated into the main model. This modularity can make for a complex modelling system, but FSSAM accommodates lower degrees of complexity depending on modelling and research needs. For example, Crowley's (2007) doctoral research simplified the system into three main 'phases': a) a Policy Phase determining whether to apply a logging action to a specific geographic 'cell' (e.g., clear cut, thin, treatment), b) a Constraint Optimization Phase that removes cells from the first phase based on constraints like biodiversity conservation and maximum/minimum harvest rules (e.g., annual allowable cut), and c) a Simulation Phase that simulates tree growth and death to project a future state of the entire forest given results from the other two phases. The model is currently being phased out by the Province due to Java licensing issues. Outputs from FSSAM are publicly available by request.

2.3.2 Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)

Natural Resources Canada's Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) simulates carbon dynamics and calculates the stock of carbon in a forest under different forest management and disturbance scenarios (Kurz et al 2009; Natural Resources Canada 2019). The

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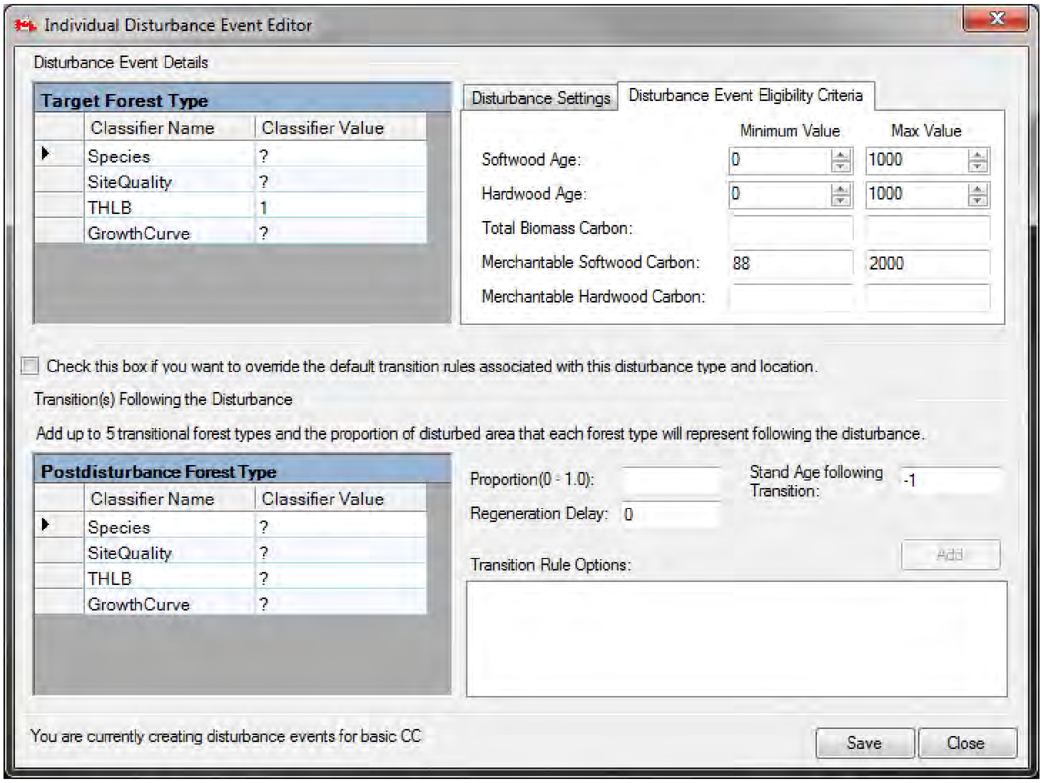
[3] Sutherland et al. (2007) took 3 years to complete their timber supply modelling of multiple Timber Supply Areas in BC's interior

model accounts for carbon stored in above and below ground biomass, as well as litter, dead wood, and soil organic carbon. CBM-CFS3 complies with the Intergovernmental Panel on Climate Change's (IPCC) carbon estimation methods outlined in Good Practice Guidance For Land Use, Land-Use Change and Forestry (2003) and is approved for use in carbon budget modelling for the BC forest sector.



Target Forest Type

Classifier Name	Classifier Value
Species	?
SiteQuality	?
THLB	1
GrowthCurve	?

	Minimum Value	Max Value
Softwood Age:	0	1000
Hardwood Age:	0	1000
Total Biomass Carbon:		
Merchantable Softwood Carbon:	88	2000
Merchantable Hardwood Carbon:		

☐ Check this box if you want to override the default transition rules associated with this disturbance type and location.

Transition(s) Following the Disturbance

Add up to 5 transitional forest types and the proportion of disturbed area that each forest type will represent following the disturbance.

Postdisturbance Forest Type

Classifier Name	Classifier Value
Species	?
SiteQuality	?
THLB	?
GrowthCurve	?

Proportion(0 - 1.0):

Regeneration Delay: 0

Stand Age following Transition: -1

You are currently creating disturbance events for basic CC

Figure 5. An example of the CBM-CFS3 user interface (in this case, the screen used to define stand age limits for disturbance simulations)

Inputs to CBM-CFS3 are generally the same as those used for timber supply models, including timber harvest scenarios, growth curves for each type of tree stand, and landcover inventories like the BC Vegetation Resources Inventory (VRI). The model operates entirely in terms of carbon, so outputs include the volume of carbon stored in each 'carbon pool' (above ground biomass, below ground biomass, and dead organic matter), the volume of carbon harvested, and tree stand age class distributions for these results. As such, the model can be used to simulate both carbon storage and, with a carbon-to-timber conversion, timber supply over defined time periods. This ability to provide both outputs is a key advantage since carbon storage/sequestration is one of the ecosystem services of interest for the current study.

The main limitation of CBM-CFS3 is that it is aspatial, although a spatially explicit version of the model is currently in development (see https://cfs.nrcan.gc.ca/projects/5/1). This means that analyses within the model cannot include overall cutblock sizes or adjacency requirements such as how far harvest cutblocks must be from one another or proximity to streams, and that post-processing analyses and reporting are not done using maps. Regardless, given a starting inventory, harvest rule sets, and stand-level growth curves, CBM-CFS3 can simulate multiple alternative scenarios and provide the resulting carbon emissions, storage, and removals in tonnes of carbon (tC). While these volume-based outputs are not tied to fine-scale geographic locations, they can be converted to hectares using some simplifying assumptions, then paired with per-hectare dollar values for a specified area or region.

An important advantage of the CBM-CFS3 approach is its ability to scale up beyond a small pilot study site if baseline harvest data, growth curves, and spatial extents are available. Additionally, the model can accommodate a wide range of scenarios, including transitional ones where different levels of old growth protection are phased in over time.

For this study we used CBM-CFS3 Version 1.2.7271.303 (December 2019). In June 2020 a new version of the CBM-CFS3 was released which fixed a bug that affected the calculation of carbon in small trees. The analyses contained within this report have not been repeated with this version of the model. In general, however, the carbon in old growth stands will be virtually unchanged, while the carbon in younger stands will be somewhat higher. This report focusses on differences between a baseline and scenarios, and there will be little impact on these differences. Therefore, while the specific numeric values could change slightly, the overall conclusions would be unaffected.

2.3.3 Modelling Procedure

CBM-CFS3 operates at an annual timestep and our application of the model uses the tree stand as its basic spatial unit of analysis. The model simulates a user-defined ‘disturbance’ scenario across all stands that are provided as inputs. A ‘stand’ in this context is an area that contains the same initial attributes such as dominant species mix, age class, and the growth curve associated with the stand’s species mix. For each annual time step, the model either simulates disturbances to any stands meeting the right criteria, or ‘grows’ the stands in accordance with their growth curves.

We acquired all input data for CMB-CFS3 modelling from the Arrowsmith Timber Supply Area Review (TSR), which we received from FLNRORD in report form and as a georeferenced shapefile that was generated from the FSSAM TSR analysis (see Section 2.3.1). All growth curves were available from these data as merchantable volume (m^3) over time in ten-year increments up to a stand age of 350 years. We made no alterations to the TSR growth curves as received. Some stands had two growth curves assigned, one for pre-harvest and one for post-harvest. Where this was the case, the CBM-CFS3 used the pre-harvest growth curve until the stand was harvested and then switched to the post-harvest growth curve for the regrowth of the stand (Figure 6).

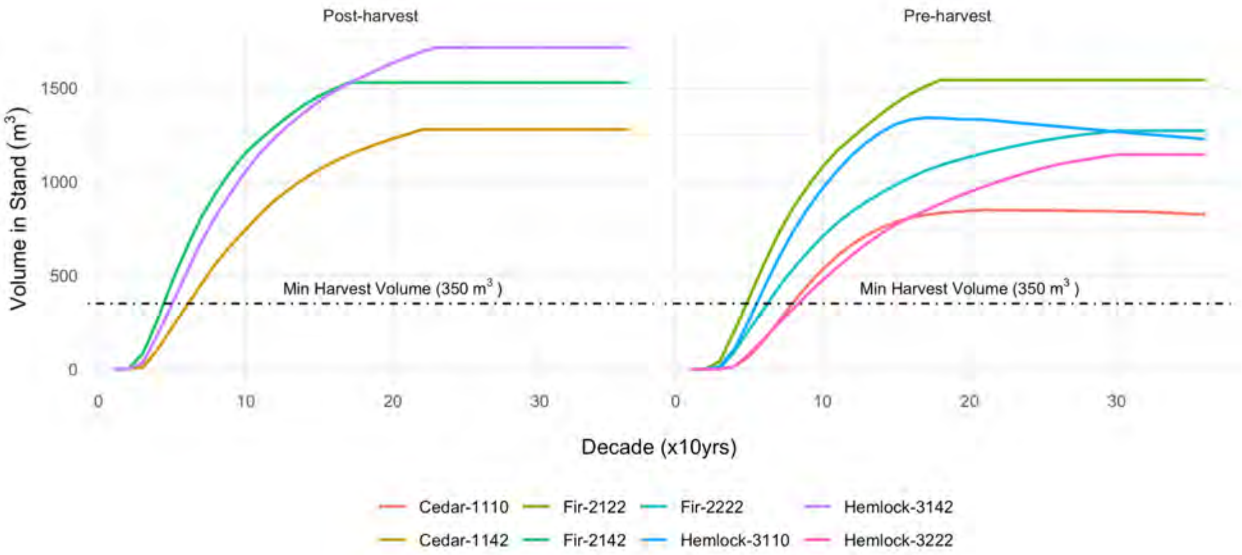


Figure 6. Example growth curves for different stand-level species classes post-harvest and pre-harvest. The minimum harvest volume is shown (dashed line). Different curve IDs indicate growth curves applied to different stands.

Key **inputs** we provided to the model include the following:

- Stand-level species classification (balsam, cedar, alder, Douglas-fir, lodgepole pine, spruce, pine, hemlock)
- Stand-level growth curves (we assume these are based on species mix, but were unable to confirm this with the documentation received from FLNRORD)
- Stand-level harvest classification (i.e., harvestable/non-harvestable)
- Stand-level age class (where each age class contains ten years)
- Planned harvest targets (tC)

We kept all other input values and parameters at the CBM-CFS3 default values for the Pacific Maritime region of British Columbia. These default values cover a range of parameter settings including decay rates, mean annual temperatures, and volume to biomass equations, among others (see Kull et al. 2019 for a full listing).

In addition to input data and parameter settings, for the model to run, CBM-CFS3 requires some starting values for biomass and dead organic matter. Initial biomass values in CBM-CFS3 are calculated based on the stand's species, age class, growth curve, and the model's default volume-to-biomass conversion factors (Kull et al 2019). Starting values for the DOM pools are calculated at the beginning of the simulation using a combination of default initial values, stand growth curve, predominant historic disturbance for the stand and the most recent disturbance for the stand. Details about this process can be found in the CMB-CFS3 user guide (Kull et al. 2019). For this analysis, we assumed that fire was the only historical disturbance type over the last millennium, except for all stands in the current inventory that were younger than 120 years. For these stands, we relied on local knowledge supplied by AFA, which suggested harvesting began in the late 1800s and increased into the mid-20th century (i.e., the 'harvest' disturbance type was assigned).

Disturbance types, the magnitude of disturbance, and the rules for selecting which areas are disturbed in the main model simulation are user-defined. Disturbance types can include fire, beetle kill, land-use change, different types of timber harvest and other disturbance. Disturbance rules can include, for example, target tree species, stand age or age class thresholds, merchantable timber volume thresholds, or can be randomized. When a stand is 'disturbed' in the simulation it results in a change to each carbon pool associated with that stand and, if it is a 'stand replacing' disturbance (i.e. the stand is completely removed), it will reset the stand's age. Different disturbance types can have different impacts. For example, a harvest disturbance might cause the 'merchantable' biomass to leave the stand (to become wood products), and allocate the remaining branches and leaves to the dead organic matter (DOM) pools, whereas a fire might change the stem biomass into a snag, but release the carbon from foliage and the aboveground DOM pools. CBM-CFS3 contains default parameter values for many different disturbance types and permits modification of these values if desired by the user. We assigned our harvest disturbance to use the CBM-CFS3 default settings for a coastal BC clear-cut with slash burn disturbance.

At every annual time step, the model seeks to achieve a user defined 'target' disturbance. In the case of harvest, all stands eligible for harvest are grouped based on growth curve, age class, species, and area-type designation (e.g., inside/outside timber harvest land base). The user defines a minimum volume threshold before a disturbance is triggered, and stand records are then sorted by volume. The harvest disturbance is applied in rank order with the highest volume stands harvested first, working down the list of eligible stands until either the target harvest level is reached or there are no more eligible stands.

During the simulation, if a stand is not disturbed, it is instead 'grown'. The CBM-CFS3 will advance the stand one year along its growth curve. At model initialization, the CBM-CFS3 changes the 'merchantable volume curve' (input by the user) into several different components: 'merchantable' carbon, non-merchantable bole, branch, leaf and root carbon (Kull et al. 2019). Using this curve, the model assigns carbon values corresponding to the new stand age. Simultaneously, the model captures the annual turnover of foliage, roots, and branches as well as any other stand decay. To do this, it makes assumptions about how much biomass should be transferred to the dead organic matter carbon pools (e.g., leaf and branch fall). Finally, and for all stands, whether they are disturbed or not, the soil pools will decay and release carbon. We used the CBM-CFS3 coastal BC default values for all biomass calculations and soil decay/transfer values (Kull et al. 2019).

Once the model simulation is complete, a set of annual **outputs** are generated that include the following:

- Harvested carbon (tC by species)
- Remaining carbon stocks[4] (tC)
- Annual change in carbon stocks (tC)
- Area (ha by age class[5] and species)

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[4] Includes above ground biomass, below ground biomass, and dead organic matter (i.e., soil, coarse woody debris, snags)

[5] There are 11 age classes. The first ten classes are 20-year classes (e.g., 0-19, 20-39, etc.), and the 11th class is all area 200 years old and older.

Since we categorize each stand in the simulations based on whether it is located inside the **timber harvest land base** (classified as harvestable per the Timber Supply Review), inside the **non-timber harvest land base** (classified as *not* harvestable per the Timber Supply Review), and inside simulated **'protected' areas** that are created within either of the previous two zones based on old growth protection targets (see Section 2.4.2), outputs from CBM-CFS3 are generated for each of these categories.

2.4 Timber Harvest Baseline and Scenario Modelling

2.4.1 Baseline Scenario

A baseline scenario provides a basis for comparison of results with other alternative harvest management scenarios. The baseline scenario we use in this study is the "business as usual" case, or the scenario that simulates what harvest management is currently planned for the study area.

Our baseline is derived from the Timber Supply Review (TSR) data received from FLNRORD (see Section 2.3), using some adjustments to account for the fact that our study area is only a subset of the full Timber Supply Area (TSA). The Arrowsmith-South Island TSR sets an annual allowable cut (AAC) at 348,000 cubic metres, distributed as follows: a) 50,000 cubic metres from the Eastern timber supply blocks of Nanaimo and Cowichan, b) 6,850 cubic metres from the Clayoquot Sound Land Use Decision area, and c) 291,150 cubic metres from the remaining Western portion of the TSA (FLNRORD 2018). Our study area is a subset of the *Western* part of the TSA, so we used a proportional assumption to estimate its AAC. Harvesting can only occur in the parts of the TSA that are designated by the TSR as 'timber harvest landbase' (THLB), so we determined the proportion of the Western THLB that is located within our study area, then multiplied the total Western AAC by this value to estimate our study area's target harvest volume (62,483 m^3, or 21% of the Western THLB). We then multiplied this volume by a standard Canadian timber-to-carbon conversion factor (0.25) to calculate the approximate planned 'carbon harvest', which is 15,620 tC. At each annual time step in the model simulation.[6] CBM-CFS3 attempts to meet this planned carbon harvest but is constrained by several rules and assumptions shown in Table 4 at the end of the next section.

2.4.2 Timber Harvest Scenarios

In addition to a baseline 'business as usual' case, at least two alternative scenarios are desirable to facilitate comparison across different old growth harvest strategies. In their valuation of old growth in the Fraser Timber Supply Area, Knowler and Dust (2008) assessed a 'Suit100' scenario that assumed 100% protection of stands currently meeting the minimum requirements for suitable Spotted Owl habitat, and a 'Terr100' scenario that assumed 100% protection of contiguous old growth regardless of meeting those minimum requirements. Because we had access to Arrowsmith TSR input data which are compatible with the CBM-CFS3 model, and due to the flexibility of CBM-CFS3, we were able to simulate many more timber harvest scenarios in a relatively short timeframe (19 in total, see Table 3).

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[6] 0.25 is a standard m^3 to tonnes of carbon conversion factor used for Canada

Table 3. Alternative timber harvest scenarios used in this study

ID	Description	Definition of Old Growth
Immediate Protection Scenarios		
1	30% of OG in thlb and non-thlb protected indefinitely in year 1	> 250 years
2	50% of OG in thlb and non-thlb protected indefinitely in year 1	> 250 years
3	70% of OG in thlb and non-thlb protected indefinitely in year 1	> 250 years
4	100% of OG in thlb and non-thlb protected indefinitely in year 1	> 250 years
5	30% of OG in thlb and non-thlb protected indefinitely in year 1	> 140 years
6	50% of OG in thlb and non-thlb protected indefinitely in year 1	> 140 years
7	70% of OG in thlb and non-thlb protected indefinitely in year 1	> 140 years
8	100% of OG in thlb and non-thlb protected regardless of time step	> 140 years
Transitional Protection Scenarios		
9	Transition from 50% to 75% OG protection within 10yrs	> 250 years
10	Transition from 50% to 100% OG protection within 4yrs	> 250 years
11	Transition from 50% to 100% OG protection within 10yrs	> 250 years
12	Transition from 50% to 100% OG protection within 20yrs	> 250 years
13	Transition from 50% to 75% OG protection within 10yrs	> 140 years
14	Transition from 50% to 100% OG protection within 4yrs	> 140 years
15	Transition from 50% to 100% OG protection within 10yrs	> 140 years
16	Transition from 50% to 100% OG protection within 20yrs	> 140 years
No Harvest Scenario		
17	No harvesting of any timber	Definition not relevant
Additional Baselines (sensitivity testing only; not reported)		
18	Base case but with no Hemlock harvest	Definition not relevant
19	Base case but prioritizing oldest stands first (instead of by volume)	Definition not relevant

As shown in Table 3, alternative timber harvest scenarios are defined by the level of old growth protection (e.g., 30%, 50%, 70%, 100%), the age at which a stand is considered ‘old growth’ (250 years, 140 years), and whether old growth protection occurs immediately or transitionally over different time periods (e.g., 50% to 100% over 4 years, 10 years, 20 years).

In most scenarios, protection of old growth is distributed across the timber harvest land base (THLB) and the non-timber harvest land base (non-THLB). For example, in Scenario 2, 50% of old growth is to be protected so 50% of the stands >250 years old are protected in the THLB, as are 50% of the stands > 250 years old in the non-THLB (older stands >250 are not prioritized over younger stands >250). In these scenarios, we do not assume non-THLB stands are already ‘protected’ because they could shift to the THLB during the next TSR. Making this assumption also errs conservatively by not ‘over-protecting’ the THLB (i.e., only protecting old growth in the THLB). For the two scenarios with 100% old growth protection (Scenario 4 and Scenario 8), all old growth is protected indefinitely in year 1 regardless of harvest designation, but for Scenario 8 any additional stands that have achieved old growth status in subsequent time steps are also protected. This means that unlike the other scenarios, the total area of protected forest increases in Scenario 8 over time.

The transitional scenarios (Scenarios 9-16) are slightly different. In all cases an initial 50% old growth protection is automatically applied and evenly distributed across the THLB and the non-THLB in the same way as the immediate protection scenarios. For the 4-year transitions (Scenario 10 and Scenario 14), we incrementally increased the proportion of protected old growth each year up to 100% in the final year. For the 20-year transitions (Scenario 12 and Scenario 16), this incremental approach led to some processing difficulties in the model.[7] Instead, we estimated a constant area (m^2) to protect each year from year 2 to year 19 (oldest stands protected first), then protected 100% of any remaining old growth in year 20 and beyond. This approach ensured 100% protection of old growth by the end of the time period but resulted in larger or smaller new area of old growth protection in year 20 compared to preceding years. For the 10-year transitions (Scenarios 9, 11, 13, 15), we completed simulations with a >250 year old growth definition in the same way as the 4-year transitions, and those with a >140 year old growth definition in the same way as the 20-year transitions (primarily due to sequencing of model runs).

All scenarios except the ‘no harvest’ scenario (Scenario 17) attempt to achieve the AAC (i.e. 62,483 m^3 / 15,620 tC per year) but in each protection scenario we adjust the AAC from the baseline to reflect the fact that the Province would change the AAC as stands eligible for harvest are reduced. We apply this adjustment proportionally using the change only in the area of the *THLB portion* of the TSA that is eligible for harvest (e.g., if an 80% OG protection scenario resulted in 10% of the original THLB area being protected, the AAC would be reduced by 10% for that scenario).

Table 4. Assumptions used in timber harvest scenarios

Assumption	Interpretation
All scenarios have a target volume, which is reduced from the base case depending on % decrease in eligible stands in the THLB	Target harvest volumes are reduced in each scenario as old growth protection increases. Volume adjustments are made proportionally based on the area of eligible stands remaining in the THLB relative to the base case.
Old growth protection is evenly distributed across stands in the THLB and non-THLB	Only eligible stands in the THLB can be harvested. Protecting stands in the non-THLB first would disproportionately reduce the impact on harvest while protecting stands in the THLB first would disproportionately increase the impact on harvest. Even distribution is a middle ground.
Individual stands are ranked for harvesting in order of highest volume first	Other harvest prioritization criteria are not considered (e.g., preferred species, highest age) in the main analysis. We ran one alternative base case as a sensitivity analysis that prioritized oldest stands first (Scenario 19)
Individual stands must be 100% harvested before the next stand is harvested	Other harvest thresholds prior to moving to the next stand are not considered. A 100% threshold may overestimate harvest efficiency (i.e., errs conservatively). Note: If the global harvest target is achieved before a stand is 100% harvested, harvest ends
There is no minimum harvest age (just a minimum harvest volume per stand)	Stands as young as 40 years are harvested in our scenarios if the minimum harvest volume is met (i.e., errs conservatively)

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[7] Because each area was disturbed by a proportion, the area left ‘not protected’ became smaller and smaller (e.g., <0.0001ha). The CBM can deal with this, but that option was not under user control in the version of the model we used (Version 1.2.7271.303 (December 2019)).

Assumption	Interpretation
The minimum volume per stand requirement is based on the Arrowsmith TSR for stands accessible by road	Stands cannot be harvested until they achieve a volume of at least 350m^3/ha (per the TSR), or ~88 tC. Assumes all stands in the study area are road accessible. This minimum volume would be lower for helicopter logged stands
Growth curves as supplied by FLNRORD from the Arrowsmith-South Island TSR	Most growth curves appear to have little or no reduction in volume at higher ages, which means they assume little deterioration or decay in old stands - in reality, decay will occur. Thus, our results may overestimate carbon stored in biomass pools and underestimate dead organic matter pools
Harvest strategy is clear cut with slash and burn	A 'clear cut only' assumption would release the same amount of carbon into the atmosphere, but more slowly over time
All stands regrow as the same species that was harvested with a 2-yr regeneration delay	We assume stands are replanted as the same species. Where specified in the FSSAM data received from FLNRORD, different growth curves are applied to some stands before and after harvest.
No disturbances other than timber harvest	While fire disturbance is uncommon for the forests in our study area, this could shift with climate change and would mean both reduced timber available for harvest and less old growth available for protection. Insect disturbances are more unlikely.
Hardwood/deciduous stands are not harvested in the simulations (left to grow)	Only 213 ha (<1%) of the landbase in our study area is hardwood/deciduous. May need to be adjusted for future application of the model to areas with more hardwood

2.5 Valuation of Ecosystem Services

Consistent with the methods applied by Knowler and Dust (2008) and the recommendations laid out in our Phase 1 report, we adopted a **benefit transfer** approach (see Appendix A) for recreation, non-timber forest products, salmon habitat, real estate, and education and research. For timber harvest we used **market prices** (also consistent with Knowler and Dust) and for carbon sequestration we used an estimate of the **social cost of carbon**. We excluded the water quality ecosystem service since Port Renfrew relies on groundwater from wells that are distant from the timber supply area (TSA) (see Section 2.5.8).

2.5.1 Timber Production

Forestry is an important part of Vancouver Island's economy. The industry employed 10,900 individuals in 2016 (MNP 2017). Nearly half of these individuals worked in forestry & logging, a third in wood product manufacturing, and the remainder in pulp and paper. As of 2015 there were 41 major timber processing facilities on Vancouver Island, including 22 lumber mills, 3 pulp and paper mills, 3 pole and post mills, and 13 other mills producing chips, veneer, or shakes and shingles.[8] Four

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[8] Note that some changes to these counts have likely occurred since 2015.

sawmills, at least one pulp mill, and all the Island's shake and shingle mills currently rely on old growth harvests (Hernandez 2018).

Calculating the value of timber harvest requires a market price approach. Timber supply models are typically used to estimate a volume (m^3) of timber harvested over a given period, and these volumes are then multiplied by a price. **Long term economic rent** is calculated as the *revenue* from harvest less all *total costs*, including fixed costs for equipment and overhead, *plus* harvesting and delivery to market, discounted to the current year (a.k.a., 'net-present value'). Revenue is the product of timber volume (m^3) harvested and price per unit volume ($\$/m^3$), and total cost is the product of the timber volume (m^3) harvested and the cost per unit volume ($\$/m^3$).

We used the Canadian Forest Service's Carbon Budget Model (CBM-CFS3) (see Section 2.3) to estimate annual timber harvest by species for our baseline timber harvest scenario and for each of our additional scenarios (see Section 2.4). Since CBM-CFS3 provides outputs in tons of carbon harvested, we converted these results to m^3 of logs by applying the standard Canadian conversion factor ($1tC\ = 4m^3$). Further, because CBM-CFS3 does not provide outputs by timber grade and age class, we apply old-growth prices to all harvests, which may result in upwardly skewed timber harvest revenues if old-growth log prices are higher than second-growth log prices.

Timber Harvest Revenue

To calculate revenue, we followed the same approach as Knowler and Dust (2008) but with updated data. For each species, Knowler and Dust (2008) developed a price by averaging grade-weighted timber prices over seven years. They obtained price data from the Province of BC's 1999-2005 Coastal Log Market Reports, and, for the same time period, volume harvested per grade and per species from the BC Harvest Billing System (BC Timber Pricing Branch, November 22, 2019). Prices were not available for second-growth timber so Knowler and Dust relied on government price conversion parameters from the Coast Log Prices report (BC Timber Pricing Branch 2012).

For this study, we used the same approach to develop a grade-weighted average price for each species but used old-growth price data from the Coastal Log Reports and harvest data for the Arrowsmith TSA from the Harvest Billing System for 2012-2018 period (BC Timber Pricing Branch, November 22, 2019; BC Timber Pricing Branch, November 22, 2019). Since the CBM-CFS3 model does not generate data on whether harvested logs are old- or second-growth we apply the old-growth price to all logs. Doing so results in timber revenues that are potentially higher than they would be if we applied second-growth prices to second-growth logs (i.e., errs conservatively). We inflated our prices for each species to 2018 CDN dollars.

Table 5. Grade-weighted annual average log prices

Species	**Price ($\$/m^3$)**
Cedar	$212.49
Fir	$111.89
Spruce	$102.23
Cypress	$98.81
Balsam	$79.13
Hemlock	$68.21
White Pine	$62.79
Lodgepole Pine	$62.79

Alder	$41.68
Maple	$29.41
Cottonwood	$21.50

Source: Estimated by the authors

Timber Harvesting Costs

To calculate total cost, Knowler and Dust (2008) relied on data from government and industry reports (e.g., Pierce Lefebvre Consulting, and D.A. Ruffle & Associates Ltd. 2003, PriceWaterhouseCoopers 2006). Since they were evaluating over a long-time horizon, both variable and fixed costs were included in their calculation of economic rent from timber harvest. For this study, we also evaluate economic rent over a relatively long-time horizon (100 years), so it is also sensible that the costs of harvesting reflect total costs (i.e., both fixed and variable costs). For variable costs we include a variety of 'avoidable' timber harvest activities (e.g., falling, yarding, loading, and delivery), head office and administrative activities (e.g., operational overhead and road building), as well as silviculture and planting activities. Fixed costs include 'unavoidable' equipment and overhead charges. Also following Knowler and Dust (2008), we remove stumpage since our analysis is focused on assessing producer surplus generally and not how it is divided among industry or government (stumpage is the share of producer surplus that goes to the Province of BC).

We estimate annual total cost per harvested volume (m^3) of timber using data specific to the Coast forest region (Xu et al. 2018). These data originate from a BC government survey of industry harvest costs and suggest a cost for softwood logs of $81 per m^3 (2014 CAD). This value represents "tree-to-truck cost, hauling cost, cost of stumpage, and costs for forest planning and administration, road development and management, and silviculture" (Xu et al. 2018, p.269). To remove stumpage from total cost we estimate the mean sawlog stumpage paid to the Province in 2014 across all species harvested in the South Island District (BC Timber Pricing Branch, January 8, 2020), where the Arrowsmith TSA is located (Table 5). This calculation yields a total cost of $74.45 per m^3 (2014 CAD), which inflates to $79.26 in 2018 CAD.

Table 6. Average stumpage for the South Island District (2014 CAD)

Species	**Average Sawlog Stumpage ($/$m^3$)**[a]
Douglas Fir	$8.50
Cedar	$8.03
Other	$6.69
Spruce	$6.29
Cypress	$5.51
Balsam	$5.50
Hemlock	$5.35
Multi-Species Average	**$6.55**

Source: BC Timber Pricing Branch (January 8, 2020)

[a] Values do not include stumpage paid for harvests of damaged timber or salvage of post-harvest material.

We also allow total costs to decrease over time to reflect lower costs required for constructing roads to access second growth stands. This change is set at $0.12/yr (2018 CAD), consistent with the value used in Knowler and Dust (2008).

We discounted future benefits and costs to 2018 using a 3% discount rate, which reflects the 'social time preference' rate suggested by the Treasury Board Secretariat of Canada (2007), then calculated a *net* present value by subtracting the present value costs from the present value revenues.[9] This final amount represents the producer surplus from timber harvests. Note that for 'low value' species like hemlock, this amount is negative, which has implications for our timber harvest valuation results. We have erred conservatively in our estimation of timber harvest revenues by applying old growth, rather than second-growth prices to all logs (second growth prices are lower and would therefore return an even greater producer deficit). In Appendix C, we also provide a sensitivity analysis that includes variation in log prices, harvest costs, and discount rates.

2.5.2 Recreation & Tourism

Recreation and tourism are closely linked since tourists may participate in recreational activities. For economic valuation, it is important to distinguish between recreation and tourism sectors to avoid double-counting economic benefits. Westcott et al. (2014) describe recreation as the "activities undertaken for leisure and enjoyment" and tourism as "the business of attracting and serving the needs of people travelling and staying outside their home communities for business and pleasure" (pp. 328-329).[10] The authors further define a tourist as someone "…who travels at least 80 kilometres from his or her home for at least 24 hours, for business or pleasure or other reasons" (p. 330). In other words, recreationists and tourists can be differentiated based on the distance, duration, and purpose for which they travel from their home community.

Importantly, the measure of value for recreation-based services has two elements depending on whether one is a consumer or a producer. For recreational users (tourists and locals), value is assessed as changes in *consumer surplus* (e.g., via WTP/WTA) while for tourism operators it is assessed as the contribution to *producer surplus*. Recreational users may also incur expenses at recreation-oriented sales outlets, but the resulting producer surplus is usually so small it is ignored. Following Knowler and Dust (2008) we assess the recreation *consumer surplus* of independent forest-based recreation accruing to BC residents, and evaluate the tourism *producer surplus* accruing to commercial outdoor recreation operators.

Consumer Surplus from Outdoor Recreation/Tourism

Outdoor recreation activities are a popular pastime in British Columbia. In 2012, 48% of respondents to a representative survey engaged in land or water-based non-motorized outdoor recreation at least once that year (Kux and Haider 2014).[11] The most popular non-motorized activity was hiking (40% of

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[9] All components of that are part of our analysis are discounted using the same rate. We conduct a sensitivity analysis using multiple discount rates, including a discount rate of 8% to reflect the 'real discount rate' recommended by the Treasury Board Secretariat of Canada (2007).

[10] Statistics Canada similarly defines tourism as "the activities of persons travelling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes". https://www.statcan.gc.ca/eng/nea/gloss/tourism

[11] Non-motorized outdoor activities were defined as those "…during which the participant relies on their own body for movement" (Kux and Haider 2014: 2). This definition included bicycling or non-motorized watercraft, as well as hunting, fishing and horseback riding although participants engaging in the latter three activities only were screened out of the second stage of more in-depth questions.

sample), followed more distantly by fishing (18% of sample) and other activities. A 2009/2010 study assessed 1300 recreation sites and 800 trails on Crown land managed by Recreation Sites and Trails BC and estimated over 3.3 million user days at recreation sites and over 6.3 million user days at trails (MNP 2011). These activities contribute significantly to local and regional economies through spending, tax revenues, and jobs (MNP 2011), and through broader benefits to society such as reduced health care costs and overall economic welfare.

To our knowledge, all BC-based assessments of old growth forest recreation values apply a benefit transfer approach (e.g., van Kooten 1995, van Kooten and Wang 1998, van Kooten and Bulte 1999, and Knowler and Dust 2008). These studies typically rely on recreation values from the province-wide 1989/1990 Outdoor Recreation Survey (BC Ministry of Forests 1991), which did not focus exclusively on recreation in old growth forests, but did estimate forest-based recreation use, preservation values, and non-use values for BC's forests more broadly. Converting values from this report into dollars-per-area requires assumptions about the area of forests used for recreation. For example, van Kooten and Bulte (1999) assumed that these dollar values applied to mature forests only, while Knowler and Dust (2008) adjusted the values to align with activities occurring in the Fraser Timber Supply Area (e.g., hunting values were excluded since hunting was not a common activity in the area). Wilson (2010) used an alternative source, instead drawing on estimated recreation expenditures reported in a 1996 national survey of natural areas (Federal-Provincial-Territorial Task Force on the Importance of Nature to Canadians 1999).[12]

For this study, we follow van Kooten and Bulte (1999) and Knowler and Dust (2008) in applying results from the 1989/1990 Outdoor Recreation Survey (BC Ministry of Forests 1991). This survey remains the most comprehensive assessment of recreational activity taking place in BC's non-park public forests and includes contingent valuation scenarios aimed at eliciting use and preservation values. Unfortunately, estimates of forest recreation values for BC have not been updated since the 1989/1990 study was released. We highlighted this key data limitation in our Phase 1 report, and AFA is currently seeking to address it for sites on Vancouver Island in collaboration with Simon Fraser University by conducting primary data collection (see Section 5). While the age of the study is concerning and updates to these data should be prioritized, some comfort may be found in the fact that a 30-year test-retest study by Neher et al. (2017) determined that surveyed WTP values for river flows to support whitewater rafting were not statistically different across time periods. Price et al. (2016) found similar results for drinking water quality over an 8-year period. Over shorter periods of time the literature is more mixed about the stability of contingent valuation estimates (e.g., McConnell, Strand, & Valués, 1998; Jorgensen, Syme, Smith, & Bishop, 2004; Brouwer & Bateman, 2005; Brouwer, 2006; Brouwer, 2012).

Our application of the 1989/1990 Outdoor Recreation Survey to the Port Renfrew region closely follows that of Knowler and Dust (2008), although there are key differences. First, Knowler and Dust estimated the total use value for the province, then a per hectare value for the Vancouver Forest Region (VFR).[13] However, the Ministry of Forests survey already reports total use values for the VFR, so we rely on these regional estimates as our starting point. Second, whereas it is unclear whether Knowler and Dust incorporated values for the entire BC population or just adults, we retain the initial Ministry of Forests' use values elicited during the CVM portion of the survey because we focus on adults only. Third, Knowler and Dust estimated recreation consumer surplus in per hectare terms only, while we

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[12] A more recent survey, the '2012 Canadian Nature Survey', estimated expenditures on nature-based recreation by the residents of each Canadian province (Federal, Provincial, and Territorial Governments of Canada 2014).

[13] The Vancouver Forest Region has since been divided into the West Coast and South Coast Regions.

apply the Ministry of Forest study's annual per capita 'recreation use days' (RUDs per BC adult) for recreation in the VFR to generate per capita use estimates. We use these estimates alongside the projected provincial adult population to predict current and future recreational use (thus our estimates are 'per adult per hectare'). Lastly, Knowler and Dust (2008) adjusted their values and RUDs for income elasticity of demand. We do not make this adjustment owing to lack of local information about elasticity rates for all outdoor recreation activities.[14] If income is positively related to demand for forest-based recreation (a reasonable assumption), our per unit recreation values yield a conservative estimate of the consumer surplus from recreation-based activities enjoyed by visitors to the study area's forests.

We estimated the total recreational use value of the VFR by summing total use values reported in the 1989/1990 study from the following activity categories: nature study; boating; motoring; fishing; camping / swimming; hiking / skiing; hunting; and 'all others'.[15] This yielded a total value of $681 million (1990 CAD) which we inflated to $1.15 billion (2018 CAD). We divide this total use value by the estimated number of adult RUDs in the VFR for the period of the study (17,125,000 RUDs), yielding $67.23 (2018 CAD) per adult RUD ($/adult-RUD). We then multiply this per RUD value by the estimated per capita RUDs that were spent in the VFR (9.92 per BC adult), yielding an annual use value per BC adult of $666.90 (2018 CAD) for recreation in the VFR ($/adult). We divided this value by the total area of land managed by the BC Forest Service in the VFR (9,920,000 hectares [from Knower and Dust (2008)]) yielding an annual 'per BC adult per hectare' use value of $0.00007 (2018 CAD) which we multiply by 1000 to match our population data (which is in 1000s of people).[16] Our final annual use value for all activities is $0.07 (2018 CAD) per 1000 adults per hectare (2018 CAD). We assume this use value is distributed evenly across the VFR.

Like Knowler and Dust (2008) we treat recreational hunting differently and remove some recreational activity types from the total use value. We disaggregate hunting based on its share of the total use value (6.2%), and remove motoring (22.8% of the total), since preferences about forest age held by this activity group are ambiguous and there is a lack of data.[17] We also remove boating because boating opportunities in the TSA are likely minimal. After removing hunting, the annual use value becomes $0.06 (2018 CAD) per 1000 adults per hectare, while removing hunting and motoring yields an annual use value of $0.05 (2018 CAD) per 1000 adults per hectare. Knowler and Dust refer to this latter value as 'water-based and human powered' recreation. Removing boating yields an annual use value of $0.04 (2018 CAD) per 1000 adults per hectare, which we refer to as 'water-based and human powered, less boating' since this category still contains water-based activities like swimming and fishing.

To calculate hunting values, we multiply the annual use value of $0.004 (2018 CAD) per 1000 adults per hectare for hunting in the VFR by the wildlife management unit's (WMU)[18] average share of the

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[14] The income elasticity of demand for recreation may not be a significant factor. For instance, Sun et al. (2005) found that the parameter representing B.C. resident hunters' income elasticity of demand was not significantly different from zero.

[15] The category 'all others' is a classification used in the Ministry of Forests (1991) report that captures all other recreational activities (the only example of these activities given in the report is "gold panning" [Ministry of Forests 1991, pg. 1]).

[16] The 9,920,000 hectares was also used to estimate per hectare recreation values by Knowler and Dust (2008). Given that it includes "…non-forest land, and area covered by tree farm licenses…" (Knowler and Dust, 2008: 52), our estimates are conservative if the non-forest area is a large share of this area.

[17] Forest harvests increase motoring accessibility, which would increase values for younger age classes, though such harvests decrease visual quality, which decreases this value. The net effect is ambiguous.

[18] Our study site is located within WMU 1-3 (occasionally written as 103).

VFR's 2009-2013 resident big game hunting days (5.17%) (Government of BC, November 18, 2019). This yields an annual hunting use value of $0.0002 (2018 CAD) per 1000 adults per hectare for the WMU. We then assume that hunting values are evenly distributed across the WMU and further adjust this value by the study site's share of the WMU (8.50%), for an annual hunting use value of $0.00002 (2018 CAD) per 1000 adults per hectare at our study site.

Again, following Knowler and Dust (2008), we add government license revenue to the total recreational use value, but only for angling since hunting data were not available. Assuming license revenue is evenly distributed across the province by angling days we first multiply the 2018 resident angling license revenue of $9,487,340 (Freshwater Fisheries Society of BC 2019), by the Vancouver Island Region's share of resident angling days (11%) (Freshwater Fisheries Society of BC, 2013), to obtain a value of $1,071,219 (2018 CAD). We then divide by the Region's area yielding an annual per hectare value of $0.23 (2018 CAD), and by the 2018 adult population of BC (in 1000s) to calculate an annual license value of $0.0001 (2018 CAD) per 1000 adults per hectare (i.e., we assume license revenues will grow in proportion to BC's adult population). Finally, we add this value to the annual 'per 1000 adults per hectare' value derived earlier for 'water-based and human powered, less boating' ($0.04 [2018 CAD]).

To allocate unit values across forest age classes in a manner that reflects recreational user preferences, we created weighted average values for our two recreation categories using the percent of the VFR's public forest in each age class in the early 1990's (BC Ministry of Forests, 1995),[19] and a relationship allocating hunting use values across forest age classes from Knowler and Dust for the hunting category (Table 7).

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[19] The data from the CBM-CFS3 has 11 age classes, while the Province's forest data has 9 classes. They largely overlap and for those that don't we match as best possible.

Table 7. Recreation values distributed across forest age classes

Age Class	**Water-Based and Human Powered** (less boating)		**Hunting**	
	Percent	Value (1000 adults/ha)	Percent	Value (1000 adults/ha)
1	9%	$0.02	16%	$0.00003
2	10%	$0.02	12%	$0.00002
3	6%	$0.01	7%	$0.00001
4	6%	$0.01	7%	$0.00001
5	4%	$0.01	7%	$0.00001
6	3%	$0.01	7%	$0.00001
7	2%	$0.00	7%	$0.00001
8	5%	$0.01	7%	$0.00001
9	5%	$0.01	7%	$0.00001
10	5%	$0.01	7%	$0.00001
11	44%	$0.08	17%	$0.00003

For each year of our modelled 100-year time horizon, we multiplied the values shown in Table 7 by BC's projected adult population for that year[20] and by the area of land at our study site in each age class in that year.

Producer Surplus from Outdoor Recreation-based Tourism

Old growth forests on Vancouver Island have clear tourism value. In 2016, the BC Chamber of Commerce approved a motion highlighting the economic importance of the remaining old growth forests to tourist dependent communities (BC Chamber 2016). Cathedral Grove in MacMillan Provincial Park near Port Alberni is a very popular and easily accessible destination for viewing old growth trees, as is the less accessible Carmanah-Walbran Provincial Park north of Port Renfrew (BC Parks 2017). Old growth forests near Port Renfrew have recently entered the public consciousness as destinations, including specific sites like Avatar Grove, Big Lonely Doug, and Mossome Grove. Awareness of these destinations has grown in part thanks to the efforts of the Ancient Forest Alliance and due to Port Renfrew's new branding as "Canada's Tall Tree Capital". After some initial publicity following the naming of Avatar Grove, Port Renfrew's accommodation providers reported occupancy growth of 75% to 100% year over year. Businesses that specifically mention old growth forests on their websites have opened or expanded, such as Handsome Dan's cottages (see testimonial from Dan Hager below) and Pacific Gateway Marina. Tour operators including Big Tree Tours, Day Trip Drea, Wild Renfrew, and Victoria's Surfside Tours all offer guided excursions to view old growth forests.

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[20] Population projections are available up to 2041. Beyond this year we use the projected adult population in 2041.

As each season goes by, we've noticed more of our guests are travelling to Port Renfrew to immerse themselves in the natural environment that our area offers. Despite the recent decline in recreational fishing activity and the discontinuance of the popular Tall Tree Music Festival, our booking activity remains constant, with summers usually close to a sell-out and the shoulder seasons each year becoming longer. By some visitors' judgements, the best time to visit old growth rainforests is when it is raining, making the Q4 and Q1 of each year quite acceptable for a visit to Port Renfrew. Our guest books are full of comments of how people enjoyed their hikes to Avatar Grove, Big Lonely Doug, or the Red Creek Fir. The increased media attention and tourist activity around Renfrew's old-growth forests over the last decade has undoubtedly increased our revenues as well as those of other tourism businesses in town and will likely continue to do so as long as those forests remain standing.

\- Dan Hager, owner of Handsome Dan's Cottage Rentals

To measure the producer surplus of commercial tourism businesses, we examined two approaches and adopted the second. First, we considered Knowler and Dust's (2008) approach and were able to gather most of the required input data using a number of steps, which we describe here. We started with the total 2005 revenue from nature-based tourism in BC ($1.2 billion) and inflated this to 2018 CAD yielding $2.028 billion annually (Destination BC 2014). Since the sector has likely grown since 2005, we also increased this value proportional to the change in tourism spending which rose 33% from 2005 to 2017 (Destination BC, 2017a, 2019). We multiplied the result by the share of Vancouver Island tourism business reliant on non-marine resources (10%) and the share of nature-based tourism revenue reliant on non-marine resources (63%) (Tourism BC 2005) to obtain a total annual revenue estimate of $169,926,120 (2018 CAD). We attributed 72% of this annual value to wilderness lands (Knowler and Dust 2008), for an adjusted total annual value of $122,346,806 (2018 CAD). Knowler and Dust then assumed that 5% of this total value is producer surplus, yielding $6,117,340 per year attributable to wilderness lands on Vancouver Island of (2018 CAD). The resulting value can then be expressed on a per hectare basis to be used in the analysis. **This 5% assumption seems low, however, when contrasted with the components of value relevant to producer surplus in our supplementary economic impact assessment** (EconIA) (see Appendix D). Let's compare.

The proportion of revenue ("total sales") that is producer surplus can also be **approximated** from standard EconIA results. Producer surplus is defined as total sales less total *variable* costs (e.g., labour, materials, which change alongside the level of output)[21], and it can be expressed as a fraction of total sales[22], with total sales derived from EconIA results for a range of sectors in the economy using the following formulas:

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[21] It is important not to confuse producer surplus with economic profit, where total *fixed* costs, like rent, lease payments that do not change regardless of the level of output, are also deducted from sales.

[22] Terminology: "total sales" is equivalent to "total expenditures" in the Input-Output modelling framework used for EconIA. The terms are used interchangeably here.

$$\%\ of\ total\ sales\ that\ is\ producer\ surplus = \frac{producer\ surplus}{total\ sales}$$

Where:

$$\begin{gathered} Producer\ surplus \\ \cong total\ sales \\ -wages\ \&\ salaries \\ -supplementary\ labour\ income \\ -taxes\ on\ products\ net\ of\ subsidies \\ -cost\ of\ intermediate\ products \end{gathered}$$

In contrast to the 5% assumption from Knowler and Dust, the estimated ratios for the accommodation and food services sector and the retail trade sector, for example, are about 8.0% and 16.6%, respectively. We used four sectors to represent the BC tourism sector (accommodation and food services, retail trade, transportation, and “other” services) and the weighted average ratio across all four sectors is about 13.2% (weighted based on % expenditure per sector). Put another way, every $1 spent in the tourism sector generates about $0.13 in producer surplus.

Applying this proportion to Knowler and Dust’s estimated total annual tourism spend of $122,346,806 (2018 CAD) yields a producer surplus value of $16,149,780 per year. Assuming this value is evenly distributed across the Island’s wilderness lands, dividing it by the Vancouver Island Tourism Region’s area (5,500,000 ha) results in $2.94 (2018 CAD) of producer surplus per hectare.

The above calculations are for illustration purposes only to demonstrate why we feel Knowler and Dust’s producer surplus ratio appears to be too low. Additional steps are needed to utilize this information in a way that provides producer surplus results consistent with our consumer surplus methodology. For example, the latter accounts for the number of recreational users per stand age class, and it is this disaggregation by stand age class that permits a linkage to old growth for harvest scenario comparisons. To achieve comparable producer surplus estimates, we generate separate producer surplus ratios for *each sector* estimated from Input-Output tables. We then multiply these ratios by estimated expenditures per sector per age class to get producer surplus per sector per age class. To estimate expenditures, we first account for projected changes in the BC population over the study’s 100-year time horizon and estimate the number of BC adults visiting the study area (and specific stand age classes) each year (see Appendix D). Summing all these values across sectors and stand age classes provides an estimate of total producer surplus for the tourism industry that varies depending on the proportion of old growth forest remaining in the study area.

2.5.3 Carbon Storage & Sequestration

Climate change resulting from human carbon emissions is one of the biggest problems facing the world today. British Columbia residents face multiple challenges related to climate change such as increased frequencies of flooding, wildfires, and drought (BC Auditor General 2018). Whether or not an old growth forest contributes to climate change mitigation depends on a long list of factors that should be carefully considered before making management decisions (Kurz et al. 1997; Sharma et al. 2013; Gray et al. 2016). Broadly, forests can help mitigate climate change by acting as a store of carbon as well as sequestering additional carbon emissions. Old growth forests store particularly large amounts of carbon above and below ground, although they grow more slowly and therefore sequester carbon at lower rates than younger forests and can emit carbon as they decay (Gray et al. 2016). Harvesting old growth forests can unlock stored carbon for release into the atmosphere, but a portion of this carbon is also converted to wood products and can be stored for short or long periods of time depending on the product.

Valuing the benefits of carbon storage typically requires estimating the volume of carbon stored and sequestered, then multiplying that amount by a per unit monetary value. The specific destination of timber as post-harvest wood products is also a key consideration since these products release carbon at different rates over time (e.g., paper products vs. wood furniture). Knowler and Dust (1999) accounted for this characteristic by first disaggregating harvested timber volumes into a) construction lumber, b) other lumber, and c) wood chips, then applying different wood product decay rates (e.g., see van Kooten 2018, Table 3) to estimate the amount of carbon released from these products over time.

Our Phase 1 review uncovered several methods for assigning a monetary value to the volume of stored carbon. Options include using a) the market-based cost of recapturing carbon, b) the cost of mitigating carbon emissions, and c) prices from actual carbon markets (e.g., cap and trade) (Kulshreshtha et al. 2000). Researchers may use multiple values of carbon to represent a range of possible market prices. For example, van Kooten and Bulte (1999) used $20/tonne, $50/tonne, and $100/tonne, while Knowler and Dust (2008) used $20/tonne, $75/tonne, and $150/tonne. More recently, Mojica et al. (2017) applied a 'social cost of carbon' at $142/ton (2016 USD) and van Kooten et al. (2019) used $50 and $100 per tonne to represent the potential value of selling carbon offset credits from forests in BC's Interior. Another option is to apply BC's carbon tax, which is currently $40/tonne and increasing annually by $5/tonne until 2021.

We estimated the value of the carbon sequestration by multiplying the amount of carbon sequestered in each year by a per unit value. We tested two different approaches to determining the unit value of carbon. The approach used for our main analysis relies on a projected 'social cost of carbon' that increases over time (ECCC 2016). Given that greenhouse gas emissions from any region of the globe affect other regions it is appropriate to adopt a global perspective when valuing the carbon sequestration service of Port Renfrew's forests. The social cost of carbon "…is a monetary measure of the global damage expected from climate change from the emissions of an additional tonne of carbon dioxide (CO_2) in the atmosphere in a given year" (ECCC 2016, p.i). This measure is appropriate for use in valuing changes in greenhouse gas emissions as part of cost-benefit analyses that compare the incremental benefits of carbon sequestration or mitigation with the corresponding incremental costs of abatement (e.g., forgone timber harvests). Note that the ECCC (2016), adopting the US Environmental Protection Agency's approach, used a discount rate of 3% when making their projection for the social cost of carbon. We used the same discount rate (3%) to value the social cost of carbon to maintain consistency with other studies and across all the ecosystem services we evaluated. We also used the GDP deflator to convert all per unit values to dollars per tonne of carbon rather than using per ton of CO_2 equivalent (CO_2e).

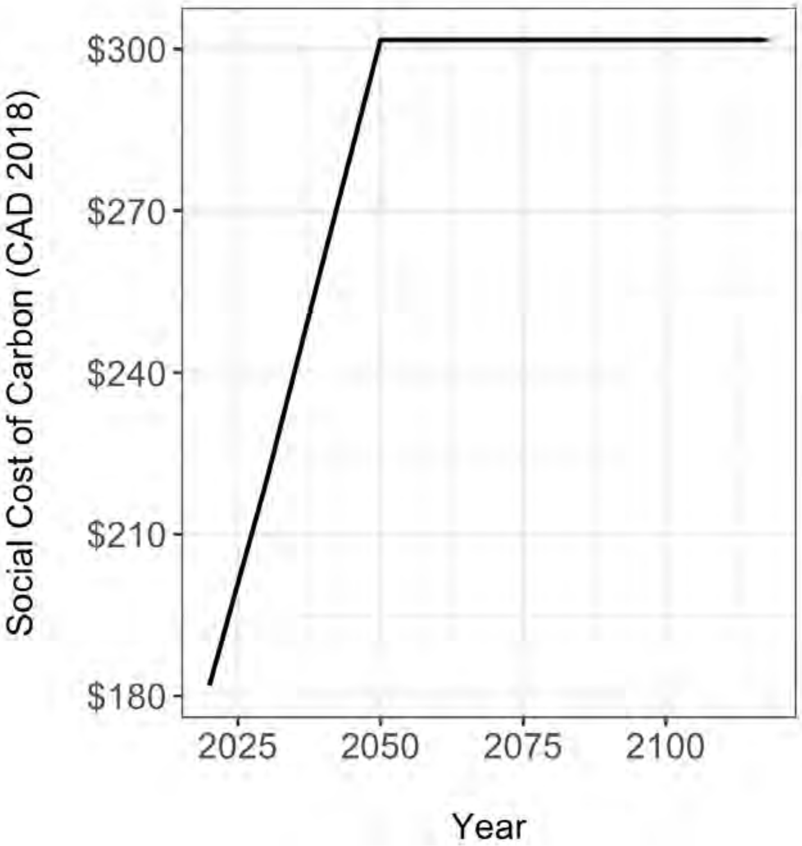

Figure 7. Social cost of carbon values used in this study, based on ECCC (2016). CAD 2018 discounted at 3%.

Since the social cost of carbon is not the same as a carbon price and a price-based method may also be of interest, the second approach we apply uses a single constant value for carbon using van Kooten et al.'s (2019) analysis of carbon offset prices. We do not use this approach in the main study, but it can be switched on or off in the economic model and we do provide sensitivity analyses using constant prices of $25, $50, and $100 per tonne in Appendix C.

We calculated changes in carbon storage for the land base as well as in wood products manufactured from harvested logs. The former volume is an output from the CBM-CFS3 model, which accounts for above and below ground biomass as well as organic matter carbon pools. We summed these pools to obtain the total carbon stored in the land base's ecosystem in each year. For wood products, we used the British Columbia Harvested Wood Product Carbon Calculator (BCMOFLNRO, 2016). This model accounts for flows of logs to various wood products and the carbon released from the decay of these wood products over time. It was developed based on Dymond's (2012) model of carbon storage and emissions from wood products harvested in BC.[23] Using the Calculator, we estimated tons of carbon stored in wood or paper products manufactured from a single m^3 of harvested logs over 100 years and then scaled this value by the total harvest in each year.[24] Since the Calculator differentiates

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[23] Dymond's (2012) model is called the British Columbia Harvested Wood Products version 1 (BC-HWPv1).

[24] Carbon stored in wood or paper products is accounted for beginning in the year the logs are harvested and in subsequent years following the relationship in Figure 1 until the end of our time horizon, which is year 100.

between cedar and SPF (spruce, pine, and fir) logs, different decay relationships are derived from each (see Figure 8).[25]

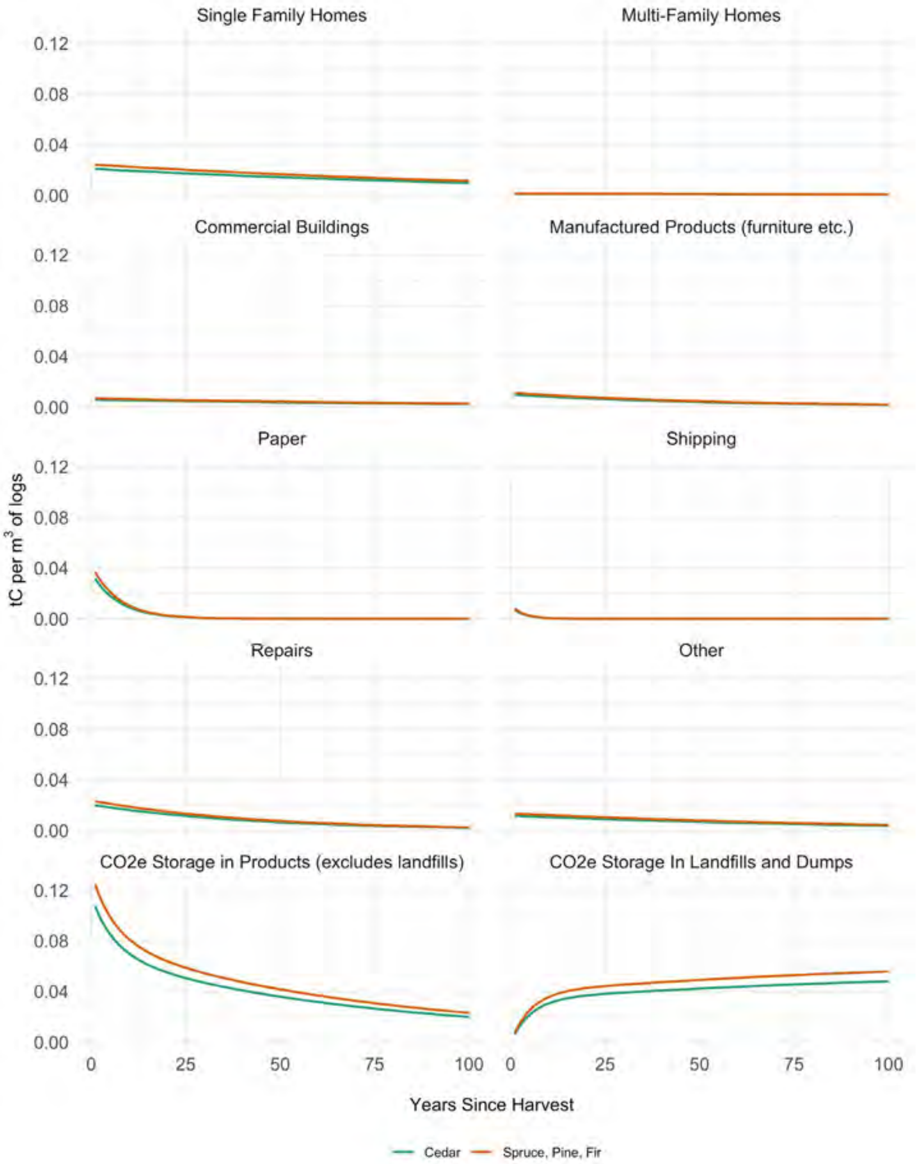

Figure 8. Carbon stored in wood or paper products for 1 m³ of harvested logs

In each year, we summed the carbon stored by the land base and in wood products to obtain a total annual carbon storage estimate. We then calculated the change in carbon storage for each time step (year *t* to *t+1*), which represents annual sequestration on the land base and in wood products. We applied our per unit carbon value to this difference. Following Knowler and Dust (2008) we did not account for emissions from harvesting equipment or wood product manufacturing (this aligns with other services, for instance, we do not account for carbon emissions during recreation). Nor do we account for substitute effects, such as wood products displacing more carbon intensive construction

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[25] We used the cedar relationship for our model's cedar harvest and the SPF relationship for all other softwood species. None of the projected harvest from our modelled scenarios are hardwood (see Section 2.3).

materials like concrete, or energy sources like fossil fuels, since the BC Harvested Wood Product Carbon Calculator does not account for such effects (BCMOFLNRO, 2016).

2.5.4 Non-timber Forest Products

Compared to forests of other age classes, old growth forests can provide unique opportunities for harvesting non-timber forest products (NTFPs) (Knowler and Dust 2008). Non-timber forest products harvested in British Columbia include floral greenery, wild edibles, medicinals, landscaping and restoration products, firewood, smoke wood, materials for arts and crafts, and ingredients for essential oils and soaps (Mitchell and Hobby 2010). These products provide benefit through commercial revenue, recreational harvesting, food supply, and cultural heritage. Due to a lack of licensing, regulation, and monitoring, information about NTFP harvests is sparse. However, more than 200 different NTFPs are estimated to be commercially harvested in BC generating over $250 million in direct revenues (de Guess 1995; Wills and Lipsey 1999).[26] The most common commercial products are wild mushrooms (pines, chanterelles, and morels), and floral greenery such as salal and coniferous boughs. Commercial harvests bring an annual average value to the provincial economy of $27.5 million for mushrooms (ranging from $9.5 to $40 million over ten years) and $38 million for floral greenery (ranging from $25.5 to $62 million over six years) (Cocksedge and Hobby 2006). These NTFPs provide tens of thousands of rural jobs, albeit with comparatively low average annual incomes (Wills and Lipsey 1999; Hobby et al. 2010). Indigenous use of NTFPs is also poorly documented, but many communities make extensive use of these products for food, clothing, medicine and cultural and spiritual practices (Mitchell and Hobby 2010). For individuals living in rural communities, access to recreational harvest of NTFPs such as berries, mushrooms, and other wild foods can also be an important local amenity.

Several Canadian and Pacific Northwest valuation studies incorporate the value of different non-timber forest products, including mushroom harvests, floral greenery, biodiversity prospecting, and Indigenous subsistence (van Kooten and Bulte 1999; Starbuck et al. 2004; Knowler and Dust 2008; Phillips et al. 2008; Mojica et al. 2017). Knowler and Dust (2008) assessed commercial mushroom harvesters' producer surplus using production data and market prices obtained from local mushroom buyers, biological productivity studies, and the Centre for Non-Timber Resources (now closed) at Royal Roads University. Phillips et al. (2008) estimated the replacement cost of NTFP harvests in Alaska's Chugach and Tongass National Forests using available harvest data multiplied by the retail cost of replacing these foods (e.g., the cost of a pound of salmon at the grocery store). Also, since one Alaskan Indigenous Nation was awarded damages for lost subsistence value resulting from the Exxon Valdez oil spill, the authors were able to calculate Indigenous subsistence values using litigation costs. Using a travel cost method, Starbuck et al. (2004) assessed the value of recreational huckleberry and mushroom picking in Washington's Gifford Pinchot National Forest, where harvesters are required to have permits (free with application). The authors calculated willingness-to-pay (WTP) for recreational NTFP harvest as a function of travel costs incurred, household income, harvesting level or quality, and socio-economic characteristics such as gender, age and education. van Kooten and Bulte (1999) used a per-hectare value for NTFPs from previous studies and Mojica et al. (2017) relied on a US Forest Service study estimating the value of timber and non-timber forest products in the Mt. Baker-Snoqualmie Forest.

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[26] This estimate includes tourism related to NTFPs. Note that these studies are also old and could use updating.

Producer Surplus from Commercial Mushroom and Salal Collection

For each of our modelled scenarios (Section 2.4.2), we estimated producer surplus (revenue minus costs) from harvesting three types of mushrooms (pines, chanterelle, and morels) as well as salal for floral use.[27] We focused on producer surplus exclusively because we were unable to obtain data about recreational mushroom picking in the study area, which would be the only source of consumer surplus. At least some of this latter value is likely captured in our assessment of recreation consumer surplus described in Section 2.5.2 because we rely on data from the BC Ministry of Forests' (1991) recreational survey, which contains a category for 'Gathering / Collecting'.

We estimated annual producer surplus on a per hectare basis via a series of steps, and then applied this value to areas of the land base relevant to each NTFP. The steps included estimating: 1) total daily revenue per harvester for each NTFP (units: $ per day per harvester); 2) total daily cost per harvester for each NTFP (units: $ per day per harvester); 3) total daily producer surplus per harvester for each NTFP by subtracting costs in Step 2 from revenues in Step 1 (units: $ per day per harvester); 4) producer surplus per unit of NTFP by dividing producer surplus from Step 3 by a harvester's anticipated daily units harvested (units: $ per kilogram); 5) the typical units harvested per hectare per year for each NTFP (units: kilograms per hectare); and 6) annual producer surplus per hectare by multiplying per unit producer surplus from Step 4 by the number of units harvested per hectare per year from Step 5 (units: $ per hectare). These steps are outlined in detail below.

Slightly different approaches were used for the mushrooms and salal NTFPs to estimate daily harvester revenues. For the three mushroom species, this involved estimating revenues to the harvester per day by establishing the number of units an experienced harvester can pick in a day and then multiplying that amount by the price per unit. Following Godoy et al. (1993) as well as Knowler and Dust, we assumed 98% of the mushrooms harvested are sold to buyers at wholesale prices while the remaining 2% are consumed by the harvester, to which we apply the retail price (see Table 8). For pines and chanterelles we rely on Knowler and Dust (2008) for daily harvest rates (in kg) as well as wholesale prices paid to pickers. For morels we use daily harvest rates reported by Olivotto (2009), and wholesale prices paid to pickers from Cocksedge and Schroeder (2006) (midpoint of the reported ranges, inflated to 2018 CAD).[28] To obtain retail prices for all three mushroom species we spot checked West Coast Wild Foods (www.westcoastwildfoods.com) on December 10, 2019. Given the daily expected harvest and price values in Table 8, total daily revenue for mushrooms is estimated at (2018 CAD): $147.65 for chanterelles; $183.56 for pines; and $287.19 for morels.

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[27] Olivotto (2009) notes that there is no commercial harvest of morels in BC's Coast region. Harvesters are likely to target burned forest as morel production is higher in these areas (fires are uncommon in the study area). Inclusion of morels does not greatly impact our overall results for NTFPs, but confirmation of their presence/absence in the Port Renfrew area should be confirmed before final results are presented. Part of our sensitivity analysis involves removing morels from our calculations.

[28] Olivotto also provides harvest rates for pines and chanterelles but does not differentiate between the two. Knowler and Dust note substantial differences in daily harvest rates and so we use their values instead.

Table 8. Parameters used to estimate per hectare values for each non-timber forest product (NTFP)

NTFB	**Daily Harvest** (kg)	**Prices per Unit**		**Biological Productivity** (kg/ha)	**Share of Productivity Harvested**	**Habitat**	
		Whole-sale	Retail			Age Class	Dominant Species
Pine	2.7	$67.80	$77.00	4.5	50%	3 to 7	Not cedar
Chanterelle	14.2	$9.60	$49.50	5.0	50%	3 to 7	Not cedar
Morel	20.0	$13.53	$55.00	1.5	35%	> 2	All
Salal	50.0	$3.04	N/A	N/A	N/A	2 & 11	Not alder or pine

For salal, we also estimated daily revenues per harvester by multiplying the number of units an experienced harvester can pick in a day, from Olivotto (2009), by the wholesale price per unit (unlike mushrooms, we assumed all salal is sold to buyers). However, we estimated per unit prices for salal differently than for mushrooms using information from Hobby et al. (2010). They conducted a survey of salal harvesters on Southern Vancouver Island in 2005 and reported that prices for 'hands' (units) of 'salal longs' ranged from $1.28 to $1.64 (midpoint: $1.46) depending on the season, and prices for 'hands' of 'salal tips' ranged from $0.65 to $0.94 (midpoint: $0.80).[29] A typical salal shipping box weighs 20kg and contains 25 tips and 20 longs (Hobby et al. 2010). Multiplying the total midpoint payment received by a harvester for each type of hand by the typical shipping box's contents yields a total value per box of $49.08; dividing this total value by the box's weight yields a per unit value for salal of $2.45/kg. Inflating this from 2005 (assumed) to 2018 CAD yields $3.04/kg. The daily revenue of an experienced salal harvester is thus $152 (2018 CAD).

We estimated the total daily cost per harvester using the same approach for all NTFPs. Following Knowler and Dust (2008) we calculated the harvesting cost as the 'variable opportunity cost of harvesting', or the wage a harvester would have otherwise earned if they were not spending their time harvesting, plus fixed daily costs incurred from harvesting (e.g., transportation). We considered the opportunity cost of harvesting NTFPs as the wage paid to labour in a similarly skilled position, which was set at $14 per hour to match the median wage of a farm harvest hand in British Columbia (ESDC, 2019). The fixed daily cost was set at $30 (2006 CAD) which we inflated to 2018 CAD, yielding $37 (Knowler and Dust 2008). We calculated the total daily cost by multiplying the hourly opportunity cost by the typical number of hours worked by a harvester per day ($14 x 6.7 hours), from Knowler and Dust (2008), and then adding the daily fixed cost ($37). These values yield a daily total cost of $130.40 (2018 CAD).

We calculated total daily producer surplus per harvester by subtracting this total daily cost from the total daily revenue estimated for each NTFP yielding: $17.25 for chanterelles; $53.16 for pines; $156.79 for morels; and $21.20 for salal. Dividing these daily values by a harvester's anticipated daily harvest from Table 8 generates per unit producer surplus values of: $1.21/kg for chanterelles; $19.69/kg for pines; $7.84/kg for morels; and $0.42/kg for salal.

For the three mushroom species, we estimated the typical units harvested per hectare per year by multiplying the 'biological productivity', or the average count of units growing per hectare per year (fresh kg/ha) by the anticipated portion of this amount that is harvested per year (Table 8). We relied on Pilz et al. (2001) for per hectare biological productivity values (kg/ha) for pines and chanterelles

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[29] Prices paid to buyers are higher when the salal harvesting season begins in the fall (Hobby et al. 2010).

growing in the Pacific Northwest, and Alexander et al. (2002) for morels growing in natural stands located in Oregon. The latter study also provides estimates of the anticipated share of each species' biological productivity that is commercially harvested: 50% for pines and chanterelles;[30] and 35% for 'natural morels' in undisturbed stands (e.g., undisturbed by fire). Multiplying these proportions by biological productivity yields the anticipated fresh weight of each mushroom species harvested per hectare per year: 2.5 kg/ha per year for chanterelles; 2.25 kg/ha per year for pines; and 0.525 kg/ha per year for morels.

Due to a lack of similar data we did not use the same procedure to estimate the units harvested per hectare per year for salal and instead relied on data from Hobby et al. (2010). Based on their 2005 survey of 4 salal buyers, Hobby et al. report shipments of between 4,000 and 20,000 hands of salal per buyer per week. Taking the midpoint of this range (12,000 hands per buyer), and assuming 36 active buyers in BC and a harvesting season of 43 weeks (both from Hobby et al.), the province-wide annual salal harvest is about 18,576,000 hands, or 8,173,440 kg.[31] The South Island Forest District — which contains the study site — contributes about 25% to this harvest (Hobby et al. 2010), or about 2,043,360 kg. The total area of the district is over 1,529,294 ha (GIS analysis, this study), which yields an annual harvest in this region of approximately 1.34 kg/ha (2,043,360 kg ÷ 1,529,294 ha).

Multiplying the estimated producer surplus per unit by the estimated units harvested per hectare per year yields producer surplus per hectare per year for each NTFP. Doing so results in producer surplus values of: \$3.04/ha/yr for chanterelles; \$44.30/ha/yr for pines; \$4.12/ha/yr for morels; and \$0.57/ha/yr for salal (2018 CAD).[32] **We excluded morels from the analysis per Olivotto (2009), which indicates there is no commercial harvest of morels in the BC Coast region** (this can be turned on or off in the economic model if new evidence suggests otherwise for the study area). In each year of the study's 100-year time horizon, we applied these *per hectare per year producer surplus values* for each NTFP to the land base. We limited the area to which these values were applied to each NTFP's favoured habitat, defined as an NTFP's preferred stand age and dominant stand species as reported in Knowler and Dust (2009), Alexander (2002), Pilz et al. (2001), Cocksege and Schroeder (2006), and Fraser et al. (1993) (see 'Habitat' columns in Table 8).[33] We discounted all NTFB producer surplus values to 2018 present values using a 3% discount rate (see Appendix C for sensitivity analyses).

2.5.5 Salmon Habitat

Old growth timber harvests can reduce the quality and availability of habitat, affecting the economic value of non-use, commercial and sport activities that rely on affected species (c.f. Bradshaw 2009; Knowler et al. 2003). For example, Vancouver Island hosts many rivers and streams that provide

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[30] The authors observed a much lower share harvested (22% in 1995 and 12% in 1996) in closed plot trials but thought this was not realistic given their observations of commercial harvests in open areas so assumed a value of 50% for pines and chanterelles.

[31] The weight of a typical hand was estimated at 0.44 kg by dividing the weight of a salal shipping box (20 kg) by the number of hands these boxes typically contain (45 hands), both from Hobby et al. (2010).

[32] Note that reducing the share of biological productivity that is commercially harvested to 15% for all mushrooms, which better reflects the data from 1995/1996 (12% and 22%), substantially reduces these producer surplus values to: \$0.91/ha/yr for chanterelles; \$13.29/ha/yr for pines; and \$1.76/ha/yr for morels. See Appendix C for sensitivity analyses.

[33] Salal prefers stands between 15 and 25 years old, as well as older forests (Cocksedge and Schroeder 2006). The younger ages overlap with 'age classes 1 and 2' in our modelled data, and since commercial quality salal is not present in recently cut areas (age class 1), we only apply \$/ha/yr producer surplus values to age class 2 as well as the oldest age class (11).

important spawning and rearing habitat for different salmonids including Chinook, pink, chum, sockeye, coho, and steelhead trout. Old growth forests in the San Juan and Gordon River watersheds near Port Renfrew contribute to these species' survival (Burt and Palfrey 2011; deVisser 2015; Quatse Salmon Stewardship Centre 2019; Labell 2009; Fraser et al. 1974). We focus on salmon in this section because, from an economic valuation perspective, they are the most widely studied species in the Pacific Northwest. Salmon also play an important role in nutrient cycling for forest ecosystems (Cederholm et al. 1999). Many other species' habitats are supported by old growth forests and can be valued using similar methods.

For each modelled scenario (see Section 2.4.2), we estimated coho salmon habitat benefits attributable to old growth forests, multiplying the area of protected forest by a per hectare habitat value. We obtained this value from Knowler et al. (2003), which applied a production function to determine benefits to the Strait of Georgia commercial coho fishery attributable to protecting forested lands from degradation around BC's South Thompson River in BC's Interior region.

Knowler et al. (2003) derive four values based on different assumptions about initial salmon habitat quality and degradation levels. Since the salmon bearing watersheds in the Port Renfrew area are not pristine, we averaged the results from this study that are associated with partial degradation of the South Thompson basin ($0.93 and $2.63 per hectare [1994 CAD] in perpetuity).[34] Averaging these two values yielded $1.78 (1994 CAD) per hectare and inflating this value to 2018 returned $2.78 per hectare. We adjusted this value to account for differences in coho salmon populations between the two regions using 12-year average escapement count data for the South Thompson in the years leading up to the Knowler et al. study, and for San Juan and Gordon Rivers in the years leading up to the current study (Irvine et al. 2001; DFO, 2019) (Table 9).

Table 9. Derivation of coho escapement adjustment to account for differences in salmon populations

Watersheds	**Coho escapement (12-yr average)**
South Thompson River	5,620
Gordon and San Juan Rivers (Port Renfrew area)	6,100
Multiplier used for adjustment (6,100 ÷ 5,620)	**1.09**

Adjusting for these differences produced a value per hectare of protected old growth forest of $3.01 (2018 CAD). In each of our modelled scenarios, we apply this value only to the area protected as that is the focus of Knowler et al.'s (2003) analysis. Since the economic values reported in Knowler et al. are "net present values (NPV) in perpetuity at a 5% social discount rate" (p.269), we only apply them in the year the protected area is designated. We discount salmon habitat values to 2018 present values using a 3% discount rate (see Appendix C for sensitivity analyses).

It is important to note that coho are not the only salmon species with natal streams inside the study area. The per hectare value we derived is very likely an underestimate (i.e., errs conservatively). Coho are a lower valued fish compared to Chinook salmon, which also spawn in the study area in significant numbers. For example, ex-vessel prices for Chinook salmon caught in the Columbia River in Washington State can range more than 50-70% higher than those for coho (Pacific Fishery

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[34] In averaging these partial degradation scenarios, we assume that the salmon habitat quality of the areas surrounding Port Renfrew are somewhere between the state of the South Thompson and pristine. We also assume that the old-growth forests to be protected in our study site are currently pristine and would deteriorate to about half their salmon habitat quality if not protected.

Management Council 2014). In addition, commercial harvest is not the only ecosystem service supplied by salmon. Morton et al. (2017), for example, evaluated recreational, commercial, subsistence, and nutrient cycling services from salmon production and found that the recreational value of salmon production can be twice that of commercial fishing. Also, fish used for household consumption, while typically a small portion of total harvest, should be valued at their traditional retail purchasing price (Godoy et al. 1993). These prices are considerably higher than the ex-vessel commercial fishing values used in Knowler et al. (2003). Developing a full bio-economic model to capture these features was beyond the scope of this study, but a future application of these methods could account for different values across multiple species and fish production services to derive a more complete per-hectare value.

2.5.6 Education & Research

Intact old growth forests offer the opportunity for education and research activities that other types of forest do not. The potential for Vancouver Island-based research about old growth forests is high given the relatively large number of nearby research institutions that host forestry and/or natural resource management departments. Examples include the University of British Columbia, Simon Fraser University, University of Victoria, British Columbia Institute of Technology, Royal Roads University, and Vancouver Island University.

Black (1996) reports an approach for assessing the social value of publications in social and natural science academic journals arising from research activities. Loomis and Richardson (2000) used this approach to assign a monetary value to such scientific research publications in roadless areas of the United States ($12,000 per study; 2000 USD), and Phillips et al. (2008) did the same for Alaska's Chugach and Tongass National Forests.

Following these studies, we used the same approach to estimate consumer surplus from education and research activities conducted in or around old growth forests. We used Loomis and Richardson's (2000) $12,000 (USD) value converted to Canadian dollars and inflated to 2018 yielding a value of $24,773 (2018 CAD) per study. We estimated the number of studies per hectare per year for Vancouver Island by searching the Web of Science database over the past 10 years (2009 to 2018) using the terms "Vancouver Island" and "old growth". This search yielded 34 studies, which we narrowed to 22 after reviewing to ensure relevance. We divided the number of studies by 10 years, and the area of Vancouver Island's old growth forest in hectares (822,772.7 ha), yielding 0.00000267 scientific studies per hectare per year.[35]

The resulting value is $0.07 (2018 CAD) per hectare. For each of our modelled scenarios, we multiplied this value by the number of hectares in the oldest age class (age class 11, which represents forests at least 200 years old). While our different scenarios reflect different assumptions about which age class represents old-growth forest (i.e., >250 years or >140years, see Section 2.4.2), for this ecosystem service, we apply dollar values to the number of hectares in CBM-CFS3 age class 11

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[35] A single value was used for the area of Vancouver Island's old growth forests since data was not available on the extent of these forests in each of the past 10 years. Age classes used to arrive at this value differ from those output from the CBM-CFS3 model. If the estimate of the extent of the Island's old growth forest reflects the average area over the 10-year timespan then the effect on the education and research monetary estimates will be minimal given that the per hectare value would be an average across this period. However, if the area estimate is too high (low) then the monetary estimates for this component will be too low (high) given that the per study amount from Loomis and Richardson (2000) is divided by this area. Regardless, the implications for the study's overall results would be negligible given the low magnitude of the education and research monetary estimates relative to those of the other components that were valued (e.g., timber, carbon, NTFPs, and recreation values are each in the millions of dollars, while the present values estimated for education and research are less than $10,000).

category to maintain consistency in what is being compared across scenarios. Otherwise differences in education and research values would arise due to the definition of old-growth forests and not the policy being investigated as part of the analysis (i.e. the area of old growth forest protected). We discounted education and research values to 2018 present values using a 3% discount rate (see Appendix C for sensitivity analyses).

2.5.7 Real Estate

Old growth forests can influence real estate values when individuals are more drawn to purchase recreational properties or permanent residences in areas with intact forests. For instance, Izón et al. (2010) used a spatially explicit hedonic pricing approach to show that properties closer to New Mexico's National Forests were 5.6% more expensive, on average, compared to other properties. Anecdotal evidence also suggests that old growth can influence real estate markets on Vancouver Island (Ancient Forest Alliance, personal communications, February 2019, see also testimonial below), and some developers are using old growth forests as a marketing tactic (e.g., see http://wildcoastcottages.com/port-renfrew/ or http://liveportrenfrew.com/ amenities/).

> *Port Renfrew Management Ltd, a privately-owned real estate investment and development firm, has seen first-hand how increased awareness and visitation of old-growth forests around Port Renfrew has influenced real estate markets and increase nearby property values. This was an important factor in our firm's decision to invest in real estate development in the town at this time. Since the protection of Avatar Grove and Port Renfrew's rebranding as the "Ancient Tree Capital of Canada", the town has become a desired destination for individuals from all over the world. Even more, it's becoming a place where people want to live. The proximity and accessibility to nature, particularly old-growth forests, is a huge draw. There's no doubt the interest in purchasing property, opening new businesses, and building homes has dramatically increased in the past several years with the enhanced awareness and marketing around the region's old-growth forests and that real estate values have increased in the region as a result.*
>
> \- Karl Ablack, Director & Managing Partner, Port Renfrew Management Ltd.

To estimate increases in real estate price premiums attributable to old growth forests, we relied on Izon et al.'s (2010) results. We averaged the relevant parameter values from the authors' three preferred 'spatial lag' models yielding a 0.667% increase in house prices given a 1% change in the area of protected old growth (or 'designated wilderness' area in Izon et al.).[36] Next, at each annual time step we calculated the percent change in protected old growth forest under each of our modelled scenarios (see Section 2.4.2) and linked this change to property prices using the relationship from Izon et al. Since the bump in prices is received only once when an area of old growth forest is protected, the price increase is a one-time benefit and not a service flow over multiple years. We estimated total initial property value for the study area by multiplying the mean 2018 sales price for the Port Alberni-West Island region ($355,816 for single family residences (VIRB, 2019)) with the number of houses in the study area. Since a current estimate of the number of houses was not

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[36] The averaged parameters were 0.641, 0.64, and 0.72.

available, as a proxy we used the total number of private dwellings in the Juan de Fuca census subdivision, which was 152 in 2016 (Statistics Canada, January 14, 2020). We discounted real estate values to 2018 present values using a 3% discount rate (see Appendix C for sensitivity analyses).

An Important Caveat for Real Estate Values

A key confounding factor that makes it difficult to parse out the price premium of real estate attributable to old growth is that proximity to the amenities offered by old growth forests is not the only thing influencing the value of real estate. The region around Port Renfrew offers a range of other, and similar, amenities, so using surveys and focus groups to determine the extent to which people attribute value to that proximity will elicit questionable results. Individual responses will very likely be confounded by those other amenities. As such, **we strongly recommend interpreting the real estate values reported in our results section (Section 3) with caution**. Because the Ancient Forest Alliance requested that real estate values be included, we have incorporated them into our main results and have provided an additional sensitivity analysis in Appendix C that excludes these values from the analysis. The impact of real estate on overall results is negligible relative to the other ecosystem services, so we do not feel this inclusion is critical.

2.5.8 Drinking Water Quality (not used in final results)

Forestry-based road construction impacts water quality because it increases surface erosion and landslides, acting as a primary source of fine-sediments in affected streams (Araujo et al. 2014; Knowler et al. 2017). Compared to decommissioned roads, these impacts increase with heavier use for logging, recreation and tourism (Araujo et al. 2014; Knowler et al. 2017). Logging roads can also increase fine-sediment deposition by disrupting sub-surface groundwater flows, leading to more frequent extreme flow events (Araujo et al. 2014). Studying watersheds of the Fraser TSA in BC's Lower Mainland, Knowler et al. (2017) used a production function approach to estimate the consumer surplus derived from forest-based water purification services. Outputs from these studies suggest a consumer surplus value from intact forests ranging from $1.79 to $21.46 per hectare per year for clean surface water.

Port Renfrew's primary water source is treated well water. While this groundwater originates from the San Juan River watershed where active logging of old growth still occurs, we could not transfer the values from Knowler et al. (2017) since they are specific to surface water. However, these values may be transferrable elsewhere, so we incorporated them into our economic valuation tool for potential future use. For example, Port Hardy draws its water from the Tsulquate River watershed (low known risks from logging, Epps 2009), and Tahsis uses the McKelvie Creek watershed, which is currently slated for logging and hosts intact old growth forest that contribute clean groundwater to the community's primary well-based water supply as well as back-up surface water supply (AFA 2018; Horel 2018).

3 Results

In this Chapter we report results from applying the methods described in Chapter 2 to the Port Renfrew pilot study site. First we review outputs from the CBM-CFS3 model for timber harvest (Section 3.1), old growth protection (Section 3.2), and carbon storage/sequestration (Section 3.3) for each of the scenarios identified in Section 2.4.2 that use >140 years as their definition of old growth (Scenarios 5-8 and 13-16 in Table 3), then we apply our valuation methods to these outputs to show the change in net present values over time and examine the influence of individual ecosystem services on the total net present value results (Section 3.4). Our primary focus is on scenarios using the >140-year definition of old growth, but we include final economic value results for the >250 year old growth definition in Section 3.4 for ease of comparison. In Appendix C, we provide a suite of sensitivity analyses including results using the >250-year definition of old growth for timber harvest, old growth protection, and carbon storage/sequestration.

3.1 Timber Harvest

As described in Section 2.4.1, we set the target timber harvest for our base ('business as usual') case, at 62,480 m^3/yr. Figure 9 shows that over the 100-year modelled time horizon, this target was met in all years (top left panel). We set this target volume using the proportion of the THLB *area* that was in our study area. We did no further adjustments, for example, by comparing the study area's potential biomass over time with that of the entire western portion of the TSA (i.e., our assumption was that the landbase and biomass growth is similar across the entire western portion of the TSA, which may not be the case).

Hemlock and Douglas fir are the most commonly harvested species in the base case, with hemlock dominating early in the time series, then fir/hemlock for about 60yrs, shifting to red cedar for about a decade, back to hemlock, then a hemlock/fir/cedar mix during the final 20yrs. Hemlock dominance early in the time series is driven by the fact that there are enough eligible hemlock stands within the Timber Supply Area's (TSA) timber harvest landbase (THLB) to meet harvest targets, and based on their volume, these stands are priority ranked for harvest over stands of other species.[37] Once these trees are harvested, fir stands are also cut because they now have high enough volumes to rise to the top of the ranked list of stands (Figure 9). Most eligible cedar stands do not begin to reach the top of the volume prioritization sequence until the middle of the time series.

For our alternative (non-baseline) harvest scenarios, as old growth protection increases harvest targets decrease in response and these targets are met in all years for every scenario. For example, at 30% old growth protection, about 91% of the base case's total 100-year harvest remains targeted, while at 100% old growth protection, about 69% remains targeted.

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[37] Recall from Section 2.4 that stands are ranked based on their volume: highest volume stands are harvested first.

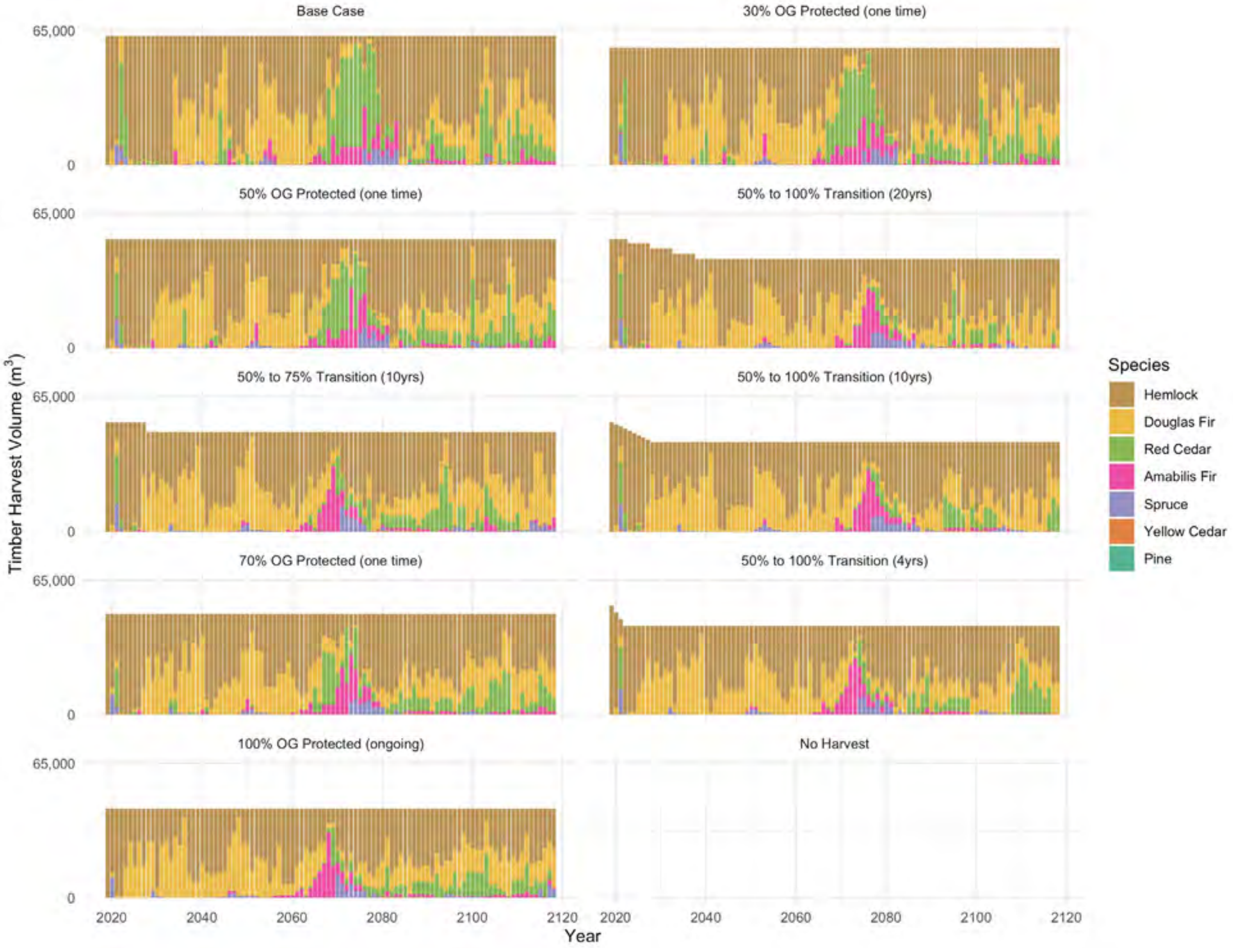


*Figure 9. Total annual volume (m^3) and species composition of timber harvests across the modelled 100-year time horizon (2018 – 2118) and for each timber harvest scenario (**140-year old growth definition**).*

We also observe a temporal shift as old growth protection increases, with dominant fir harvests extending earlier into the time series and becoming increasingly balanced with hemlock throughout the rest of the period. Fir's increased dominance is partly explained by this species' more rapid harvest-and-regrowth cycle. Up to 75% of fir stands are eligible for harvest before they reach 40-60 years old (based on stand volume). In contrast only 18% of cedar stands are eligible that early, and none are eligible before 50 years old. Fir can therefore be harvested earlier and for a second and third round in the time series compared to other species. In contrast, cedar harvests decline as old growth protection increases because the starting ages of many cedar stands in the THLB already fall within the >140-year definition of old growth and therefore become protected. Immediate protection scenarios (e.g., 30%, 50%, 100%) generate higher overall cedar harvests than the 10yr and 20yr 50%-100% transitional scenarios because more higher volume fir and hemlock stands are available later in the time series (vs. being immediately protected), causing fewer cedar stands to be priority ranked later.

3.2 Old Growth Protection

Figure 10 shows that no old growth is protected in the base case (top left panel), and all stands are protected in the no-harvest case (bottom right panel). As old growth protection is increased from the base case, the area that is protected, of course, increases. For example, the area protected under the 30% old growth protection scenario is 815 hectares, which increases to a maximum of 2,940 hectares for the 100% old growth protection scenario. Transitional scenarios take a little longer to achieve their full protection levels as expected.

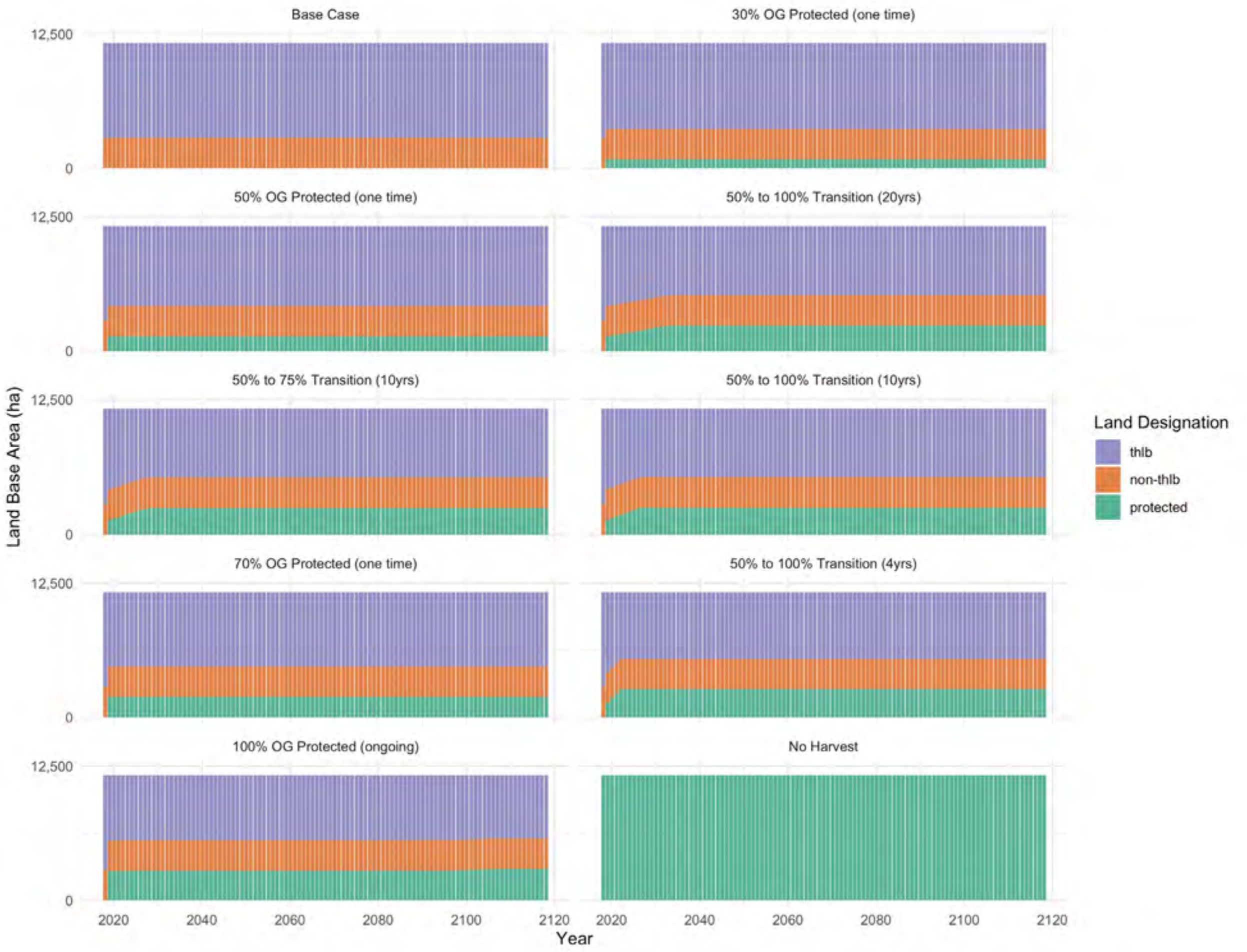


Figure 10. Total annual area (ha) of each land use designation across the modelled 100-year time horizon (2018 – 2118) and for each timber harvest scenario (140-year old growth definition).

Figure 11 shows the implications of these protection scenarios for the area of standing old growth. The base case would result in a 28% decrease from the current 4,658.4 ha in the TSA by 2118, while the 100% OG Protection scenario would result in an 17% increase (5,466.8 ha). It is helpful to compare these results with the No Harvest case, which would increase the area of old growth to 8,299.2 ha (78% increase) by 2118.

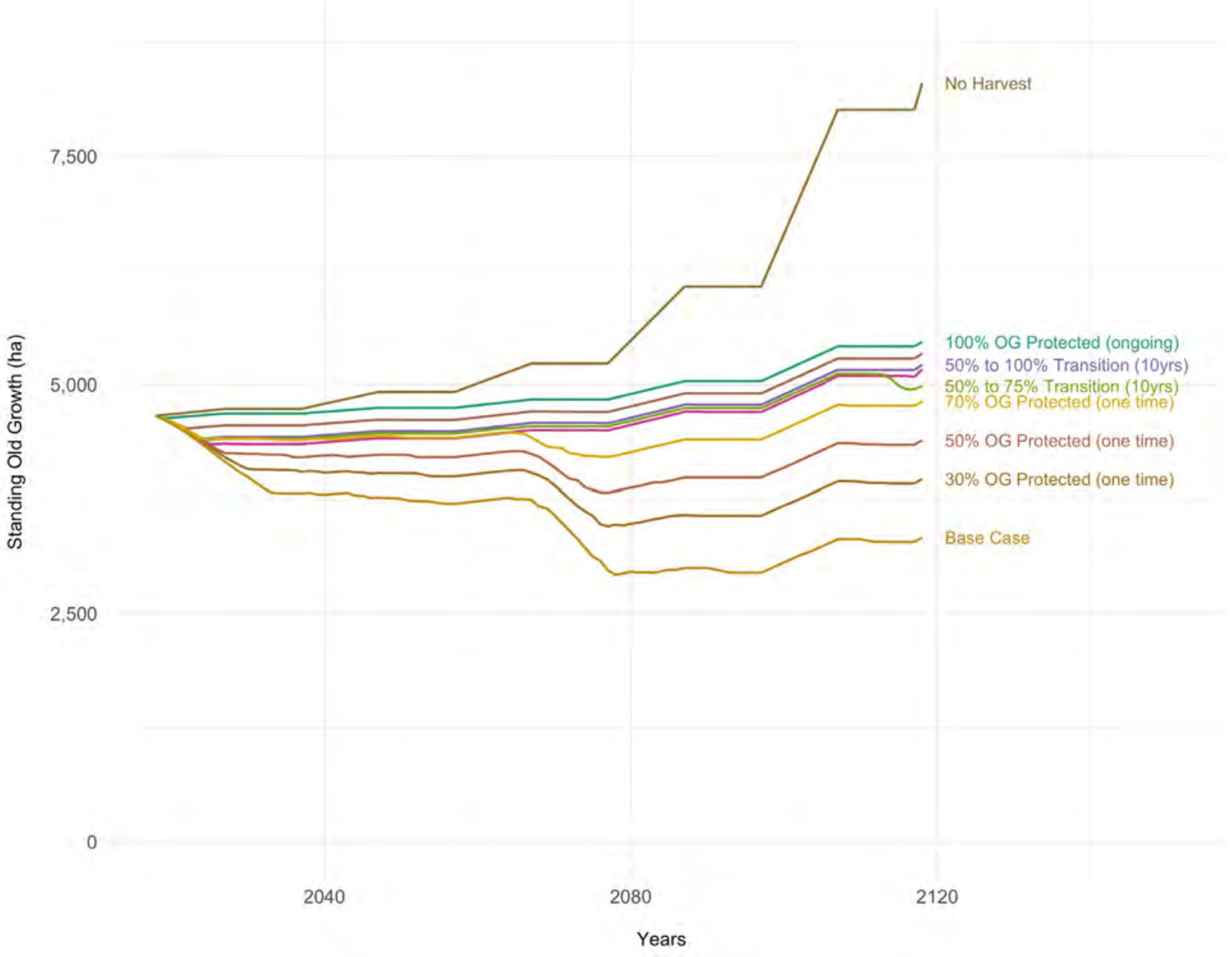


Figure 11. Area (ha) of standing old growth across the modelled 100-year time horizon (2018 – 2118) and for each timber harvest scenario (140-year old growth definition).

3.3 Carbon Storage & Sequestration

Figure 12 shows the change in total carbon storage over 100 years for each of our harvest scenarios and suggests that our pilot site's forest land base acts as a net carbon source under business as usual but that **this source status decreases with increasing protection of old growth, and even flips to sink status for two scenarios** (50% to 100% Transition – 10yrs, 20yrs). Excluding the No Harvest scenario, the total volume of carbon stored at the end of 100 years ranges across scenarios from about 6.14 million tC (base case) to 6.84 million tC (50% to 100% Transition – 10yrs) as compared to 6.82 million tC at year 0. The base case misses 100-year carbon neutral status by over 680,000 tC while the 100% OG Protected scenario misses it by only about 111,000 tC, an improvement in total 100-year carbon storage of over 569,000 tC.

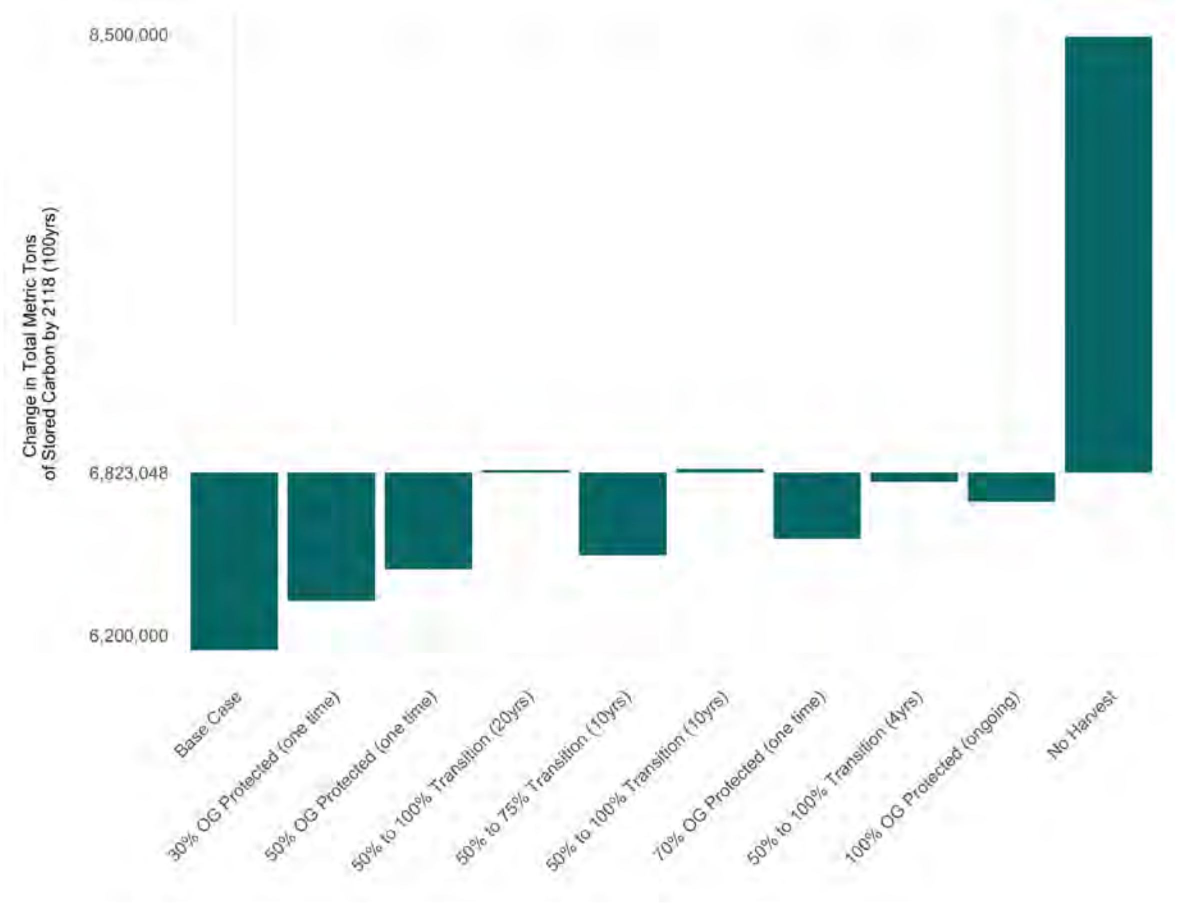


*Figure 12. Change in total carbon storage after 100 years (2018-2118) from total stored carbon in year 0 (6,823,048 tC) for each scenario (**>140 year old growth definition**). Values below 6,823,048 tC indicate a net carbon source. Values above 6,823,048 tC indicate a net carbon sink. The plot shows how Increasing old growth protection decreases the source status of the timber harvest land base.*

Figure 13 provides additional detail and helps to explain the above findings. Unlike the preceding graph, these plots show the annual change in carbon by carbon pool (wood products, above ground biomass, below ground biomass, dead organic matter). Annual change is measured as the difference in total carbon volume from one year to the next i.e., $tC_t - tC_{t-1}$. As for preceding figures, to interpret Figure 13 it is useful to start by comparing the top left panel (base case) with the bottom right panel (no harvest). These results show that while harvest does result in some transfer of stored carbon to wood products (i.e. a carbon sink) under the base case, this transfer is insufficient to counterbalance the loss of carbon from above and below ground biomass. If there were no harvest at all (bottom right panel), these biomass pools would continue to grow, sequestering more carbon (albeit at a decreasing rate as stands mature) and ensuring the forest land base acts as a net carbon sink in all years. Comparing with the other panels in Figure 13, it is clear that the biomass pools release less carbon across the time series with increasing levels of old growth protection compared to the base case (esp. above ground biomass).

Figure 13. Annual change in carbon storage by pool of carbon (wood products, below ground biomass, above ground biomass, dead organic matter) over the modelled 100-year time horizon (2018-2118) for each timber harvest scenario (140-year old growth definition). Values below zero indicate a net carbon source. Values above zero indicate a net carbon sink.

Much of this pattern is driven by the fact that many stands achieve protected status *while they are still growing or growing more rapidly and sequestering carbon*. If they were not protected, they would likely be harvested at some point in the first 60 years of the simulation. Thus, as protection increases, more stands continue to grow and take up carbon, and fewer are harvested and release carbon. It should be noted, however, that toward the end of the time horizon, fewer stands in the protected area are still growing and some have started to decay.

Figure 14 offers another way of looking at the results shown in Figure 13. In these plots, it is easier to see the temporal shift toward increasingly later source status over progressively longer periods as old growth protection is increased. Transitional scenarios return to sink status toward the end of their time series. We believe this is because the earlier cut of older larger trees in these scenarios results in a cascade effect in the way stands are prioritized throughout the time series such that more protected trees are at a “high-sequestering” age near the end of the 100-year time horizon.

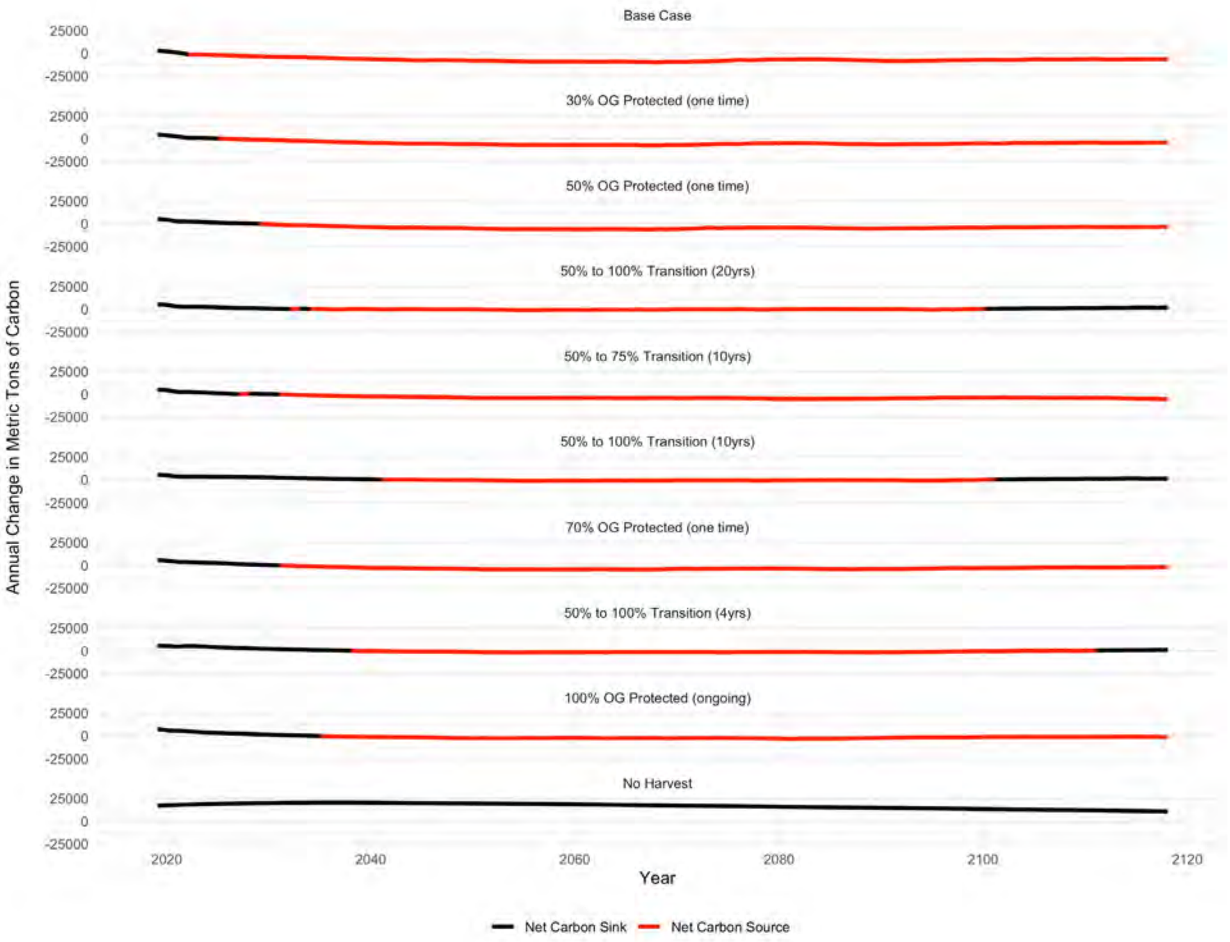
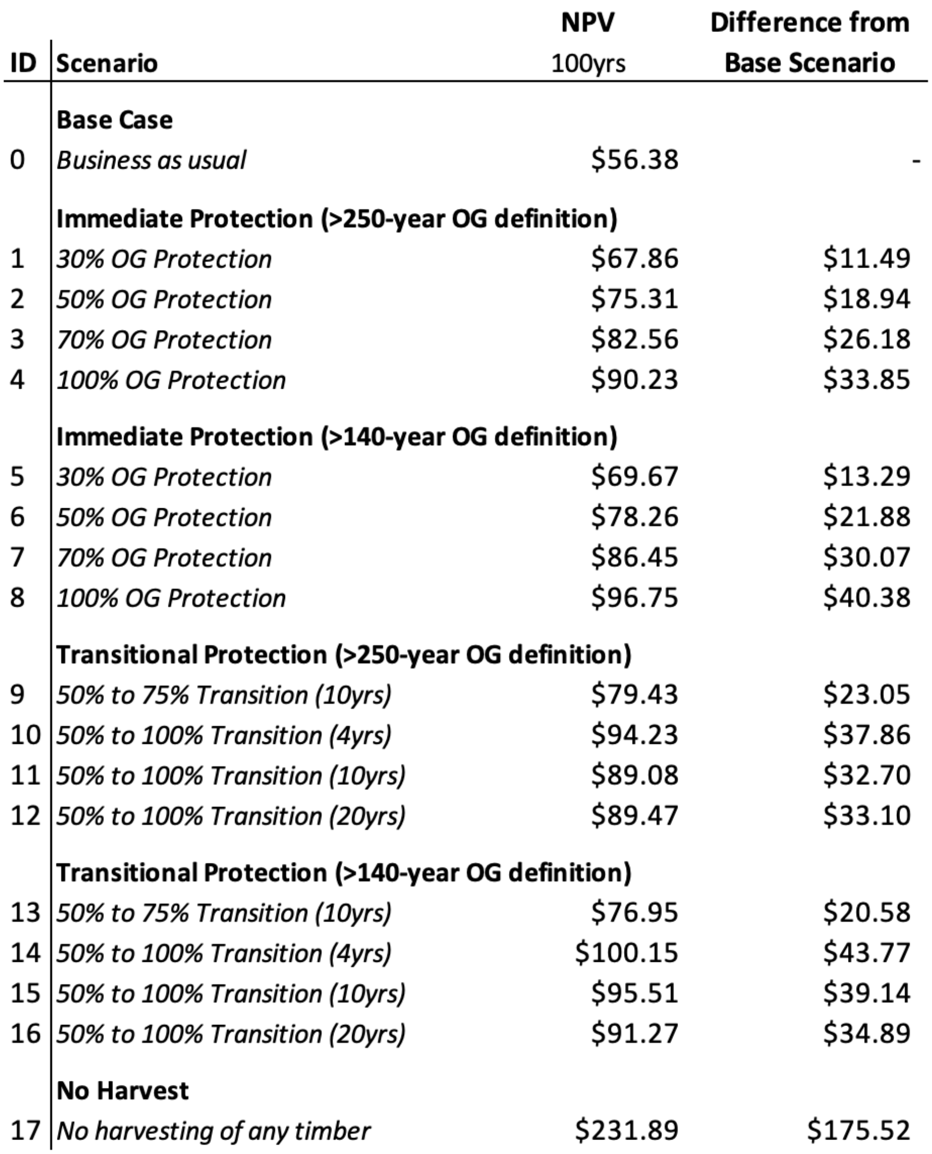


Figure 14. Annual change in carbon sequestration services over a modelled 100-year time horizon (2018-2118) for each timber harvest scenario (140-year old growth definition). Black line segments indicate when the forest land base is a net carbon sink, red line segments indicate when the forest land base is a net carbon source (includes wood products). Fluctuations from source to sink occur primarily due to variations in above-ground biomass resulting from timber harvest (see Figure 13).

3.4 Economic Valuation

Our economic valuation results indicate that as protection of trees older than 140 years increases in the portion of the TSA within our study area, society is increasingly better off compared to the business as usual case (Table 10). In the 100% protection case (ID8), the ‘incremental’ economic benefit to society from protecting all old growth would be $40.4 million (net present value at a 3% discount rate; alternative minus the base case). Using the more conservative >250-year definition of old growth (ID4), this benefit would be $33.9 million. For the two scenarios with the least old growth protection, society would be better off by $13.3 million with just 30% protection of trees older than 140 years (ID5), but only $11.5 million if the >250-year definition of old growth is used (ID1). As described in further detail below, these values are largely driven by three ecosystem services: a) carbon sequestration, b) timber production, and c) recreation consumer surplus (see Figure 15).

Table 10. Economic valuation results with comparison to the base case. Results are in net present value (2018 CAD millions) discounted at 3% over 100 years



ID	Scenario	NPV 100yrs	Difference from Base Scenario
	Base Case		
0	*Business as usual*	$56.38	-
	Immediate Protection (>250-year OG definition)		
1	*30% OG Protection*	$67.86	$11.49
2	*50% OG Protection*	$75.31	$18.94
3	*70% OG Protection*	$82.56	$26.18
4	*100% OG Protection*	$90.23	$33.85
	Immediate Protection (>140-year OG definition)		
5	*30% OG Protection*	$69.67	$13.29
6	*50% OG Protection*	$78.26	$21.88
7	*70% OG Protection*	$86.45	$30.07
8	*100% OG Protection*	$96.75	$40.38
	Transitional Protection (>250-year OG definition)		
9	*50% to 75% Transition (10yrs)*	$79.43	$23.05
10	*50% to 100% Transition (4yrs)*	$94.23	$37.86
11	*50% to 100% Transition (10yrs)*	$89.08	$32.70
12	*50% to 100% Transition (20yrs)*	$89.47	$33.10
	Transitional Protection (>140-year OG definition)		
13	*50% to 75% Transition (10yrs)*	$76.95	$20.58
14	*50% to 100% Transition (4yrs)*	$100.15	$43.77
15	*50% to 100% Transition (10yrs)*	$95.51	$39.14
16	*50% to 100% Transition (20yrs)*	$91.27	$34.89
	No Harvest		
17	*No harvesting of any timber*	$231.89	$175.52

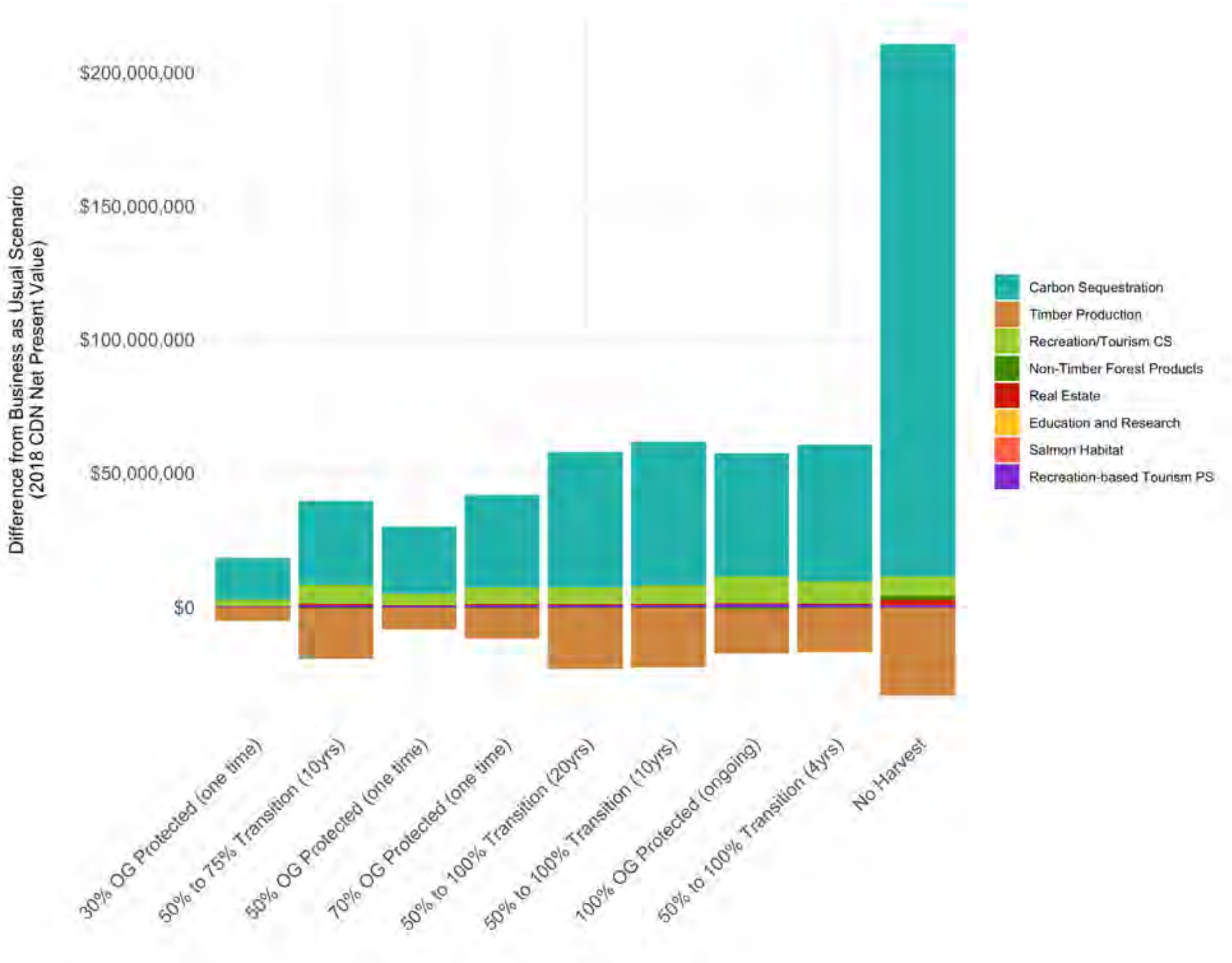


*Figure 15. Difference in economic benefit to society relative to the base case for each scenario (**>140 year old growth definition**). Results are in net present value (2018 CAD) discounted at 3% over 100 years.*

Figure 15 illustrates how our results are distributed across different ecosystem services. Carbon sequestration is clearly a main driver of value. Timber production benefits are negative relative to the base case for all scenarios and this loss increases as old growth protection increases, but even more in the transitional scenarios. In all protection scenarios, these losses are exceeded by gains in welfare from carbon sequestration alone. Recreation/tourism consumer surplus (CS) and tourism producer surplus (PS) also show improvement compared to the base case, with the 100% OG Protection scenario showing the greatest improvement in recreation and tourism benefits. Based on our model assumptions, the other ecosystem services have comparatively negligible effects when compared with the base case.

One key element of the timber harvest valuation is that negatively valued hemlock is the dominant harvest species over significant portions of all scenarios. Based on our assumptions about price and cost (fixed + variable, less stumpage), it costs $11.05/m^3 more to harvest hemlock than is gained from selling it (see Section 2.5.1), so harvesting less hemlock by protecting old growth hemlock stands makes society better off. As increasing levels of old growth protection are applied, less and less hemlock is harvested (see Figure 9). This pattern reduces losses from hemlock harvests compared to the base case, but the reduction is insufficient to compensate for the loss of benefits from the harvest of other species or the overall reduction in AAC. Thus, despite the net cost of harvesting hemlock, timber harvest benefits remain negative as old growth protection increases. Because we apply a discount rate of 3% (applied to all ecosystem services), as old growth protection increases hemlock's negative value has increasingly less effect over time on overall results (see Appendix B for an explanation of the discounting procedure we used). The non-transitional scenarios have a less negative effect on timber harvest benefits than the transitional scenarios because they all harvest lower volumes of hemlock early in the time series where less discounting has been applied.

Despite overall timber production losses from hemlock, logging companies may continue to harvest logs over short-run periods of time if the revenue they generate exceeds their *variable* costs. Although recent data are unavailable for the variable costs of log harvests, we estimated the share of total cost that are variable from data compiled by Knowler and Dust (2008). The authors report annual total and variable costs from 1998 to 2001 (Table 11). Over these four years, the mean share of variable costs is 58% so we estimate variable cost per m^3 by multiplying our total cost estimate of $79.26/$m^3$ (2018 CAD) by 0.58, yielding $45.97/$m^3$ (2018 CAD). This variable cost falls within the $42 to $46 range used for a recent study assessing carbon and timber opportunities in the Pacheedaht First Nation's traditional territory north of Port Renfrew (Davey et al. n.d.).

Table 11. Share of total timber harvest cost that is variable (2006 CAD)

Year	**Cost ($/m³)**		**Variable Share**
	Variable	Total	
1998	$49.23	$89.33	55%
1999	$49.12	$85.09	58%
2000	$53.84	$93.64	57%
2001	$54.95	$91.04	60%
Mean	**$51.79**	**$89.78**	**58%**

Source: Knowler and Dust (2008)

For all species, this variable cost estimate is easily covered by the selling price per m^3, including for hemlock (see Table 5). Over the long-run, companies need to cover total costs in order to stay in business. Our analysis shows that in all scenarios over the 100-year time horizon, revenue from timber harvests does in fact cover total cost, largely due to higher volumes of fir and cedar harvested in the middle parts of the time series. Firms may also choose to sustain losses over short periods if they perceive other benefits from continuing to operate such as maintaining employees, sunk costs (e.g., investments in training), or because they receive subsidies. These types of benefit are beyond the scope of our analysis.

Our sensitivity analyses of timber harvest price and cost variables suggest that if log prices for each species were to increase by between 0.1% and 0.4% per year (Knowler and Dust 2008) and harvest costs were to decrease by 10%, it would increase the NPV from the '100% OG Protected' scenario by about $17 million (see Appendix C).

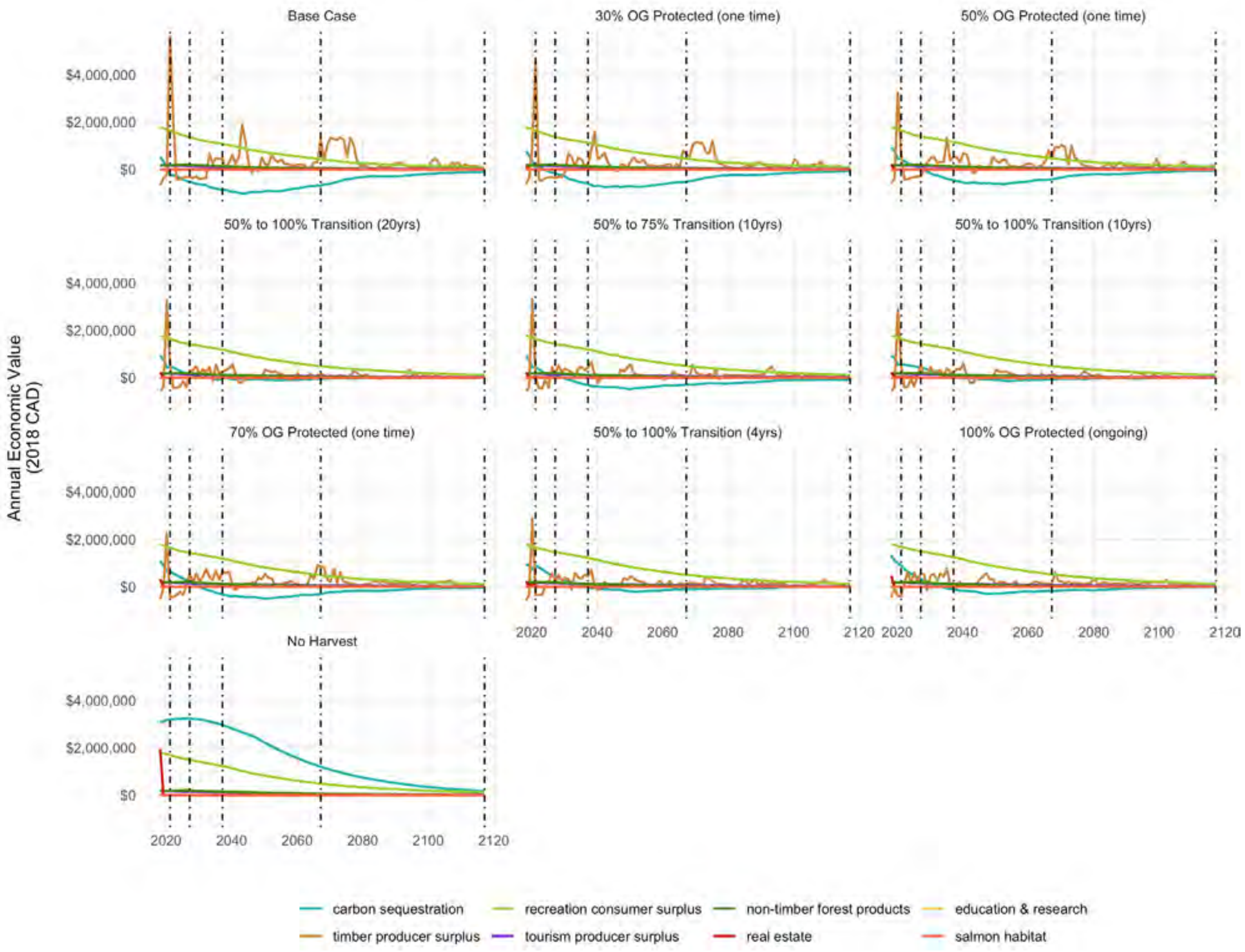


*Figure 16. Present value (2018 CAD) of annual values for each ecosystem service over the modelled 100-year time horizon for all scenarios (**>140 year old growth definition**). Dotted lines represent 4yr, 10yr, 20yr, 50yr, and 100yr time steps. Net present values reported in Table 9 are the sums of these values across the full time horizon. All ecosystem services converge toward zero in present value terms primarily due to the discount rate of 3% (see Appendix B).*

Figure 16 illustrates how annual 'present values' (i.e., discounted) behave over the 100-year simulation for each ecosystem service (these are total values, not incremental values). The 3% discount rate causes future benefits to be valued less than current or near-term benefits, which is the primary reason all ecosystem services eventually converge toward zero in the time series. The most important patterns to observe in this diagram are that as old growth protection increases, carbon sequestration benefits tend to become less negative increasingly early in the time series and timber harvest benefits decline. Consumer surplus from recreation remains comparatively similar across all scenarios, which is consistent with the incremental results shown in Figure 15. While difficult to see in the plots, tourism producer surplus and non-timber forest products play a minor role overall, with the former slightly increasing and the latter slightly decreasing benefits with old growth protection. The decrease from non-timber forest products occurs because the shift in harvest practices means unprotected stands less frequently occur in the preferred younger to middle age classes for pine mushrooms (age classes

3-7, see Table 8). Pine mushrooms are the main driver of NTFP benefits, exceeding the NPV of chanterelles and salal by one to two orders of magnitude (i.e., $6 million versus $414,000 and $84,000 respectively for the base case). The No Harvest scenario consistently has the most stands in age classes 3-7 and therefore produces the greatest net benefit from NTFPs.

We report net present value and incremental benefit results for each ecosystem service in Section 3.4 (Table 12).

		TOTAL		Carbon Sequestration		Timber Producer Surplus		Rec/Tourism Consumer Surplus		Tourism Producer Surplus	
ID	**Scenario**	**NPV**	**Difference from Base Scenario**	**NPV**	**Difference from Base Scenario**	**NPV**	**Difference from Base Scenario**	**NPV**	**Difference from Base Scenario**	**NPV**	**Difference from Base Scenario**
	Base Case										
0	*Business as usual*	$ 56.38	$ -	$ (48.35)	$ -	$ 33.08	$ -	$ 58.64	$ -	$ 6.46	$ -
	Immediate Protection (>250-year OG definition)										
1	*30% OG Protection*	$ 67.86	$ 11.49	$ (34.68)	$ 13.67	$ 28.50	$ (4.59)	$ 60.77	$ 2.13	$ 6.71	$ 0.25
2	*50% OG Protection*	$ 75.31	$ 18.94	$ (25.93)	$ 22.42	$ 25.51	$ (7.57)	$ 62.28	$ 3.64	$ 6.89	$ 0.42
3	*70% OG Protection*	$ 82.56	$ 26.18	$ (17.56)	$ 30.80	$ 22.57	$ (10.51)	$ 63.94	$ 5.30	$ 7.08	$ 0.61
5	*100% OG Protection*	$ 90.23	$ 33.85	$ (7.69)	$ 40.66	$ 16.92	$ (16.16)	$ 67.16	$ 8.53	$ 7.45	$ 0.99
	Immediate Protection (>140-year OG definition)										
6	*30% OG Protection*	$ 69.67	$ 13.29	$ (32.88)	$ 15.47	$ 28.12	$ (4.97)	$ 61.12	$ 2.48	$ 6.75	$ 0.29
7	*50% OG Protection*	$ 78.26	$ 21.88	$ (23.14)	$ 25.21	$ 24.96	$ (8.12)	$ 62.93	$ 4.30	$ 6.96	$ 0.50
8	*70% OG Protection*	$ 86.45	$ 30.07	$ (13.88)	$ 34.47	$ 21.72	$ (11.37)	$ 64.94	$ 6.30	$ 7.19	$ 0.73
10	*100% OG Protection*	$ 96.75	$ 40.38	$ (2.35)	$ 46.00	$ 16.75	$ (16.33)	$ 68.49	$ 9.85	$ 7.59	$ 1.13
	Transitional Protection (>250-year OG definition)										
11	*50% to 75% Transition (10yrs)*	$ 79.43	$ 23.05	$ (20.46)	$ 27.89	$ 21.49	$ (11.60)	$ 64.77	$ 6.13	$ 7.18	$ 0.72
12	*50% to 100% Transition (4yrs)*	$ 94.23	$ 37.86	$ (4.29)	$ 44.06	$ 18.74	$ (14.34)	$ 65.91	$ 7.27	$ 7.30	$ 0.84
13	*50% to 100% Transition (10yrs)*	$ 89.08	$ 32.70	$ (10.05)	$ 38.30	$ 18.71	$ (14.37)	$ 66.68	$ 8.04	$ 7.39	$ 0.93
14	*50% to 100% Transition (20yrs)*	$ 89.47	$ 33.10	$ (5.10)	$ 43.26	$ 16.21	$ (16.87)	$ 64.48	$ 5.84	$ 7.15	$ 0.69
	Transitional Protection (>140-year OG definition)										
15	*50% to 75% Transition (10yrs)*	$ 76.95	$ 20.58	$ (16.95)	$ 31.40	$ 14.35	$ (18.74)	$ 65.84	$ 7.20	$ 7.31	$ 0.84
16	*50% to 100% Transition (4yrs)*	$ 100.15	$ 43.77	$ 2.57	$ 50.93	$ 16.64	$ (16.44)	$ 66.94	$ 8.30	$ 7.42	$ 0.96
17	*50% to 100% Transition (10yrs)*	$ 95.51	$ 39.14	$ 5.09	$ 53.44	$ 10.74	$ (22.35)	$ 65.64	$ 7.00	$ 7.28	$ 0.82
18	*50% to 100% Transition (20yrs)*	$ 91.27	$ 34.89	$ 2.11	$ 50.46	$ 10.21	$ (22.88)	$ 64.98	$ 6.34	$ 7.21	$ 0.74
	No Harvest										
19	*No harvesting of any timber*	$ 231.89	$ 175.52	$ 150.77	$ 199.13	$ -	$ (33.08)	$ 65.98	$ 7.34	$ 7.29	$ 0.83

Table 12. Economic valuation results with comparison to the base case for all scenarios and all ecosystem services. Results are in net present value (2018 CAD millions) discounted at 3% over 100 years.

		Non-Timber Forest Products		Real Estate		Education & Research		Salmon Habitat	
ID	**Scenario**	**NPV**	**Difference from Base Scenario**	**NPV**	**Difference from Base Scenario**	**NPV**	**Difference from Base Scenario**	**NPV**	**Difference from Base Scenario**
	Base Case								
0	*Business as usual*	$ 6.53	$ -	$ -	$ -	$ 0.01	$ -	$ -	$ -
	Immediate Protection (>250-year OG definition)								
1	*30% OG Protection*	$ 6.44	$ (0.10)	$ 0.12	$ 0.12	$ 0.01	$ 0.00	$ 0.00	$ 0.00
2	*50% OG Protection*	$ 6.35	$ (0.18)	$ 0.20	$ 0.20	$ 0.01	$ 0.00	$ 0.00	$ 0.00
3	*70% OG Protection*	$ 6.24	$ (0.29)	$ 0.28	$ 0.28	$ 0.01	$ 0.00	$ 0.00	$ 0.00
5	*100% OG Protection*	$ 5.94	$ (0.59)	$ 0.42	$ 0.42	$ 0.01	$ 0.00	$ 0.01	$ 0.01
	Immediate Protection (>140-year OG definition)								
6	*30% OG Protection*	$ 6.41	$ (0.12)	$ 0.14	$ 0.14	$ 0.01	$ 0.00	$ 0.00	$ 0.00
7	*50% OG Protection*	$ 6.30	$ (0.24)	$ 0.23	$ 0.23	$ 0.01	$ 0.00	$ 0.00	$ 0.00
8	*70% OG Protection*	$ 6.15	$ (0.39)	$ 0.32	$ 0.32	$ 0.01	$ 0.00	$ 0.01	$ 0.01
10	*100% OG Protection*	$ 5.79	$ (0.74)	$ 0.46	$ 0.46	$ 0.01	$ 0.00	$ 0.01	$ 0.01
	Transitional Protection (>250-year OG definition)								
11	*50% to 75% Transition (10yrs)*	$ 6.10	$ (0.43)	$ 0.33	$ 0.33	$ 0.01	$ 0.00	$ 0.01	$ 0.01
12	*50% to 100% Transition (4yrs)*	$ 6.18	$ (0.35)	$ 0.37	$ 0.37	$ 0.01	$ 0.00	$ 0.01	$ 0.01
13	*50% to 100% Transition (10yrs)*	$ 5.93	$ (0.60)	$ 0.39	$ 0.39	$ 0.01	$ 0.00	$ 0.01	$ 0.01
14	*50% to 100% Transition (20yrs)*	$ 6.37	$ (0.16)	$ 0.34	$ 0.34	$ 0.01	$ 0.00	$ 0.01	$ 0.01
	Transitional Protection (>140-year OG definition)								
15	*50% to 75% Transition (10yrs)*	$ 6.01	$ (0.52)	$ 0.38	$ 0.38	$ 0.01	$ 0.00	$ 0.01	$ 0.01
16	*50% to 100% Transition (4yrs)*	$ 6.13	$ (0.40)	$ 0.42	$ 0.42	$ 0.01	$ 0.00	$ 0.01	$ 0.01
17	*50% to 100% Transition (10yrs)*	$ 6.36	$ (0.17)	$ 0.39	$ 0.39	$ 0.01	$ 0.00	$ 0.01	$ 0.01
18	*50% to 100% Transition (20yrs)*	$ 6.39	$ (0.14)	$ 0.37	$ 0.37	$ 0.01	$ 0.00	$ 0.01	$ 0.01
	No Harvest								
19	*No harvesting of any timber*	$ 7.84	$ 1.30	$ 1.94	$ 1.94	$ 0.01	$ 0.00	$ 0.03	$ 0.03

Table 11. Cont’d

4 Community Implications for Focal Scenarios

In the preceding sections we outline our methods and provide results from a range of old growth protection scenarios for the Port Renfrew study site. In this section, to the extent possible with data collected and generated for this report, we connect our results to the different community interests that may be impacted for three focal scenarios. **Since these narratives are incomplete, we recommend improving them in collaboration with other interested parties to provide additional context** (e.g., the Pacheedaht Nation, Teal-Jones, FLNRORD, and residents and business owners in Port Renfrew).

Business as Usual (Base Case) – Net **Benefit** of $56 Million

In the baseline scenario, forest management in the Timber Supply Area (TSA) continues per the harvest plans reported in the 2016 Arrowsmith-South Island Timber Supply Review (TSR). In the spring of 2021, following an election promise to adopt all recommendations of the BC Old Growth Strategic Review panel, the Province implements an old growth forest management strategy that results in neither an increase nor a decrease of current old growth harvest practices in the TSA around Port Renfrew. Overall, timber harvest from this part of the TSA generates about 14 full-time equivalent (FTE) jobs for the Province and contributes about half a million dollars annually to the provincial GDP (see Appendix D).

Over the next 50 years (i.e., by 2068), the area of standing old growth **decreases** by 21% (987 ha) from the current 4,658 ha in the TSA, and 28% (1,325 ha) over the next 100 years (i.e., by 2118). In the portion of the TSA that is currently harvestable (THLB), most old growth is red cedar, hemlock, and Amabilis fir. Decreases in old growth mostly occur in red cedar and hemlock with very little old red cedar left in the THLB by 2118. Hemlock is the dominant harvested species in the TSA until about 2035, at which point it is joined by Douglas fir until cedar begins to dominate harvest in the late 2060s for about a decade. At $111.89/m^3 (2018 CAD), the log price for fir averages less than half that of cedar but may increase if a broader decline in the availability of cedar drives an increase in demand for fir.

Local timber processing facilities that produce cedar products are affected by the decreased availability of large cedar trees, which requires retrofitting to accommodate different species and log grades. This impact partly depends on how many non-THLB cedar stands are reassigned by the Province to the THLB over time, and the extent to which processing facilities rely on timber from the TSA (this study) versus timber from private lands and Tree Farm Licenses (TFLs). About 21% of the TSA's cedar stands are currently located in the non-THLB and, if permitted to grow, most of these trees will be older than 140 years by 2118. The extent to which the Province reassigns non-THLB stands to the THLB during the next TSR cycle is unknown. The extent to which local timber processing facilities rely on the TSA versus other forest lands also is not publicly available information. However, the Pacheedaht Nation produces ~140,000 m^3 of timber annually, owns/operates a log sorting facility for TFL 61 that employs 12 people (including 2 Pacheedaht members), and owns/operates a sawmill that processes 10,000 m^3 per year into high value specialty cedar products, employing 8 people (including 6 Pacheedaht members). The Nation's plans to build a new chipping facility may be affected.

A decrease in old hemlock trees (>140yrs) available for harvest also occurs. At present, about 38% of the hemlock stands in the TSA are older than 140 years and most of the remaining stands are younger than 59 years. About 24% of the TSA's hemlock stands are in the non-THLB, and like cedar stands, most of these are older than 140 years by 2068 if allowed to grow. In the THLB, the proportion of hemlock stands that are old growth (currently 29%) decreases to 24% by 2118. The story is different for old growth fir, which increases in the TSA from just 95 ha to 400 ha by 2118, with 56% in the non-THLB and 44% in the THLB.

Over the 100-year time horizon, timber supply generates economic benefits with a net present value of $33 million (CAD 2018) (see Table 12). Due to harvest cycles, the TSA land base remains a net carbon source, which has both local and non-local implications in terms of climate change impacts. Based on the social cost of carbon (see Section 2.5.3), carbon sequestration *deficits* under this scenario are estimated at $48 million (Table 12). Old growth recreation and tourism opportunities decline, generating net economic benefits of about $59 million to consumers and $6.5 million to producers (less than under all other scenarios). Tourism generates about 25 FTE jobs and about $930,000 dollars annually to the provincial GDP. Mushroom and salal harvesters continue to do well since harvest cycles ensure stands are more frequently in the preferred age classes for these non-timber forest products. Pine mushroom, chanterelle, and salal harvesters generate about $6.5 million in economic benefits. The overall value of this scenario is a net benefit of $56.4 million.

Immediate and Ongoing Protection of all Old Growth in the TSA – Net **Benefit** of $97 million

In the spring of 2021, the Province of BC interprets the Old Growth Strategic Review panel's recommendations as requiring immediate and ongoing protection of all old growth stands in the TSA around Port Renfrew. 'Old growth' is defined as 140 years. Over the next 50 years (i.e., by 2068), the area of standing old growth **increases** by nearly 4% (178 ha) from the current 4,658 ha in the TSA, and over the next 100 years it rises by 17% to 5,467 ha. This gain occurs across all species types in stands that are excluded from harvest in both the THLB and the non-THLB, but the largest increases occur in Douglas fir (369% increase to 447 ha), hemlock (12% increase to 2,394 ha), and red cedar (6% increase to 1,536 ha).

Due to the protection of old growth stands, only 69% of the base case's cumulative annual allowable cut in the TSA is harvested over 100 years. Fir and hemlock are the most harvested species, with fir being of highest value overall since its net worth is about $33/m^3 (price minus fixed and variable costs) compared to hemlock's *negative* $11/m^3. Unlike the base case, higher value red cedar stands do not achieve sufficient volumes or ages to be prioritized for harvest until about 2070. After 2070, red cedar harvest remains fairly steady, but comprises only about one tenth to one third of the total harvest in any given year. Since cedar's net worth is about $133/m^3, this harvest is not insignificant, but it is lower than for the base case where red cedar dominates harvest for about a decade around the 50-year mark (see Figure 9). While the reduction in cedar harvest reduces overall timber harvest benefits, it also results in a less volatile, more predictable cedar harvest in the second half of the 100-year period, with fewer years having zero harvest of cedar-dominant stands.

By 2118, the remaining *unprotected* stands in the THLB are comprised primarily of younger stands (<59 years), with a small amount of mature hemlock, Douglas fir, and red cedar remaining (>99yrs and <140yrs). The species composition of these younger stands is predominantly hemlock (55%), followed by Douglas fir (24%), red cedar (14%), and Amabilis fir (6%). In the non-THLB, which is comprised of hemlock (53%), red cedar (21%), Amabilis fir (15%), and Douglas fir (11%), stands are permitted to grow with most achieving protected status (i.e., >140 yrs) by 2118. The extent to which younger stands in the non-THLB are reassigned to the THLB during the next TSR cycle is unknown but given the reduction of available timber in the THLB, it is highly likely some non-THLB stands are reassigned to help sustain the adjusted AAC.

The reduction of harvestable timber has implications for provincial employment with this scenario generating approximately 7 fewer FTE jobs from the timber harvest sector and reducing this sector's contribution to the provincial GDP by about $247 thousand annually (see Appendix D). Changes in the availability of harvestable timber impacts those local wood processing facilities that depend heavily on TSA logs. All logging companies operating in the area are affected, but the change benefits smaller local companies that are able to take a greater share of the annual allowable cut when larger companies withdraw their operations. Reductions to jobs and GDP are also partially compensated for by increases in the tourism sector of about 7 FTE jobs, and an additional $162 thousand annually to the provincial GDP (see Appendix D).

Overall *net* benefits to societal welfare from carbon sequestration, recreation, and tourism easily compensate for losses from timber harvest (see Figure 15). Over the 100-year time horizon, timber supply will generate economic benefits with a net present value of about $17 million (CAD 2018), or $16 million less than the base case. Like the base case, the TSA land base will remain a net carbon source, but to a much lesser extent. The larger volumes of standing old growth that are still growing (vs. decaying) will generate carbon sequestration benefits of $46 million compared to the base case (Table 11). The increased availability of old growth stands for tourism and recreation also raises net benefits to tourism/recreation consumers by $9.9 million and to tourism producers by $1.1 million[38]. Pine mushroom, chanterelle, and salal harvesters will generate $5.8 million in net benefits, which is less than under the base case by about $0.7 million. Combining all ecosystem services, this scenario will provide $97 million in net benefits to British Columbians, or a $40 million improvement over the base case.

Immediate and Ongoing Protection of 50% of all Old Growth in the TSA – Net **Benefit** of $78 Million

In the spring of 2021, the Province of BC interprets the Old Growth Strategic Review panel's recommendations as requiring partial protection of all old growth stands in the TSA around Port Renfrew. 'Old growth' is defined as 140 years and 50% of all old growth stands in the TSA around Port Renfrew are immediately protected in perpetuity. Over the next 50 years (i.e., by 2068), the area of standing old growth **decreases** by almost 10% (448 ha) from the current 4,658 ha in the TSA but bounces back slightly for an overall decrease of only 6% (267 ha) over the next 100 years (i.e., by 2118), or an improvement from the base case of 22%.

84% of the base case's cumulative annual allowable cut in the TSA can still be harvested over 100 years. Unlike the full old growth protection scenario, some cedar harvests do occur in the first 50 years but to a reduced extent. Fir and hemlock are the most harvested species, with hemlock harvest dominating the first decade of the time period. The impact to the BC economy is a reduced contribution from timber harvest to the provincial GDP by about $122 thousand annually, and fewer jobs by just over 3 FTEs. Reductions to jobs and GDP are partially compensated for by increases in the tourism

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[38] Results from the cost-benefit analysis that is the focus of the main body of this report cannot be added to the results of the economic impact assessment in Appendix D. These values are *net* benefits from increases to consumer and producer surplus caused by increasing the area of available old growth. Impacts to GDP and jobs from tourism are a separate analysis and are based on the sum of direct, indirect, and induced effects of estimated gross tourism revenues as determined by applying regionally adjusted multipliers from provincial input-output models.

sector of about 3 FTE jobs, and an additional $72 thousand annually to the provincial GDP (see Appendix D).

Like the 100% old growth protection scenario, overall *net* benefits to societal welfare from carbon sequestration, recreation, and tourism easily compensate for losses from timber harvest (see Figure 15), but these benefits are somewhat muted in comparison. Over the 100-year time horizon, timber supply generates economic benefits with a net present value of about $26 million (CAD 2018), or about $8 million less than the base case. Like the previous scenario, the TSA land base remains a net carbon source but to a lesser extent than the base case. The larger volumes of standing old growth that are still growing (vs. decaying) generate additional carbon sequestration benefits of $22 million compared to the base case (Table 12). The increased availability of old growth stands for tourism and recreation also raises net benefits to tourism/recreation consumers by $3.6 million and to tourism producers by $0.4 million[39]. Pine mushroom, chanterelle, and salal harvesters generate $6.3 million in net benefits, which is less than under the base case by about $0.2 million. The combined benefits from all ecosystem services provides an overall net benefit from this scenario of $78 million, or a $22 million improvement over the base case.

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[39] Results from the cost-benefit analysis that is the focus of the main body of this report cannot be added to the results of the economic impact assessment in Appendix D. These values are *net* benefits from increases to consumer and producer surplus caused by increasing the area of available old growth. Impacts to GDP and jobs from tourism are a separate analysis and are based on the sum of direct, indirect, and induced effects of estimated gross tourism revenues as determined by applying regionally adjusted multipliers from provincial input-output models.

5 Next Steps

Based on the methods and results reported in Chapters 2, 3 and 4, this section provides some suggested next steps for the Ancient Forest Alliance (AFA) to consider.

5.1 Outreach and Science Communication

This report is designed to be shared and discussed. An important part of economic valuation exercises like this one is ensuring results are communicated to a broader audience in an easily digestible, and accurate way. This broader communication will ensure the public and interested groups are aware of the economic benefits of old-growth forests beyond those supplied by timber harvest, and that they understand the rigorous methods used to arrive at those results. Several approaches can be used to engage a wider audience including media releases, submission of results for government review, effective science communication materials (brochures, policy briefs), focus groups, face-to-face meetings with other interested parties, and publication of results in peer reviewed academic journals.

The benefits of strong science communications include extending learning beyond project leads and technical experts by building capacity, empowering local communities and helping to ‘close the learning loop’ by providing opportunities for input from those interested but not directly involved in the project. These steps can improve broad buy-in for a project, which aids in smoother implementation and monitoring of alternative management practices. Additionally, creative data visualization techniques and quality graphic design can extend the lifespan and learning benefits of project outputs by engaging audiences in ways that help them digest and understand large amounts of complex information relatively quickly.

Carefully considering the sequencing of these approaches is important. For example, given the potential implications of old growth protection scenarios for timber processing facilities and logging companies in the study area, engaging groups like the Pacheedaht Nation prior to issuing media releases can build trust by signalling an openness to work together to build a shared narrative. Any such shared narrative should emphasize common ground without overlooking potential challenges and possible solutions.

Our suggested next steps for outreach and science communications include the following:

- Continue to engage the Province of British Columbia (esp. through consultations regarding the implementation of the Old Growth Strategic Review Panel's recommendations)
- Engage the Pacheedaht Nation and other interested groups to communicate the findings of this report and build a shared narrative prior to releasing results to the media
- Host a technical briefing prior to releasing results to the media to ensure technical accuracy (can also include media representatives)
- Issue press releases
- Develop science communications materials that summarize the results of this report in an easily digestible way, using creative data visualization and quality graphic design
- Publish results in a scientific, peer reviewed journal

5.2 Addressing Data Gaps & Conducting Additional Analyses

The net economic benefits from the ecosystem services we evaluate in this report are incomplete estimates of the total economic value (TEV) of old growth forests in the study area. Our results do not include several services supplied by these forests such as cultural value, health and well-being, and fish production services other than commercial harvest. We did not include these services either due to a lack of required data (cultural value, health and well-being) or the need to conduct more extensive modelling outside the scope of this project (fish production services). We err conservatively in many of our model assumptions and provide sensitivity analyses to capture more and less conservative assumptions across key parameter values. Nevertheless, as with most ecosystem service valuation exercises, our results should be interpreted as underestimates of TEV. Even these underestimates suggest significant economic benefits from old growth protection. To obtain a more complete picture of TEV our methods could be improved in the following ways:

Recommendations for Addressing Data Gaps

- Conduct a stated preference survey to improve upon the Province's 1989/1990 Recreation Study (BC Ministry of Forests 1991) and update the economic model with more current recreation data *[AFA is currently pursuing this in collaboration with Simon Fraser University)]*
- Conduct surveys and/or focus groups with local tour guide, restaurant, and accommodation businesses to establish what proportion of expenditures by visitors or tourists (by sector) attributed to forests can be attributed specifically to old growth forests. Incorporate these findings into the economic model
- Conduct surveys and/or focus groups with local real estate agents to establish what proportion of real estate price premiums that are attributed to forests can be attributed specifically to old growth forests (e.g., hedonic property price analysis – see Appendix A). Incorporate these findings into the economic model
- Conduct surveys and/or focus groups with local residents to identify the most commonly harvested non-timber forest products in the study area. Incorporate these into the economic model

Recommendations for Additional Analyses

- In the CFS-CBM3 model, permit harvest rates to change over time instead of (or in addition to) applying a constant harvest target that may or may not be met in a given year. This adjustment would more realistically capture the response of the timber harvest industry to changes in available timber under different protection scenarios (e.g., the rate may increase or decrease in the stands that remain eligible for harvest depending on management responses).
- In the valuation of carbon storage via wood products, account for substitute effects such as wood products displacing more carbon intensive construction materials like concrete, or energy sources like fossil fuels. In this study, we used the BC Harvested Wood Product Carbon Calculator, which does not account for such effects (BCMOFLNRO, 2016). We expect that this additional sensitivity analysis would result in an increase in the contribution of wood products to stored carbon.

- Account for climate change in the CBM-CFS3 model by permitting periodic forest fire and beetle infestation disturbances in the land base. In our application of the model, we assumed the only disturbance type was harvest, which is currently appropriate for BC coastal forests. However, climate change may alter the validity of this assumption, which we could address using additional sensitivity analyses.
- Develop a bio-economic model across multiple salmon species that captures additional fish production services and identifies what proportion of these services can be attributed to old growth forests (i.e., recreational and subsistence fishing; nutrient cycling). Based on salmon valuation studies we have completed elsewhere, the fish production results reported in this study are likely under-estimates that could be improved with more refined modelling. Incorporate these results into the economic model.

5.3 Scaling Up & Conservation Financing

This pilot study represents a first step towards improving the valuation of non-market ecosystem services from Vancouver Island forests and highlights an important opportunity for a broader program of research. A surprise result from our Phase 1 scoping and feasibility assessment was the absence of economic valuation studies focusing on Vancouver Island forests as well as some significant primary data gaps. With this preliminary work, AFA is well positioned to lead the charge toward an improved assessment of non-market values for old growth forests Island-wide. In the Phase 1 report we highlighted opportunities to partner with academics to complete more up-to-date and region-specific primary data gathering in the form of stated preference valuation studies (esp. recreation) and AFA has now initiated such a partnership with Simon Fraser University. Partnerships with ENGOs and Indigenous Nations may also support the leveraging of additional funding and capacity. Collaboration with Indigenous Nations would aid in developing a better understanding of how cultural ecosystem services generate economic benefits and how these benefits can be incorporated into assessments of non-market values on the Island.

As evidenced in the Great Bear Rainforest (GBR), ideas like conservation financing can have important implications for Indigenous communities and can also advance old growth conservation efforts by more clearly defining habitat values and conservation hotspots. In the GBR, the provincial and federal governments and philanthropic foundations provided significant conservation funding via Coast Funds (www.coastfunds.ca), but these amounts needed to be divided across each Nation based on the habitat values present within different territories. The approach taken was to develop a GIS-based ‘Relative Biodiversity Index’ (RBI) that allowed a proportional representation of habitat value within each territory (personal communications, Jody Holmes, February 11, 2019). The index incorporates protected forests, ungulate winter ranges (black-tailed deer and mountain goat), wildlife habitat areas (marbled murrelet, northern goshawk, tailed frog, grizzly bear), BC red and blue listed ecosystems, and riparian features (Lewis and Kremsater 2009). Relative RBI contributions by territory were used to divide available conservation financing proportionally across individual Nations. With available forest and species data, the RBI approach may also be replicable on Vancouver Island with minimal effort, capitalizing on the work already completed in the GBR. Completing such an exercise would have useful applications beyond supporting valuation (e.g., locating biodiversity hotspots), and would greatly facilitate the allocation of any future conservation investments across affected parties and Indigenous Nations.

5.4 Prioritizing Old Growth Stands for Protection

While the results in this report suggest significant economic benefits from protecting old growth, 100% old growth protection around Port Renfrew may not be feasible in the near term. As such, it may be desirable to identify specific stands that can be targeted for protection under alternative management scenarios that provide the greatest value per effort/resources. Prioritization for ecological restoration and protection is a multi-criteria selection process that requires careful planning. The objective is typically to maximize the breadth of benefits at least cost within feasibility constraints. At its core, the desired outcome of any prioritization exercise is a rank ordered list of items. These can be lists of restoration, monitoring, and evaluation actions in a conservation plan, or, as in this case, lists of specific tree stands for protection.

In instances where a prioritization scheme may be scaled up beyond a pilot region, it is especially important to develop prioritization criteria that are both scientifically defensible, repeatable, and can be monitored over time. Often in conservation planning it is useful to begin with some ‘Big Questions’, or uncertainties that are important to address to support conservation goals. These questions can be elicited in a variety of ways including document review, convening focus groups of experts, or implementing full participatory planning processes. The extent to which protecting certain stands would achieve learning benefits toward addressing these Big Questions can be a key prioritization criterion, as can the extent to which limiting factors or environmental ‘stressors’ would be reduced.

The modelling conducted for this report applied some built-in prioritization criteria to identify candidate old growth stands for protection. These criteria are described in Sections 2.3 and 2.4 and included the landscape level protection target (e.g., 100% OG Protection, 50% OG Protection) and the age class of the stand (e.g., >140yr, >250yr). The volume of harvestable timber in a stand also played a role in determining whether younger stands were harvested before they achieved old growth status. Many other criteria can be applied, for example, the number of endangered or threatened species that would benefit if the stand were protected, contribution to habitat connectivity, stand-specific carbon storage volumes and sequestration rates, the current status or potential of a stand as a recreation and/or tourist opportunity, the degree of stand impairment/risk (e.g., see Figure 2), the feasibility of implementing protection, the cost involved in protecting the stand(s), the extent of multi-lateral agreement/support for protection, the stand’s contribution to human well-being (e.g., using results like those reported here), and more.

Once criteria are developed, they can be used to assign scores to each stand using spatial analysis. Each criterion can also be assigned a weight to reflect perceived differences in the importance of some criteria over others and these weights can be adjusted to generate different prioritization outcomes for analysis. This type of weighting can be particularly useful in situations where multiple interest groups have a stake in conservation outcomes and may have competing or diverging viewpoints that need to be considered. In addition, criteria can be assessed in the short-term, medium-term, and/or long-term to develop dynamic rank ordered lists that change depending on the time scale of relevance.

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Appendix A. A Short Primer on Valuing Non-market Ecosystem Services

Two basic types of information are required to assign a monetary value to an ecosystem service: 1) the number of units of each service (e.g., number of tourist visits to an old growth stand), and 2) a corresponding per unit dollar value (e.g., the value of a visit to the old growth stand). Obtaining these data is not always straightforward, potentially requiring field research if local unit counts are unavailable and/or if there are no known per unit dollar values.

Many forest-based services have market prices. In British Columbia (BC), for example, studies have used existing market prices to assess the carbon offset value of forests (e.g., van Kooten 2019), and the value of BC's non-timber forests products (Wills and Lipsey 1999, Knower and Dust 2008). If such prices are available, the task of estimating the value of goods and services flowing from forests can be greatly simplified, but this is not always possible, for instance in the case of pure public goods, or when market prices poorly reflect overall societal value. In these cases, non-market valuation can be applied.

Because market prices, or their absence, can be an inadequate proxy for the overall value of a good or service to society, the 2003 Millennium Ecosystem Assessment proposed the Total Economic Value (TEV) framework, which is now widely used by environmental economists as a way of organizing different types of economic value. The TEV framework specifies two broad categories: a) use value, and b) non-use value (see Figure 1). The first type of value is derived from consumptive or non-consumptive interaction by people with a resource and can be further subdivided into direct (e.g., timber harvest, recreational use) and indirect use values (e.g., water purification). Non-use value is derived from people assigning value to a resource even though they may never use it (e.g., the existence of old growth forests, intact forests for future generations, cultural value).

In welfare-based approaches to economics, overall benefits to society are typically measured as either changes in 'consumer surplus' or 'producer surplus' (Hanley and Barnier 2009), where the former is the difference between what a *consumer* is willing to pay for a good or service and the actual price paid for it, and the latter is the difference between what a *producer* is willing to accept for a good or service and the actual price received for it. Non-market valuation attempts to value consumer and producer surpluses by eliciting 'willingness to pay' (WTP) or 'willingness to accept' (WTA) for a change in the number of units of a good or service. Willingness to pay is the amount of money an individual would be willing to pay to obtain a positive change or forgo a negative change. Willingness to accept is the amount of money an individual would require to endure a negative change or forgo a positive change.

Each type of value specified in the TEV framework can have non-market elements that are captured using different methods. To assess WTP or WTA, three main methodological approaches are typically used: a) stated preference, b) revealed preference, and c) benefit transfer (National Research Council 2005). **Stated preference** approaches elicit monetary values by querying individuals directly using a hypothetical market. Two common stated preference methods are called 'contingent valuation' and 'discrete choice experiments', both of which are usually administered using surveys to elicit WTP and WTA (see Section 0). **Revealed preference** approaches indirectly assign value by observing individual behaviors in a market.[40] Common revealed preference methods include 'travel cost' and 'hedonic pricing' (see Section 0). **Benefit transfer** applies monetary values already elicited elsewhere to the study site, sometimes directly with caveats or by adjusting to account for differences across the sites (e.g., population, demographics, temporal differences, etc.) (see Section 0).

In addition to these three approaches, **production functions** can be used to establish a mathematical relationship between an environmental input (e.g., river flow, temperature), and a valued good or service. This technique is typically used to value environmental goods or services that have a market price (e.g., salmon production), but can also incorporate stated preference, revealed preference, and benefit transfer values.

Cost-based approaches do not rely on WTP/WTA and so are not true reflections of consumer or producer surplus (i.e., they do not provide a true indication of overall welfare benefits to society). These methods use the market cost of either 'averting behaviour' to avoid detrimental environmental impacts (e.g., staying home to avoid an air quality alert), or 'replacement' of an environmental good or service usually with a built alternative that has a known market price. Because cost-based approaches do not capture overall welfare effects, they are typically used only as a last resort in welfare-based approaches to CBA.

Table 13 summarizes these approaches and some of the ecosystem services they are commonly used to assess. Subsequent sections provide additional detail about each of the three main approaches.

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[40] Market prices, both competitive and simulated, fall into the revealed preference category (National Research Council 2004).

Table 13. Methods for valuing non-market benefits of ecosystem services

Method	Description	Common Ecosystem Service Applications
Stated Preference		
Contingent valuation and Choice experiments	Individuals state WTP/WTA by participating in surveys that present hypothetical market scenarios	Recreation, human health & safety (e.g. pollution control, flood mitigation), existence value (species, ecosystems), biodiversity, water supply, water purification, food production (e.g., fish)
Revealed Preference & Cost Based		
Travel cost	Recreational users reveal WTP via travel and accommodation expenses	Recreation, biodiversity
Hedonic pricing	Owners/investors reveal WTP/WTA via changes in real-estate sale prices or wages in labour markets	Safety (e.g., flood risk) and health (e.g., air quality), biodiversity, water supply, water purification, amenity value (e.g., old growth forest)
Production function	A mathematical relationship is established between an environmental input (e.g., river flow, temperature) and a valued good or service (typically one that has a market price, e.g., salmon)	Human health & safety (e.g., flood mitigation), food production (e.g., fish, agriculture), biodiversity, water supply, water purification, recreation (e.g., fishing), invasive species control
Averting behavior	Individuals reveal WTP to avoid detrimental effects (e.g., by foregoing wages to stay home)	Human health & safety (e.g., air quality)
Replacement cost / Avoided cost	Individuals reveal WTP through goods and services with market values that can be used as proxies	Recreation, human health & safety (e.g., engineered infrastructure as a proxy for value of natural assets for flood mitigation), food production, nutrient cycling
Benefit Transfer		
Benefit Transfer (unit value transfer; function transfer)	WTP/WTA values from another site are either directly applied to the study site or adjusted using mathematical relationships to reflect differences between sites	Recreation, human health & safety (e.g., flood mitigation), existence value, food production, biodiversity, water supply, water purification, invasive species control

Source: Adapted from National Research Council (2005) Table 4-1 and Hanley and Barbier (2009) Table 9.2.

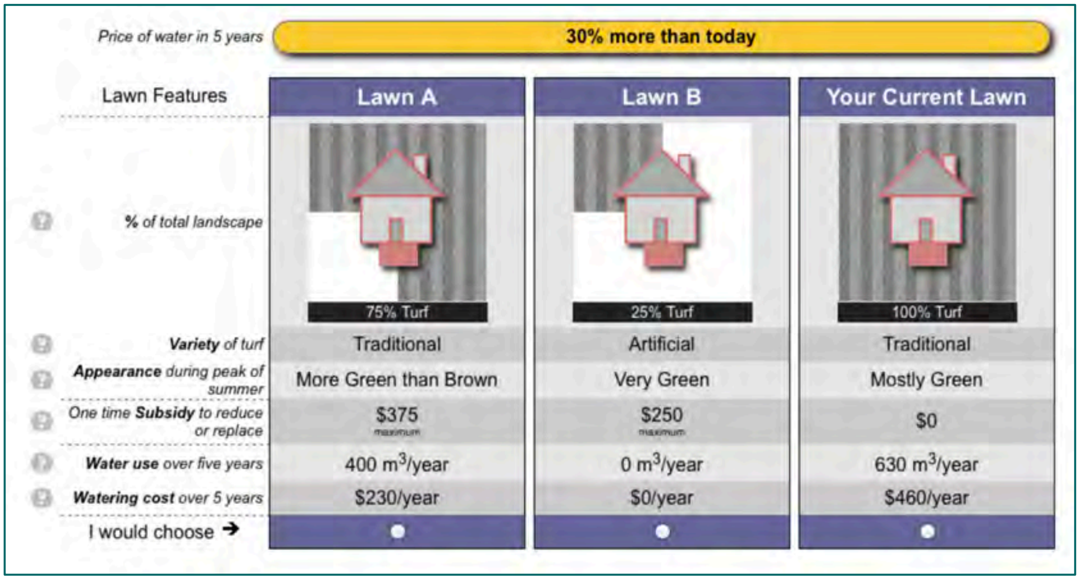
A.1 Stated Preference

Stated preference techniques are survey-based approaches that ask individuals about their WTP/WTA for a change in a good or service (Hanley and Barbier 2009). These techniques are the only valuation methods capable of estimating: a) non-use values, and b) potential changes in service provision that have yet to occur. The two main methods used by environmental economists are contingent valuation and discrete choice experiments.

The contingent valuation method (CVM) is the simplest of the two approaches (Hanley and Barbier 2009). The technique is widely used and has been applied to forests in Canada, British Columbia, and elsewhere in the Pacific Northwest to assess residents' WTP for protecting riparian buffers, creating or increasing protected areas (Watson 1994, Wilson et al. 2012, Trenholm et al. 2013), and protecting old growth forests from fire (Loomis et al. 1996).

Survey respondents are asked to make choices about how much they would be willing to pay (or accept) for a change in the good or service. Once CVM results are collected, averages or statistical models are used to estimate the overall average WTP. For instance, after being provided with some information about the state of Vancouver Island's old growth forests a respondent might be asked how much money they would be willing to pay to protect some or all of the remaining stands (open-ended). Alternatively, the respondent may be asked whether they would be willing to pay for a specified amount or to choose the highest amount they would pay from a list of monetary values (dichotomous choice or payment card, respectively). The recently postponed auction of timber rights near Port Renfrew would lend itself well to a clear CVM survey question: e.g., "how much would you contribute to a fund that will be used to purchase timber rights and set old growth forest aside for protection?".

Similarly, discrete choice experiments (or 'choice experiments') ask survey respondents to make choices in a hypothetical market but unlike CVM, this method involves repeated questioning rather than a single question about WTP/WTA (Hoyos 2010). Bradshaw (2009) used this approach to value alternative forest management options in BC's Lower Mainland and included different extents of remaining old growth forests as a characteristic in the experiment's 'choice set' scenarios. From a different study, Figure 17 shows an example of a single choice set with three scenarios.



Price of water in 5 years **30% more than today**

Lawn Features	Lawn A	Lawn B	Your Current Lawn
% of total landscape	75% Turf	25% Turf	100% Turf
***Variety** of turf*	Traditional	Artificial	Traditional
***Appearance** during peak of summer*	More Green than Brown	Very Green	Mostly Green
*One time **Subsidy** to reduce or replace*	$375 maximum	$250 maximum	$0
***Water use** over five years*	400 m^3/year	0 m^3/year	630 m^3/year
***Watering cost** over 5 years*	$230/year	$0/year	$460/year
I would choose ➔	○	○	○

Figure 17. Example of a single choice set with three scenarios used as part of a web-based discrete choice experiment (Conrad 2016)

Choice experiments present the respondent with multiple choice sets comprising alternative scenarios generated by the researcher using an experimental design. For example, one choice set might contain two alternative options and a status quo option, each describing a good or service in terms of its key characteristics (including monetary value) and the levels these characteristics may take (Figure 17). After being presented with some information about the state of the good or service, the respondent is asked to choose their preferred alternative within each of several choice sets. From all responses, statistical models are then used to estimate the average or median WTP or WTA.

A.2 Revealed Preference & Cost Based Approaches

There are several revealed preference techniques (Hanley and Barbier 2009). Broadly, these approaches involve linking a change in a non-market good or service to a change in a good or service that has a market price. For example, **travel cost** methods are commonly used to value changes in environmental quality as they relate to recreational uses that involve travel costs such as fishing, hunting, boating, and forest visitation. Englin and Mendolsohn (1991), and Englin et al. (2006) applied travel cost models to value the benefits of hiking trails through old growth forest in the Pacific Northwest, and the benefits of ancient forest ecosystems in Jasper National Park. *Visitation* travel cost models relate demand for a site (e.g., how many trips) to the costs of getting to the site. *Random utility* travel cost models determine values for environmental features by examining users' choices among a set of recreation sites. Both techniques require surveying recreationists about out of pocket expenses for their trip as well as the time-cost involved in travelling to a site.

Hedonic pricing methods assume that a) the value of a good or service is derived from its attributes, b) each good or service represents a bundle of attributes, and c) the value of this bundle is divisible among the attributes ('theory of value') (Hanley and Barbier 2009).[41] For non-market valuation of environmental goods and services, hedonic pricing usually involves linking a change in goods or services to real estate prices, where each good or service is considered part of the property's bundle of attributes. This bundle can include structural features such as the number of bedrooms or bathrooms in a house as well as neighbourhood characteristics such as crime, forest cover, or park access. Many hedonic pricing studies relate property prices to forest cover, parks, or open space (e.g., Brander and Koetse 2011). Izón et al. (2010) also linked the price of property to roadless areas in New Mexican National Forests. A hedonic pricing model could yield an amenity value for old growth forests by relating different levels of forest cover to a property's market value. However, relative to other approaches, the technique is data intensive, may require fine scale spatial data, and can be associated with significant statistical hurdles (National Research Council 2005).

Production function techniques treat the environment as a factor in the production of a good or service that has a market price (Hanley and Barbier 2009). Mathematical models are constructed to relate an environmental input (or inputs) with production, thus permitting an assessment of changes in consumer and producer surplus for a good or service. This approach was used by Page (2010) and Knowler et al. (2011) to value the water purification/filtration services of temperate coastal rainforests in BC's Fraser Timber Supply Area, and by Knowler et al. (2003) to value salmon production services provided by forest habitat. Drawing on the latter study, Morton et al. (2017) applied similar methods to value salmon production in the Columbia River based on different reservoir management scenarios and their impact on river habitat quality.

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[41] Random utility travel cost models and discrete choice experiments are also rooted in the attributes-based theory of value.

As stated, **cost-based** methods do not truly capture consumer and producer surplus and therefore cannot reveal true welfare measures. These approaches should be used only as a last resort in non-market valuation. **Averting behavior** methods are typically used to value the health effects of pollution, or general health improvements (National Research Council 2005; Hanley and Barbier 2009). These techniques are based on the premise that households will incur costs to avoid negative health outcomes. For example, households may purchase a filter to remove a pollutant from tap water or forego wages to avoid an air quality alert. Since averting behaviour methods are not applicable to the ecosystem services reviewed in this report, they are not considered further.

Replacement cost is another cost-based technique that assigns a monetary value to a non-market good or service by estimating the cost of replacing it (Hanley and Barbier 2009). For example, the cost of replacing a mangrove forest with a physical barrier might be used as an indicator of the forest's coastal protection value (Chong 2005). A forest's drinking water purification services might be estimated using the cost of building a treatment plant capable of replacing those services (Chichilnisky and Heal 1988). Wilson (2010) prioritized such cost-based approaches when valuing certain ecosystem services in the BC's Lower Mainland. Similarly, **avoided cost** techniques estimate a monetary value for a non-market good or service by calculating costs that would be avoided if it were maintained in a current or improved state.

A.3 Benefit Transfer

Stated or revealed preference studies can be time consuming and costly. When the resources required to conduct such studies are insufficient analysts often rely on benefit transfer (Johnston et al. 2015). This technique involves transferring existing monetary values estimated previously at another location (known as the 'study site') to the area of the current analysis (known as the 'policy site'). There are two main types of benefit transfer: 1) unit value transfer; and 2) function transfer. *Unit value transfer* involves transferring *average* WTP/WTA estimates that may or may not be adjusted for certain differences between the study and policy sites. *Function transfer* involves the construction of mathematical models that relate WTP/WTA to study site characteristics based on empirical data (e.g., demographics, socio-economic variables, population size). Once parameters are developed, policy site data are substituted into the model to yield a site-adjusted monetary estimate. *Meta-analysis* is a related type of function transfer that involves aggregating multiple valuation studies into a single mathematical model. [42] Several authors have compiled reviews of the benefit transfer method and examples of its use (e.g., Johnston et al. 2015; Richardson et al. 2015).

Rather than relying on a single value, both *unit value transfer* and *function transfer* approaches may use estimates from multiple studies to acquire a range WTP/WTA values. Several databases are available that collate research-derived monetary values for different ecosystem services. Examples include the Environmental Valuation Reference Inventory (EVRI available at www.evri.ca/en/splashify-splash), The Economics of Ecosystems and Biodiversity Valuation Database (TEEB available at http://www.teebweb.org/publication/tthe-economics-of-ecosystems-and-biodiversity-valuation-database-manual/), and the Recreation Use Value Database (RUVD available at http://recvaluation.forestry.oregonstate.edu/).

Many forest-based studies reviewed for this report (including old growth studies) used benefit transfer in some fashion (see Table 14). For example, van Kooten (1995) and van Kooten and Bulte (1999)

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[42] Meta-analysis is a more advanced version of function transfer in which the details of multiple studies are used in a regression to create an entirely new function.

made extensive use of transfers to assign monetary values to ecosystem services provided by BC's interior forests and coastal rainforests. Knowler and Dust (2008) applied the approach to evaluate management options specifically for old growth forests in BC's Fraser Timber Supply Area. Other applications in BC and neighbouring US states estimated the value of the Chugach and Tongass National Forests in coastal Alaska, and the Mt. Baker-Snoqualmie National Forest in Washington (Phillips et al. 2008; Mojica et al. 2017), select ecosystem services supplied by Canada's boreal forests (Anielski and Wilson 2005), and Metro Vancouver's 'natural capital' (Wilson 2010).

A.3.1 Spatially Explicit Approaches to Benefit Transfer

In addition to these approaches, spatially explicit applications of benefit transfer can be useful for valuing landscapes such as forested areas (Troy and Wilson 2006). Eade and Moran (1996) were perhaps the first to propose linking spatial analysis and valuation using a case study from the Rio Bravo Conservation area in Belize. The technique can streamline analyses that must consider multiple landcover scenarios (e.g., different areas of old growth forest remaining after different timber harvest applications).[43] This approach was also applied to the valuation of natural capital (including forests) in Southern Ontario (Troy and Bagstad 2009), and in two of the studies previously noted (Mojica et al. 2017, Wilson 2010).[44] Spatially explicit benefit transfer assesses the monetary value of ecosystem services based on the areal extent of landcover, ideally after applying some variation of the steps shown in Box 1 (from Troy and Wilson 2006).

BOX 1: STEPS TO CONDUCT A SPATIALLY EXPLICIT BENEFIT TRANSFER

1. Define the boundaries of the study area
2. Inventory the different types of land cover present in the study area and the ecosystem services flowing from them
3. Review the literature to obtain a range or average WTP/WTA values in dollars per area (e.g., $/ha) from studies with similar contexts to the study area
4. Create a landcover map using GIS software to obtain the number of areal units of each landcover (e.g., hectares, square kilometers)
5. Estimate the total value of ecosystem services in the study area by multiplying the monetary values by the number of areal units for each landcover and then summing the resulting values
6. Summarize these values within a policy-relevant mapping unit, such as a watershed or town
7. Analyze alternative management scenarios or historical changes by altering the inputs into steps 4 and 5.

Source: Troy and Wilson (2006)

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[43] Alternatively, the changes in the extent or distribution of old growth forests outlined in the scenarios could be linked to each valued component such that changes in the units of each components could be measured and then a per unit monetary value applied. For example, a reduction of X hectares of old growth forest results in Y fewer recreational visits which has an economic value of $Z.

[44] Earth Economics (Mojica et al.), based out of Tacoma, Washington, often uses this spatial benefit transfer approach. See www.eartheconomics.org/publications-archive for a list of their publications.

To accomplish Step 3 in Box 1, databases like TEEB conveniently provide some ecosystem values on a per acre or per hectare basis. Researchers either directly source such area-based monetary values from TEEB, other databases, or other literature, or estimate average area-based values using simple calculations (e.g., by dividing the overall economic value from a source study by the study site's area). Sometimes more complicated approaches are required depending on the research context. Wilson (2010), for example, applied interim steps to obtain the economic value of climate regulation services provided by Metro Vancouver's forests, including: a) estimating carbon storage using studies reporting CO^2/ha in similar forests elsewhere, b) modelling annual carbon uptake using a GIS-based model, and c) multiplying final outputs by the social cost of carbon.

Existing studies in BC tend to focus on a single landcover (albeit with differing age classes and site quality) (e.g., van Kooten 1995, van Kooten and Bulte 1999, Knowler and Dust 2008), and several of these studies relate selected ecosystem service values directly to forests using average per hectare values obtained from the literature. van Kooten (1995) and van Kooten and Bulte (1999), for example, used per hectare values to estimate a suite of BC forest-based ecosystem services including recreation, timber supply, non-timber forest products, and non-use amenities. Knowler and Dust (2008) also employed per-hectare benefit transfer for some of the ecosystem services they evaluated.

A.3.2 Limitations of Benefit Transfer

Benefit transfer's relative ease of use and low cost make it a powerful valuation tool compared to other valuation methods, but it can result in large errors since study and policy sites will always be inherently different (Trenholm et al. 2019). The risk of error is especially present for unit value transfer, where effort should be made to ensure WTP/WTA values are drawn from study sites that are as similar as possible to the policy site (e.g., population, similar physical characteristics) (Boyle et al. 2010). However, even in cases where a strong analogue to the policy site is available, WTP/WTA values may need to be adjusted to fit the context of the specific valuation task, and non-economic data may still need to be gathered (e.g., tourism and recreation visits). Researchers should be careful to clearly and transparently communicate these limitations and assumptions to target audiences and identify any supplementary data needs.

Spatially explicit benefit transfer has additional limitations. First, the approach is only suitable for smaller scale landcover changes. Large scale changes can shift economy-wide price relationships for environmental amenities in ways not easily captured by this type of benefit transfer (Palmquist 1991). Troy and Wilson (2006) suggest their case studies in Massachusetts, Maury Island (Puget Sound, WA), and Humboldt, Napa, and San Bernardino Counties (California) are small enough to avoid affecting prices/values in this way. Most of these extents are greater than those considered for our proposed pilot study on Vancouver Island. Second, the use of average values can misrepresent landscape heterogeneity. The true value of an ecosystem service may be unevenly distributed across a forested landscape. This can be problematic if, for example, a timber harvest scenario is focused exclusively on high or low value areas, but average values are still used, thus resulting in over or underestimates.

In the case of old growth forests, landscape heterogeneity and the use of average values is less of an issue, since assessment would focus on a single high-value forest type. To some degree, landscape heterogeneity can also be captured using ranges of values rather than averages (e.g., Troy and Wilson 2006; Mojica et al. 2017). However, if greater resolution is desired, software packages like the Integrated Valuation of Ecosystems and Tradeoffs (InVEST) tool by Stanford University's Natural Capital Project (Sharp et al. 2018) can be used to map and value goods and services produced by heterogenous landscapes or seascapes. InVEST's models improve upon average values by using production functions that relate a study area's structural and functional characteristics to flows of ecosystem services on a spatial unit-by-unit basis. InVEST's tools are open-source and can be used to asses a wide range of ecosystem services, including landscape-level carbon storage/sequestration, coastal protection from natural assets, fish production, and recreation and tourism, among others.

A.4 Approaches Used in Reviewed Forest Valuation Studies

While the approaches described above can all be used independently, CBA studies that evaluate multiple ecosystem services often rely on combinations of approaches including the use of market prices where no alternatives are available or applicable. Table 14 summarizes the approaches used in the studies we reviewed for the Phase 1 assessment, most of which focus on the Pacific Northwest and Canada and have some forest valuation component.

Table 14. Summary of economic valuation approaches used by studies reviewed for this report (in chronological order)

Study	Market Prices	Non-Market Valuation						
		CVM	Discrete Choice	Travel Cost	Hedonic Pricing	Benefit Transfer	Production Function	Cost Based
Chichilnisky and Heal 1988								■
Englin and Mendelsohn 1991				■				
Watson 1994		■						
van Kooten 1995	■					■		
Loomis et al. 1996		■						
van Kooten and Wang 1998						■		
van Kooten and Bulte 1999	■					■		
Knowler et al. 2003							■	
Starbuck et al. (2004)				■				
Anielski and Wilson 2005	■					■		
Chong 2005								■
Englin et al. 2006				■				

	Market Prices	Non-Market Valuation						
Study		CVM	Discrete Choice	Travel Cost	Hedonic Pricing	Benefit Transfer	Production Function	Cost Based
Knowler and Dust 2008	■					■		
Phillips et al. 2008	■					■		
Bradshaw 2009			■					
Izón et al. 2010					■			
Page 2010							■	
Wilson 2010	■					■		■
Knowler et al. 2011							■	
Wilson et al. 2012		■						
Trenholm et al. 2013		■						
Mojica et al. 2017	■					■		

Appendix B: Future Discounting

When benefits or costs are accrued across time, they must be adjusted to account for differences in the way people prioritize benefits now versus in the future (Hanley and Barbier 2009).[45] This is known as discounting and involves dividing future values by a discount factor using the following equation:

$$Present\ Value = \frac{Future\ Value}{(1+r)^t}$$

Where *r* is the discount rate and *t* is the year in which the future value accrues. Applying this equation while holding *r* constant will ensure that future values are weighted less than more current values because as *t* increases, the denominator will also increase, thereby reducing the present value. Similarly, higher discount rates (r) result in future values receiving less weight than lower discount rates. These influences are illustrated in Figure 18 using the hypothetical example of $100 received annually over a time horizon of 100 years. A discount rate of 0% has the same effect as not discounting, while positive discount rates clearly influence present values. Summing across the 100-year time horizon yields the following present values: $10,000 for the 0% discount rate; $6,302.89 for the 1% discount rate; $3,159.89 for the 3% discount rate; $1,984.79 for the 5% discount rate; and $1,249.43 at the 8% discount rate.

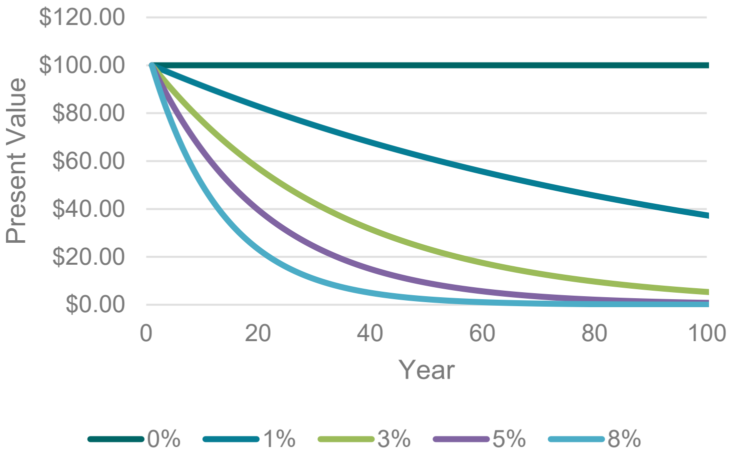

Figure 18. Present values of an annual stream of $100 over 100 years for different discount rates

Discounting is clearly an important factor influencing our study's results, particularly given its 100-year time horizon and the fact that in our alternative scenarios values are often unevenly distributed across time for certain ecosystem services. For example, in some scenarios low value species are harvested early in the time horizon with higher value species being cut later. In other scenarios higher value species are harvested earlier than lower value species. In the case of the former scenarios, the higher value harvests will receive less weight than the lower value harvest, while the reverse is true for the latter scenarios.

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[45] Hanley and Barbier (2009) identify two main reasons for discounting: 1) preferences; and 2) the productivity of capital. Briefly, the former reflects the innate human desire to receive benefits sooner than later, for instance think of the interest accruing on a savings account. While the latter reflects the forgone benefits — or the opportunity cost — of investing capital in one scheme and not another.

Consider a scenario in which higher value species are harvested first, followed by low value species, yielding an undiscounted flow of $100 per year over the first five years and $50 over the last five years (Table 15). An alternative scenario harvests the low value species first resulting in an annual flow of $50 for the first 5 years followed in the next 5 years by the higher value harvests that generate $100 per year. The undiscounted flow totals $750 for both scenarios; however, assuming a discount rate of 3%, the present value of the 'high value first' scenario is $655 while that of the 'low value first' scenario is $624.

Table 15. Comparing the producer surplus of hypothetical log harvests to illustrate the influence of discounting with positive values

Scenario	**Year**										
	1	2	3	4	5	6	7	8	9	10	PV
High Value Species Harvested First											
Undiscounted	$100	$100	$100	$100	$100	$50	$50	$50	$50	$50	$ 750.00
Discounted (3%)	$97	$94	$92	$89	$86	$42	$41	$39	$38	$37	$ 655.00
Low Value Species Harvested First											
Undiscounted	$50	$50	$50	$50	$50	$100	$100	$100	$100	$100	$ 750.00
Discounted (3%)	$49	$47	$46	$44	$43	$84	$81	$79	$77	$74	$ 624.00

Discounting is an even more important consideration if losses are incurred in early years, which is the case in our study when harvests of low value hemlock dominate in early years. Losses from these harvests will receive higher weight than positive returns from harvesting higher value species in later years. Similarly, for most of our scenarios carbon sequestration is negative in earlier periods but occasionally becomes positive in later years. Because we apply a discount rate, these positive values in later years receive less weight than the negative values in early years.

As another hypothetical example, consider two scenarios with the same magnitude negative returns in the time horizon's early period followed by slightly different positive returns in the latter half of the time horizon (Table 16). One scenario yields $5 more than the other annually from years 6 to 10. Both scenarios yield positive undiscounted producer surplus across the whole 10 years ($25 or $50). However, the scenario with the lower value harvest in the latter period generates a producer surplus of -$12 across all ten years while the scenario with slightly higher returns in the latter period results in a producer surplus of $8.

Table 16. Comparing the producer surplus of hypothetical log harvests to illustrate the influence of discounting with negative initial values followed by positive returns

Scenario	**Year**										
	1	2	3	4	5	6	7	8	9	10	PV
Lower Value Harvest											
Undiscounted	-$50	-$50	-$50	-$50	-$50	$55	$55	$55	$55	$55	$ 25.00
Discounted (3%)	-$49	-$47	-$46	-$44	-$43	$46	$45	$43	$42	$41	-$ 12.00
Higher Value Harvest											
Undiscounted	-$50	-$50	-$50	-$50	-$50	$60	$60	$60	$60	$60	$ 50.00
Discounted (3%)	-$49	-$47	-$46	-$44	-$43	$50	$49	$47	$46	$45	$ 8.00

Appendix C. Additional Sensitivity Analyses

The scenarios we assess in the main report examine how old-growth age class definitions (140yrs; 250yrs), extent of old growth protection (30%, 50%, 70%, 100%), and different phase-in periods (e.g., 50% to 100% over 4 years) for old growth forest protection influence results. However, key parameters specific to each ecosystem service can also have an impact. Timber production, carbon sequestration, and recreation are key drivers of our results so, while we have erred conservatively, small changes in our assumptions about these ecosystem services could have a large impact. Discount rates may also have a large influence given our 100-year time horizon (a typical time horizon for estimating net present value) and the fact that economic values from some ecosystem services are unevenly distributed across this period, especially timber production.[46] As additional sensitivity analysis we assess the influence of several key parameters and, for three of our scenarios, report these results below (Table 17).

Increasing log prices and decreasing harvest costs will increase producer surplus from timber harvests, raising the opportunity costs of protecting forests. Alternatively, decreasing prices and rising harvest costs will decrease producer surplus. Log prices have fluctuated widely in the past (Sun et al. 2015). For instance, the weighted average of prices for all species in our data rose from $89.79 in 2012 to $140.42 in 2018, an increase of 56% over 7 years (calculated via Coast Log Market Reports and the Harvest Billing System). We tested annual rates of increase and decline for log prices following Knowler and Dust (2008) (Table 18) and investigated the effects of a ±10% change in total harvest cost. To evaluate the case where economic rent of timber harvest is on the high end of the spectrum, we also combine the price increase rates with the 10% decrease in costs. This latter sensitivity analysis represents a situation in which the opportunity cost of old-growth protection is high (see Table 17).

In the main analysis, we use ECCC's (2016) social cost of carbon forecast which increases over time. In their separate analyses of forest harvests in the BC Interior, Knowler and Dust (2008) use constant prices of $20, $75, $150, and $350 per tonne of carbon and van Kooten et al. (2019) use $50 and $100 per tonne of carbon. To err conservatively, for our sensitivity analyses we test constant prices of $25, $50 and $100 per tonne (see Table 17).

Recreation values may change over time, for instance due to increasing tastes for outdoor recreation or a larger population. Also, if future development decreases the supply of forested areas in which to recreate, then the areas remaining untouched may increase in terms of recreational value (i.e., more people will choose to recreate at the remaining locations due to a lack of substitutes). Knowler and Dust (2008) included an annual 0.5% increase in recreation consumer surplus to account for changing factors such as population increases, rising incomes, and increased preferences for environmental characteristics. Since we already include projected population changes in our main analysis, we conservatively halve Knowler and Dust's (2008) 0.5% annual increase, using a change of ±0.25% to account for changing incomes and recreational tastes starting in year 2 of our 100-year time horizon.

Our main analysis uses a discount rate of 3%, which corresponds with the social time preference discount rate listed in the Treasury Board Secretariat of Canada's (2007) most recent iteration of the *Canadian Cost-Benefit Guide*. Knowler and Dust (2008) used discount rates of 1%, 4%, and 7% in their analysis. Similarly, we use 1% as the low-end rate for our sensitivity analysis, but 8% as the

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[46] Positive discount rates result in values accruing further into the future being smaller than those accruing closer to the present time (future values receive less weight than more current values). Higher discount rates amplify these differences relative to lower rates. See Appendix B.

high-end rate since the Treasury Board Secretariat of Canada (2007) recommends using this rate when assessing the benefits and costs of Canadian regulatory interventions. We also apply a mid-range rate of 5%.

To test the effects of a lower rate of commercial harvest for pine mushrooms, chanterelle mushrooms and salal, we used a 15% rate instead of our 50% rate. The latter rate was suggested by Alexander et al. (2002) despite having observed rates of 12% and 20%. Our sensitivity analysis is meant to capture the lower end of the observed range.

Finally, we also provide a sensitivity analysis with the real estate ecosystem service "turned off" in the economic model.

Table 17 shows that when comparing to the corresponding results from our main analysis, different assumptions about the **discount rate** have the greatest impact on results followed by different assumptions about **carbon prices**, then **log prices / harvest costs**.

Table 17. Sensitivity analysis results for key parameters, including comparison with the main analysis (2018 CAD millions). ***>140 year old growth definition.***

	Sensitivity Results		Difference from Main Analysis	
Sensitivity	**NPV** Year 100	**Difference from Base Scenario**	**NPV** Year 100	**Difference from Base Scenario**
Rising Log Prices				
30% OG Protection	$80.98	$11.45	$11.31	($1.84)
50% to 100% Transition (10yrs)	$101.67	$32.14	$6.16	($7.00)
100% OG Protection	$103.91	$34.38	$7.16	($6.00)
Declining Log Prices				
30% OG Protection	$60.30	$14.44	($9.37)	$1.15
50% to 100% Transition (10yrs)	$89.07	$43.21	($6.44)	$4.07
100% OG Protection	$90.02	$44.16	($6.73)	$3.78
Higher Total Harvest Costs: +10%				
30% OG Protection	$55.48	$14.76	($14.19)	$1.47
50% to 100% Transition (10yrs)	$84.41	$43.68	($11.10)	$4.54
100% OG Protection	$85.99	$45.26	($10.76)	$4.88
Lower Total Harvest Costs: -10%				
30% OG Protection	$82.56	$11.96	$12.89	($1.33)
50% to 100% Transition (10yrs)	$105.61	$35.01	$10.10	($4.13)
100% OG Protection	$106.53	$35.93	$9.78	($4.45)
Rising Log Prices & Lower Total Harvest Costs: -10%				
30% OG Protection	$93.87	$10.11	$24.20	($3.18)
50% to 100% Transition (10yrs)	$111.76	$28.01	$16.25	($11.13)
100% OG Protection	$113.69	$29.93	$16.94	($10.45)
Rising Recreation CS: 0.25%				
30% OG Protection	$74.22	$13.59	$4.55	$0.30
50% to 100% Transition (10yrs)	$100.61	$39.98	$5.10	$0.84
100% OG Protection	$102.10	$41.48	$5.35	$1.10
Declining Recreation CS: -0.25%				
30% OG Protection	$65.62	$13.03	($4.05)	($0.26)
50% to 100% Transition (10yrs)	$91.00	$38.41	($4.51)	($0.73)
100% OG Protection	$92.01	$39.42	($4.74)	($0.96)
Constant Carbon Price: 25 tCO2e				
30% OG Protection	$92.43	$3.25	$22.76	($10.04)
50% to 100% Transition (10yrs)	$93.06	$3.88	($2.45)	($35.26)
100% OG Protection	$99.61	$10.43	$2.86	($29.95)
Constant Carbon Price: 50 tCO2e				
30% OG Protection	$82.32	$8.69	$12.65	($4.60)
50% to 100% Transition (10yrs)	$95.70	$22.07	$0.19	($17.07)
100% OG Protection	$100.11	$26.48	$3.36	($13.90)
Constant Carbon Price: 100 tCO2e				
30% OG Protection	$62.09	$19.55	($7.58)	$6.26
50% to 100% Transition (10yrs)	$100.98	$58.44	$5.47	$19.30
100% OG Protection	$101.12	$58.58	$4.37	$18.20
Discount Rate: 1%				
30% OG Protection	$133.28	$26.55	$63.61	$13.26
50% to 100% Transition (10yrs)	$181.56	$74.83	$86.05	$35.69
100% OG Protection	$188.20	$81.48	$91.45	$41.10
Discount Rate: 5%				
30% OG Protection	$47.58	$8.28	($22.09)	($5.01)
50% to 100% Transition (10yrs)	$63.99	$24.69	($31.52)	($14.45)
100% OG Protection	$64.45	$25.15	($32.30)	($15.23)
Discount Rate: 8%				
30% OG Protection	$34.29	$4.96	($35.38)	($8.33)
50% to 100% Transition (10yrs)	$44.09	$14.76	($51.42)	($24.38)
100% OG Protection	$44.57	$15.23	($52.18)	($25.15)
NTFP: 15% Mushroom Harvest Rates				
30% OG Protection	$65.24	$13.38	($4.43)	$0.09
50% to 100% Transition (10yrs)	$91.13	$39.27	($4.38)	$0.13
100% OG Protection	$92.77	$40.91	($3.98)	$0.53
Real Estate: Excluded				
30% OG Protection	$69.53	$13.16	($0.14)	($0.13)
50% to 100% Transition (10yrs)	$95.12	$39.92	($0.39)	$0.78
100% OG Protection	$96.29	$38.75	($0.46)	($1.63)

Table 18. Annual change rates per species applied to timber price sensitivity analyses (from Knowler and Dust 2008)

Species	Price Per m3	Annual Change	
		If an Increase	If a Decrease
Balsam	$79.13	0.1%	-0.2%
Fir	$111.89	0.2%	-0.2%
Hemlock	$68.21	0.1%	-0.2%
Cedar	$212.49	0.4%	-0.2%
Cypress	$98.81	0.2%	-0.2%
Alder	$41.68	0.2%	-0.2%
Spruce	$102.23	0.2%	-0.2%
White Pine	$62.79	0.2%	-0.2%
Maple	$29.41	0.2%	-0.2%
Cottonwood	$21.50	0.2%	-0.2%
Lodgepole Pine	$62.79	0.2%	-0.2%

In the following figures we provide the equivalents to Figure 9, Figure 13, and Figure 14 for the >250 year definition of old growth (Figure 19, Figure 20, Figure 21). Economic values for this definition of old growth are reported at the beginning of Section 3.4 (Table 10).

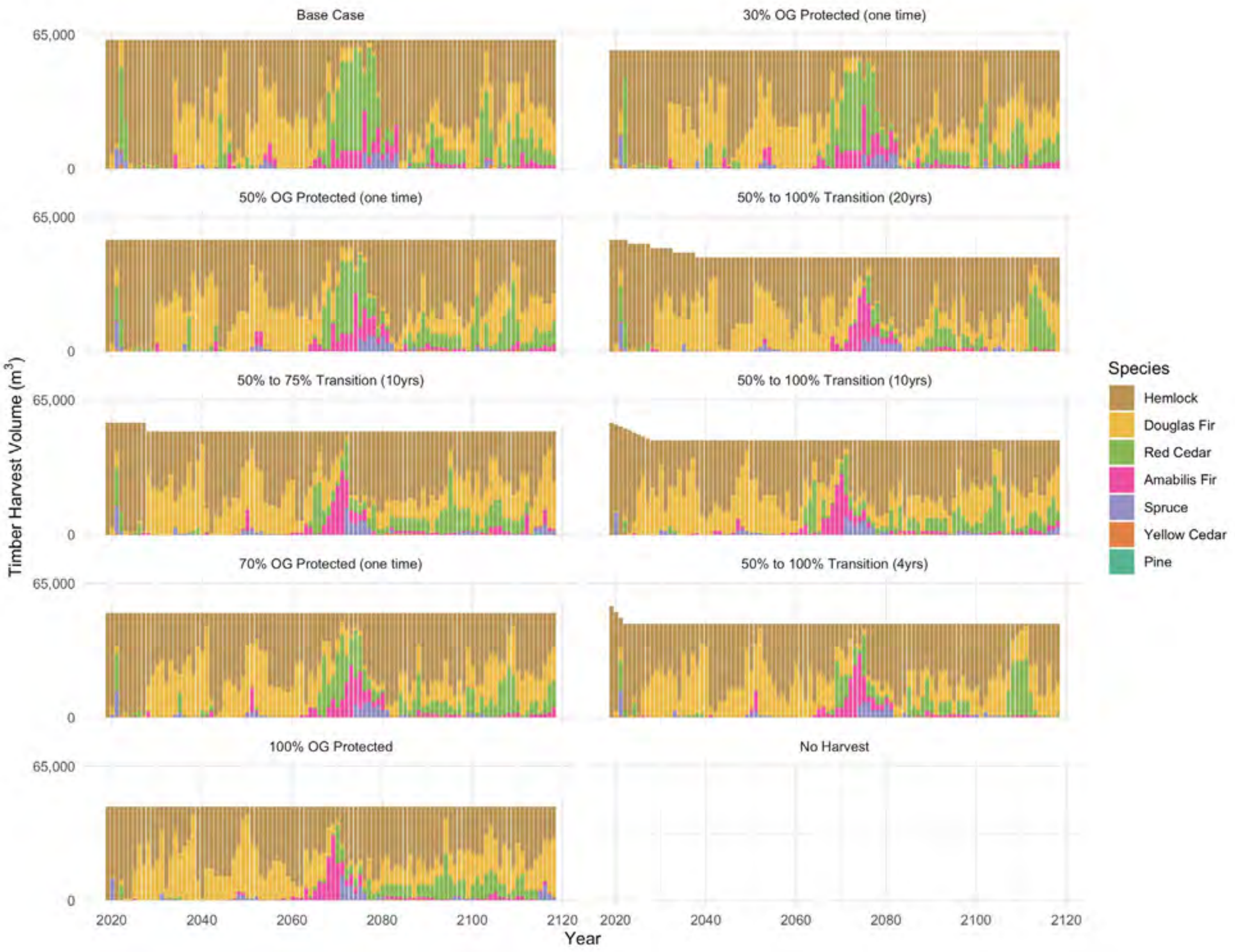

Figure 19. Total annual volume (m^3) and species composition of timber harvests across the modelled 100-year time

*horizon (2018 – 2118) and for each timber harvest scenario (**>250-year old growth definition**).*

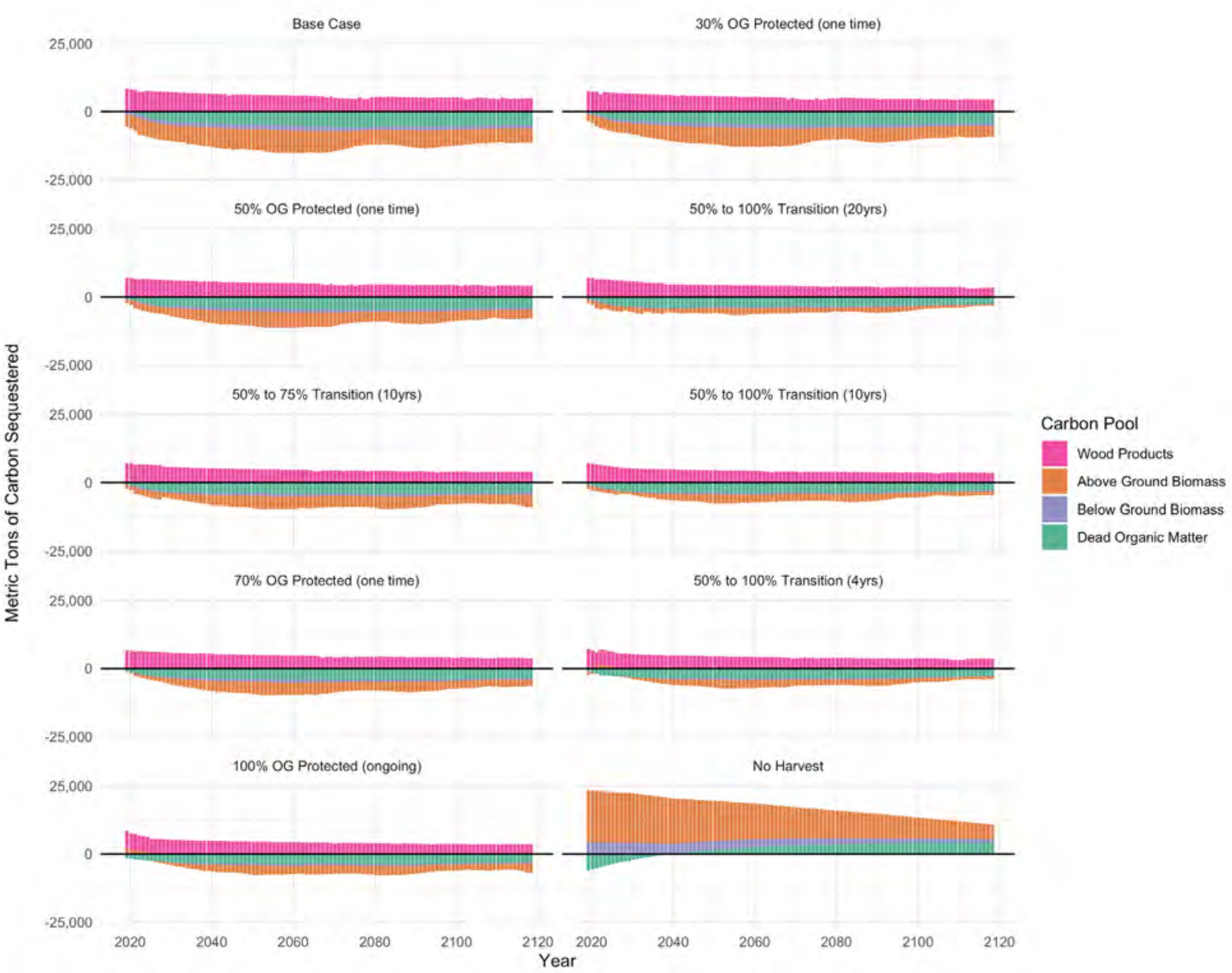

*Figure 20. Annual change in carbon storage by pool of carbon (wood products, below ground biomass, above ground biomass, dead organic matter) over the modelled 100-year time horizon (2018-2118) for each timber harvest scenario (**>250-year old growth definition**). Values below zero indicate a net carbon source. Values above zero indicate a net carbon sink.*

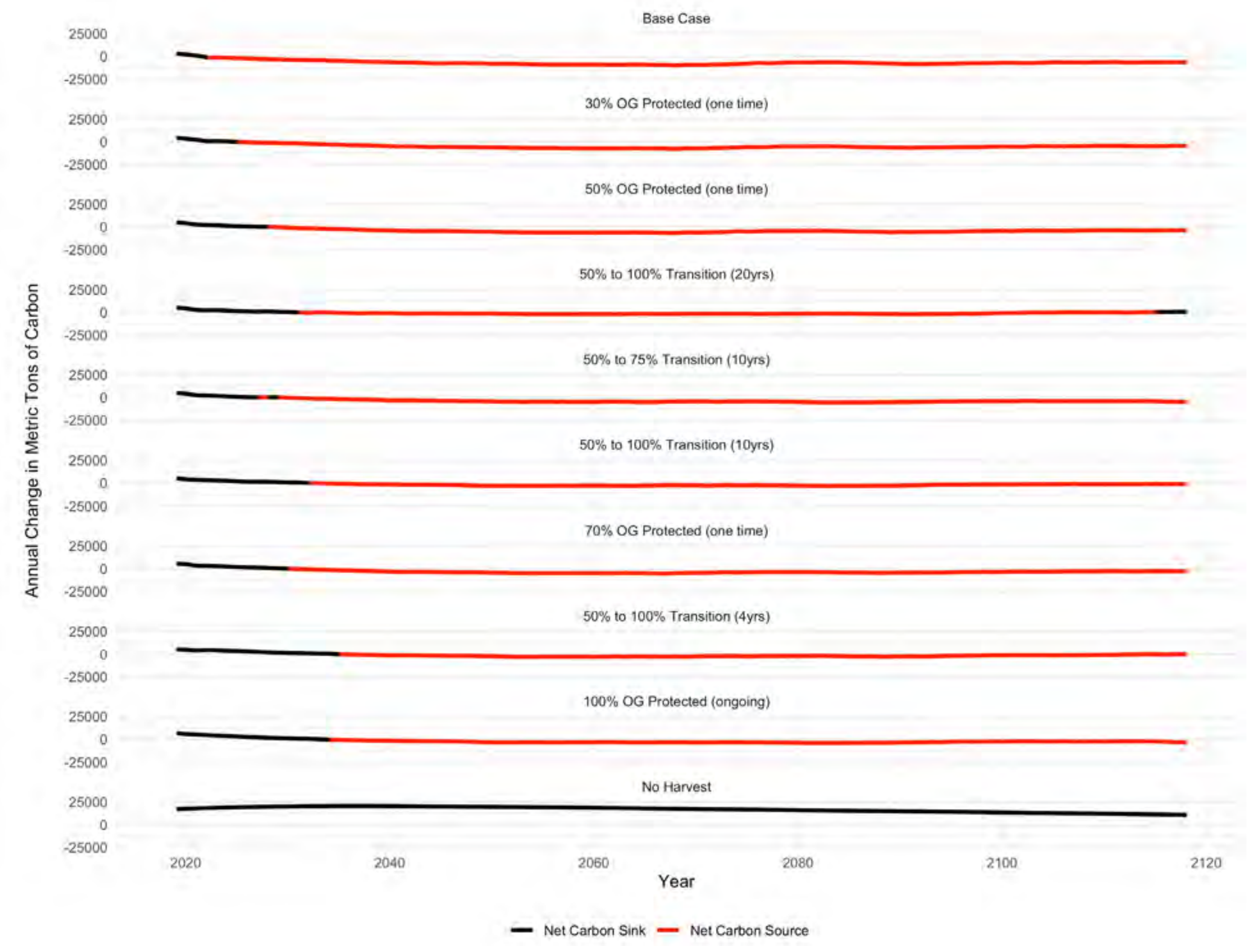

*Figure 21. Annual change in carbon sequestration services over a modelled 100-year time horizon (2018-2118) for each timber harvest scenario (**>250-year old growth definition**). Black line segments indicate when the forest land base is a net carbon sink, red line segments indicate when the forest land base is a net carbon source (includes wood products). Fluctuations from source to sink occur primarily due to variations in above-ground biomass due to harvest (see Figure 13).*

As a supplementary study, we also applied our modelling procedure to the full land base within the 35km buffer around Port Renfrew (see Figure 4). Because we did not have access to growth curves or timber harvest plans for stands outside the TSA, we estimated our information for the broader land base from what we knew about the TSA. We used the Province's Vegetation Resource Inventory (VRI) to assign species types based on the leading tree species in each stand and divided the area in each stand evenly across the assigned age class. For growth curves, we used a subset of the growth curves that were part of the TSR analysis. We assigned the most commonly applied growth curve for each species/age class combination in the TSR that was also present in the broader land base. If we assigned a growth curve from the TSR-study that changed to a different growth curve post-harvest, we retained that shift for this separate study. Because the VRI data contains more species classifications than the TSR analysis, we mapped the new VRI species classifications to existing TSR species for the purposes of assigning growth curves (e.g., all hardwood species were assigned the same growth curve as were all spruce species and all cedar species). The landbase for this expanded study contained formally protected areas (provincially and federally) and we maintained this protection. However, for the remaining area the VRI data do not specify which stands are part of the harvestable landbase or the non-harvestable landbase. More detailed analysis (like a TSR) is required to produce accurate THLB and non-THLB designations. As a first approximation, we simply assumed, as in the TSR-study, that about two-thirds of non-protected area was THLB. We applied this proportion evenly across the non-protected landbase. **This approach means that all THLB and non-THLB areas had the same age-class structure and the same types and productivity of stands. If a true TSR-style analysis were completed for the area, this would not be the case - age classes and productivity would vary and could have large impact on results.** We estimated the annual harvest by scaling up the TSA-study's harvest relative to the amount of area in the THLB in both study areas. We also maintained the same harvest rules as for the TSA study[47], assumed no disturbances other than harvest, and made the same assumptions about the initial origin of the existing stand (fire or harvest).

Since the methods we describe above are very coarse, the results should be interpreted with a high degree of caution. Therefore, we do not report quantitative amounts here but instead describe the outputs qualitatively. We ran this supplementary study only for the Base Case and the 100 OG Protection scenario (140yr old growth definition). Notable in these preliminary results is the fact that extending the analysis to the full forest landbase generates a significant jump in incremental net benefits compared to the equivalent scenario in our main study. Unlike in our main analysis, the broader landbase is a net carbon sink so incremental net benefits from fully protecting old growth are lower for this ecosystem service compared to the main study's equivalent scenario. Incremental net losses from timber production are also greater. The increase in incremental net benefits is driven by a large increase in tourism/recreation consumer surplus. Since these results are only preliminary, we are not able to draw strong conclusions from them currently. Refining these results would require working with timber harvest companies and/or the Province to identify more accurate growth curves and harvest plans.

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[47] We did evaluate hardwood harvesting in this study as there is more hardwood in this landbase than in the TSA. This addition of hardwood harvest was important in a few years, but we decided not to include these results for consistency with the previous methods.

Appendix D. Economic Impact Assessment of Recreation-based Tourism and Timber Harvest

As another supplementary study we performed an economic impact assessment (EconIA) of recreation-based tourism and timber harvest. Economic impact assessment is a methodology for evaluating the impact of a project, program or policy on the economy of a region. Like CBA, EconIA can help inform decisions about allocating public funds to support a sector, but with a specific focus on the contribution to value added, jobs and income to the economy, including citizens who pay taxes. It also considers impacts on tax revenues which can be distributed for the broader social good. In the context of old growth protection, EconIA is part of an overall economic picture that can provide communities like Port Renfrew with an added rationale for investing, for example, in the promotion of forest-based tourism and for lobbying the provincial government to protect the area's old growth trees from logging. Alternatively, EconIA can help evaluate some of the potential trade-offs associated with that protection such as job loss in the timber harvest sector. This section outlines our methods and presents results in terms of changes to several macroeconomic indicators like GDP, income and jobs associated with each of our old growth protection scenarios.

D.1 Methods

Conducting an EconIA begins with gathering base unit data relevant to the sector of interest. For recreation-based tourism, the base units used in this study are the number of visitors and their expenditures. For timber harvest, the base unit is net timber harvest revenue. Once expenditure and revenue data are assembled, these amounts are then used to introduce a demand "shock" to an Input-Output model. Input-Output models represent cross-sectoral interdependencies, capturing how one sector's outputs can either be used as inputs to another sector or become part of final demand (e.g., consumed by households or government), and tracing direct, indirect, and induced economic effects throughout the economy. In Canada, national and provincial Input-Output models are constructed by Statistics Canada from symmetric industry by industry and final demand input-output tables, So-called "multipliers" can be generated from these models; these multipliers can be applied to expenditure data to estimate a range of different macroeconomic outcomes.

In this study, we used the symmetric industry by industry and final demand input-output tables for BC from Statistics Canada to generate regionalized multipliers for the following industries of interest: a) Accommodation and food, b) Transportation, c) Retail trade, d) Other services, and e) Forestry and logging (Table 19).

Table 19. Industries of interest in this study and the corresponding Statistics Canada label/code used for input-output multipliers

Industry of Interest	Corresponding Label/Code from Statistics Canada
Accommodation and food	Accommodation and food services [BS720]
Transportation	Transportation and warehousing [BS4B0]
Retail trade	Retail trade [BS4A0]
Other services *vehicle rentals, tourism related recreation & entertainment, vacation homes*	Arts, entertainment, and recreation [BS710]
Forestry and logging	Forestry and logging [BS113]

Using the symmetric tables[48], we first constructed both an "open" and "closed" Input-Output model for BC. Open models estimate direct and indirect effects while closed models estimate direct, indirect, and induced effects (see Table 20). We report results from both models below.

Table 20. Direct, indirect, and induced effects

Direct effects	Money initially spent in the study area on salaries, supplies, raw materials, operating expenses
Indirect effects	Money spent by businesses at other businesses throughout BC due to increased spending on intermediate goods and services resulting from direct effects
Induced effects	Money spent by households at businesses throughout BC due to more jobs and household income available for the purchase of goods and services made possible by direct and indirect effects.

To get a more accurate estimate of the macroeconomic impacts of changes in expenditures in the Port Renfrew area it is necessary to regionalize the provincial level Input-Output models. This is done by first estimating "location quotients" using the proportions of employed individuals in each sector of the economy in the study area relative to those employed at the provincial levels. Using the approach described by Flegg and Tohmo (2013), we derived location quotients based on sectoral employment summed across the three census divisions that overlap with our study area (Juan de Fuca (Part 2), Gordon River, Cowichan Valley F) with that of the entire province of BC. We then used these location quotients to adjust the technical coefficients in the provincial Input-Output models prior to generating a set of regionalized "simple industry" (open model) and "total industry" (closed model) multipliers to be used in the analysis.

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[48] We used summary-level tables available from StatsCan, not disaggregated ones

Tourism

We estimated tourism visitation in the study area as "annual recreational use days per BC adult per hectare". The 1989/1990 BC Outdoor Recreation Survey reports 9.92 recreational use days (RUDs) per BC adult per year for British Columbians in the Vancouver Forest District. We divided this by the area of the Vancouver Forest District used in that study (9,920,00 ha) to get 0.000001 adult RUDs per hectare. We then distributed this value across stand age classes using the same proportions reported in Table 7 and, for each year in the 100-year simulation, we multiplied these values by the projected provincial population to get the total number of BC adult-RUDs per hectare attributable to each age-class. We based our provincial population projections to 2118 on Statistics Canada's "Population Projections for Canada (2018 to 2068), Provinces and Territories (2018 to 2043), Population Projections for Canada (2018 to 2068), Provinces and Territories (2018 to 2043): Technical Report on Methodology and Assumptions".[49] We extended these projections to 2118 using a linear regression.

To estimate tourism expenditures, we used a value of $112 per visitor per night, which is reported in Destination BC's Vancouver Island Regional Tourism Profile for 2017 (https://www.destinationbc.ca/content/uploads/2018/05/Vancouver-Island-Regional-Tourism-Profile_2017.pdf). We used the consumer price index to adjust this value to 2018 CDN and removed 7% sales tax for a final value of $107.52/night. We assumed a "visitor-night" is equivalent to an RUD. For all 100 years, we then multiplied this $/RUD value by the number of adult-RUDs per hectare in each stand age-class to get expenditures per adult-RUD per hectare for each age class and for that year's projected BC population. We repeated these steps for all timber harvest scenarios.

To determine what proportion of expenditures are attributable to each of the tourism-related industries shown in Table 19, we divided our results using each industry's share of BC tourism revenues as reported in Destination BC's 2017 Value of Tourism report (https://www.destinationbc.ca/content/uploads/2019/10/2017-Value-of-Tourism_FINAL.pdf) (Table 21).

Table 21. Share of BC tourism revenues by industry in 2017

Industry	Share
Accommodation & Food	36.3%
Transportation	31.9%
Retail	25.7%
Other	6.1%

Source: Destination BC (2017)

We then used our regionally adjusted multipliers for both open and closed models to estimate economic impacts for seven key macroeconomic indicators (see Table 22 for a description of these indicators and Table 23, Table 24 for results). All monetary economic impacts are reported as annualized values, based on a 3% annual discount rate applied over the 100-year time horizon. We

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[49] Available at: https://www150.statcan.gc.ca/n1/daily-quotidien/190917/dq190917b-eng.htm.

used the following equation to annualize our results (derived from the present value ordinary annuity equation):

$$annualized\ value\ of\ indicator = present\ value\ of\ indicator\ \div \frac{1-\ (1+d)^{-t}}{d}$$

Where d is the annual discount rate and t is the number of years in the simulation.

We report job impacts as simple annual average full-time equivalents (FTEs) (see Table 22).

Timber Harvest

We estimated the economic impact of timber harvest by applying regionally adjusted multipliers for forestry and logging directly to un-discounted net timber harvest revenues, which were estimated as part of the main study. Like tourism expenditures, we report these results in annualized present value using a 3% discount rate applied over the 100-year time horizon.

D.2 Results

Economic impact assessments typically report economic impacts across seven macroeconomic indicators. In the following two sub-sections we provide four tables that report incremental (i.e., difference from base case) and non-incremental results for tourism and timber harvest across all seven of these indicators. While results are reported separately for each indicator, they are not all additive. For example, GDP is a sub-component of total output and GDP itself includes tax revenues, labour income and gross operating surplus, as well as subsidies (not reported separately in the tables). Table 22 below provides a plain language definition of each indicator. More detail about how Statistics Canada defines these terms is available the Statistics Canada Glossary of Terms (available at: https://www150.statcan.gc.ca/n1/pub/13-605-x/gloss/gloss-a-eng.htm).

Table 22. Description of Economic Impact Assessment indicators

Macroeconomic Indicator	Description
Taxes on products (e.g., sales taxes)	Taxes that are payable to government by those who supply a good or service, usually when it is sold, produced or imported. Product taxes are charged either per unit quantity or per dollar value of good or service sold. Provincial sales tax and taxes on fuel, for example, account for nearly 30% of provincial government tax revenues. Product taxes payable vary with the quantity or value of goods or services sold.
Taxes on production (e.g., property taxes)	Taxes and duties that are payable to government for imports, the employment of labour, and the use of land, buildings, vehicles and other assets in the production of goods and services. Property tax, for example, is the main source of revenue for most local governments in BC. Taxes on production are incurred irrespective of the quantity or value of goods or services produced.
Labour income	Total remuneration, in cash or in kind, payable to employees in return for work done, plus contributions paid by employers to government social security funds or other private insurance schemes to secure benefits for employees.

Gross operating surplus	The surplus left over from the sale of goods and services after paying for inputs to production, payroll and taxes net of subsidies. It is the income available to the producer to reward the providers of capital, to pay direct taxes, and to finance further investment. From a business perspective, it is an important measure of operating profitability—analogous to Earnings before Taxes and Interest (EBIT).
Output	The total value of goods and services produced during a specific period that may be sold, stocked as inventory, traded, or retained for use internally either as an input to current production or to increase fixed assets. Some goods and services sold may also have come out of existing inventories and were not produced in the current period. Think of output as total sales adjusted for changes (positive or negative) in inventories.
Gross domestic product (GDP)	The total *unduplicated* value of the goods and services produced by establishments in a specific area over some unit of time. GDP is the difference between output and intermediate consumption, and therefore is a measure of the value establishments add (i.e., the "value-added") to the products used to produce output. Using the definitions given above, GDP is equal to sales minus purchases plus net inventory changes. Think of it as the amount of money generated by production that remains available to pay wages and salaries, social insurance contributions, taxes, interest on loans, dividends to shareholders, or finance further investment.
Jobs (avg. full-time equivalent employment)	All persons, both employees and self-employed persons, that are engaged in some productive activity that falls within a specific area. Jobs are measured here as "full-time equivalents" (FTEs) FTE employment is defined by Statistics Canada as the "total hours actually worked by all employed persons divided by the average number of annual hours actually worked in full-time jobs". This FTE metric is used to bring part-time and full-time jobs to a common scale for comparison. Results in this study are presented as annual average FTEs over the 100-year simulation period.

Source: adapted from Statistics Canada Glossary of Terms available at: https://www150.statcan.gc.ca/n1/pub/13-605-x/gloss/gloss-a-eng.htm

D.2.1 Recreation-based Tourism Results

Table 23. Economic impacts from recreation-based forest ***tourism*** *for the study area (accommodation, food, transportation, retail trade, and other services). All dollar values are* ***annualized in millions of 2018 CDN dollars*** *[term=100yrs; discount rate = 3% per year]*

			Open model (direct + indirect effects)							Closed model (direct + indirect + induced effects)						
ID	**Scenario**	**Tourism expenditures** $millions	**Taxes on products** sales tax	**Taxes on production** property tax	**Labour income**	**Gross operating surplus**	**Output**	**GDP**	**Jobs** avg FTE	**Taxes on products** sales tax	**Taxes on production** property tax	**Labour income**	**Gross operating surplus**	**Output**	**GDP**	**Jobs** avg FTE
	Base Case															
0	*Business as usual*	$1.55	$0.04	$0.04	$0.64	$0.24	$1.80	$0.93	25.1	$0.04	$0.05	$0.56	$0.32	$1.78	$0.94	26.8
	Immediate Protection (>250-year OG definition)															
1	*30% OG Protection*	$1.61	$0.04	$0.04	$0.66	$0.25	$1.87	$0.96	26.8	$0.04	$0.05	$0.58	$0.33	$1.85	$0.97	28.6
2	*50% OG Protection*	$1.65	$0.04	$0.04	$0.68	$0.26	$1.91	$0.99	27.9	$0.04	$0.06	$0.59	$0.34	$1.89	$1.00	29.8
3	*70% OG Protection*	$1.69	$0.04	$0.04	$0.70	$0.27	$1.97	$1.02	29.1	$0.04	$0.06	$0.61	$0.35	$1.95	$1.02	31.0
4	*100% OG Protection*	$1.78	$0.04	$0.04	$0.74	$0.28	$2.07	$1.07	31.5	$0.04	$0.06	$0.64	$0.37	$2.05	$1.08	33.6
	Immediate Protection (>140-year OG definition)															
5	*30% OG Protection*	$1.62	$0.04	$0.04	$0.67	$0.26	$1.88	$0.97	27.0	$0.04	$0.05	$0.58	$0.33	$1.86	$0.98	28.8
6	*50% OG Protection*	$1.67	$0.04	$0.04	$0.69	$0.26	$1.94	$1.00	28.4	$0.04	$0.06	$0.60	$0.34	$1.91	$1.01	30.3
7	*70% OG Protection*	$1.72	$0.04	$0.04	$0.71	$0.27	$2.00	$1.03	29.8	$0.04	$0.06	$0.62	$0.35	$1.98	$1.04	31.7
8	*100% OG Protection*	$1.82	$0.04	$0.04	$0.75	$0.29	$2.11	$1.09	32.1	$0.05	$0.06	$0.65	$0.37	$2.09	$1.10	34.2
	Transitional Protection (>250-year OG definition)															
9	*50% to 75% Transition (10yrs)*	$1.72	$0.04	$0.04	$0.71	$0.27	$2.00	$1.03	30.0	$0.04	$0.06	$0.62	$0.35	$1.98	$1.04	32.0
10	*50% to 100% Transition (4yrs)*	$1.75	$0.04	$0.04	$0.72	$0.28	$2.03	$1.05	30.5	$0.04	$0.06	$0.63	$0.36	$2.01	$1.06	32.6
11	*50% to 100% Transition (10yrs)*	$1.77	$0.04	$0.04	$0.73	$0.28	$2.05	$1.06	30.9	$0.04	$0.06	$0.64	$0.36	$2.03	$1.07	33.0
12	*50% to 100% Transition (20yrs)*	$1.71	$0.04	$0.04	$0.71	$0.27	$1.99	$1.03	30.0	$0.04	$0.06	$0.62	$0.35	$1.97	$1.04	32.0
	Transitional Protection (>140-year OG definition)															
13	*50% to 75% Transition (10yrs)*	$1.75	$0.04	$0.04	$0.72	$0.28	$2.03	$1.05	30.8	$0.04	$0.06	$0.63	$0.36	$2.01	$1.06	32.9
14	*50% to 100% Transition (4yrs)*	$1.78	$0.04	$0.04	$0.73	$0.28	$2.06	$1.07	31.2	$0.04	$0.06	$0.64	$0.36	$2.04	$1.07	33.3
15	*50% to 100% Transition (10yrs)*	$1.74	$0.04	$0.04	$0.72	$0.28	$2.02	$1.05	30.5	$0.04	$0.06	$0.63	$0.36	$2.00	$1.05	32.6
16	*50% to 100% Transition (20yrs)*	$1.72	$0.04	$0.04	$0.71	$0.27	$2.00	$1.04	30.2	$0.04	$0.06	$0.62	$0.35	$1.98	$1.04	32.2
	No Harvest															
17	*No harvesting of any timber*	$1.75	$0.04	$0.04	$0.72	$0.28	$2.03	$1.05	29.9	$0.04	$0.06	$0.63	$0.36	$2.01	$1.06	31.9

Table 24. Scenario differences from the base case for economic impacts from recreation-based forest ***tourism*** *in the study area (accommodation, food, transportation, retail trade, and other services). All dollar values are* ***annualized in thousands of 2018 CDN dollars*** *[term=100yrs; discount rate = 3% per year]*

			Open model (direct + indirect effects)							**Closed model (direct + indirect + induced effects)**						
ID	**Scenario**	**Tourism expenditures** $thousands	**Taxes on products** sales tax	**Taxes on production** property tax	**Labour income**	**Gross operating surplus**	**Output**	**GDP**	**Jobs** avg FTE	**Taxes on products** sales tax	**Taxes on production** property tax	**Labour income**	**Gross operating surplus**	**Output**	**GDP**	**Jobs** avg FTE
	Base Case															
0	*Business as usual*	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	0.0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	0.0
	Immediate Protection (>250-year OG definition)															
1	*30% OG Protection*	$59.33	$1.35	$1.35	$24.54	$9.39	$68.92	$35.61	1.6	$1.48	$2.00	$21.38	$12.15	$68.20	$35.89	1.8
2	*50% OG Protection*	$101.28	$2.31	$2.30	$41.89	$16.04	$117.65	$60.78	2.8	$2.53	$3.42	$36.50	$20.73	$116.41	$61.26	3.0
3	*70% OG Protection*	$146.68	$3.34	$3.33	$60.67	$23.23	$170.39	$88.03	4.0	$3.67	$4.95	$52.87	$30.03	$168.60	$88.72	4.2
4	*100% OG Protection*	$236.11	$5.38	$5.36	$97.66	$37.38	$274.27	$141.69	6.3	$5.90	$7.97	$85.10	$48.34	$271.38	$142.81	6.8
	Immediate Protection (>140-year OG definition)															
5	*30% OG Protection*	$69.11	$1.57	$1.57	$28.58	$10.94	$80.28	$41.47	1.9	$1.73	$2.33	$24.91	$14.15	$79.43	$41.80	2.0
6	*50% OG Protection*	$119.21	$2.72	$2.71	$49.31	$18.88	$138.48	$71.54	3.2	$2.98	$4.03	$42.96	$24.40	$137.02	$72.10	3.5
7	*70% OG Protection*	$174.09	$3.97	$3.95	$72.01	$27.57	$202.23	$104.48	4.6	$4.35	$5.88	$62.75	$35.64	$200.10	$105.30	4.9
8	*100% OG Protection*	$270.29	$6.16	$6.14	$111.80	$42.80	$313.98	$162.21	6.9	$6.76	$9.13	$97.42	$55.33	$310.67	$163.49	7.4
	Transitional Protection (>250-year OG definition)															
9	*50% to 75% Transition (10yrs)*	$171.81	$3.91	$3.90	$71.06	$27.20	$199.58	$103.11	4.9	$4.30	$5.80	$61.92	$35.17	$197.48	$103.92	5.2
10	*50% to 100% Transition (4yrs)*	$201.23	$4.58	$4.57	$83.23	$31.86	$233.75	$120.76	5.4	$5.03	$6.79	$72.53	$41.20	$231.29	$121.72	5.8
11	*50% to 100% Transition (10yrs)*	$221.53	$5.05	$5.03	$91.63	$35.08	$257.34	$132.95	5.8	$5.54	$7.48	$79.84	$45.35	$254.63	$133.99	6.2
12	*50% to 100% Transition (20yrs)*	$165.24	$3.76	$3.75	$68.35	$26.16	$191.95	$99.17	4.9	$4.13	$5.58	$59.56	$33.83	$189.93	$99.95	5.2
	Transitional Protection (>140-year OG definition)															
13	*50% to 75% Transition (10yrs)*	$201.84	$4.60	$4.58	$83.48	$31.96	$234.46	$121.13	5.7	$5.05	$6.82	$72.75	$41.32	$231.99	$122.08	6.1
14	*50% to 100% Transition (4yrs)*	$229.56	$5.23	$5.21	$94.95	$36.35	$266.67	$137.77	6.1	$5.74	$7.75	$82.74	$47.00	$263.86	$138.85	6.5
15	*50% to 100% Transition (10yrs)*	$195.23	$4.45	$4.43	$80.75	$30.91	$226.78	$117.16	5.4	$4.88	$6.59	$70.36	$39.97	$224.39	$118.08	5.8
16	*50% to 100% Transition (20yrs)*	$177.85	$4.05	$4.04	$73.56	$28.16	$206.59	$106.73	5.1	$4.45	$6.01	$64.10	$36.41	$204.42	$107.57	5.4
	No Harvest															
17	*No harvesting of any timber*	$198.39	$4.52	$4.50	$82.06	$31.41	$230.45	$119.06	4.8	$4.96	$6.70	$71.50	$40.61	$228.02	$119.99	5.1

D.2.2 Timber Harvest Results

Table 25. Economic impacts from ***timber harvest*** *for the study area. All dollar values are* ***annualized in millions of 2018 CDN dollars*** *[term=100yrs; discount rate = 3% per year]*

			Open model (direct + indirect effects)							**Closed model (direct + indirect + induced effects)**						
ID	**Scenario**	**Harvest revenue** $millions	**Taxes on products** sales tax	**Taxes on production** property tax	**Labour income**	**Gross operating surplus**	**Output**	**GDP**	**Jobs** avg FTE	**Taxes on products** sales tax	**Taxes on production** property tax	**Labour income**	**Gross operating surplus**	**Output**	**GDP**	**Jobs** avg FTE
	Base Case															
0	*Business as usual*	$1.05	$0.02	$0.02	$0.27	$0.20	$1.23	$0.50	13.3	$0.02	$0.03	$0.24	$0.23	$1.22	$0.50	14.2
	Immediate Protection (>250-year OG definition)															
1	*30% OG Protection*	$0.90	$0.02	$0.02	$0.24	$0.17	$1.06	$0.43	11.5	$0.02	$0.02	$0.21	$0.20	$1.05	$0.43	12.2
2	*50% OG Protection*	$0.81	$0.02	$0.02	$0.21	$0.15	$0.95	$0.38	10.1	$0.02	$0.02	$0.18	$0.18	$0.94	$0.39	10.8
3	*70% OG Protection*	$0.71	$0.01	$0.01	$0.19	$0.14	$0.84	$0.34	9.0	$0.01	$0.02	$0.16	$0.16	$0.83	$0.34	9.6
4	*100% OG Protection*	$0.54	$0.01	$0.01	$0.14	$0.10	$0.63	$0.25	6.7	$0.01	$0.01	$0.12	$0.12	$0.62	$0.26	7.1
	Immediate Protection (>140-year OG definition)															
5	*30% OG Protection*	$0.89	$0.02	$0.02	$0.23	$0.17	$1.04	$0.42	11.2	$0.02	$0.02	$0.20	$0.20	$1.04	$0.43	11.9
6	*50% OG Protection*	$0.79	$0.02	$0.02	$0.21	$0.15	$0.93	$0.38	9.9	$0.02	$0.02	$0.18	$0.17	$0.92	$0.38	10.5
7	*70% OG Protection*	$0.69	$0.01	$0.01	$0.18	$0.13	$0.81	$0.33	8.5	$0.01	$0.02	$0.16	$0.15	$0.80	$0.33	9.1
8	*100% OG Protection*	$0.53	$0.01	$0.01	$0.14	$0.10	$0.62	$0.25	6.6	$0.01	$0.01	$0.12	$0.12	$0.62	$0.25	7.0
	Transitional Protection (>250-year OG definition)															
9	*50% to 75% Transition (10yrs)*	$0.68	$0.01	$0.01	$0.18	$0.13	$0.80	$0.32	8.0	$0.01	$0.02	$0.16	$0.15	$0.79	$0.33	8.5
10	*50% to 100% Transition (4yrs)*	$0.59	$0.01	$0.01	$0.16	$0.11	$0.70	$0.28	6.9	$0.01	$0.02	$0.14	$0.13	$0.69	$0.28	7.3
11	*50% to 100% Transition (10yrs)*	$0.59	$0.01	$0.01	$0.16	$0.11	$0.69	$0.28	7.5	$0.01	$0.02	$0.14	$0.13	$0.69	$0.28	7.9
12	*50% to 100% Transition (20yrs)*	$0.51	$0.01	$0.01	$0.13	$0.10	$0.60	$0.24	5.7	$0.01	$0.01	$0.12	$0.11	$0.60	$0.25	6.1
	Transitional Protection (>140-year OG definition)															
13	*50% to 75% Transition (10yrs)*	$0.45	$0.01	$0.01	$0.12	$0.09	$0.53	$0.22	7.1	$0.01	$0.01	$0.10	$0.10	$0.53	$0.22	7.6
14	*50% to 100% Transition (4yrs)*	$0.53	$0.01	$0.01	$0.14	$0.10	$0.62	$0.25	6.0	$0.01	$0.01	$0.12	$0.12	$0.61	$0.25	6.3
15	*50% to 100% Transition (10yrs)*	$0.34	$0.01	$0.01	$0.09	$0.06	$0.40	$0.16	4.6	$0.01	$0.01	$0.08	$0.07	$0.40	$0.16	4.9
16	*50% to 100% Transition (20yrs)*	$0.32	$0.01	$0.01	$0.08	$0.06	$0.38	$0.15	4.0	$0.01	$0.01	$0.07	$0.07	$0.38	$0.15	4.3
	No Harvest															
17	*No harvesting of any timber*	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	0.0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	0.0

Table 26. Scenario differences from the base case for economic impacts from ***timber harvest*** *in the study area. All dollar values are* ***annualized in thousands of 2018 CDN dollars*** *[term=100yrs; discount rate = 3% per year]*

			Open model (direct + indirect effects)							**Closed model (direct + indirect + induced effects)**						
ID	**Scenario**	**Harvest revenue** $thousands	**Taxes on products** sales tax	**Taxes on production** property tax	**Labour income**	**Gross operating surplus**	**Output**	**GDP**	**Jobs** avg FTE	**Taxes on products** sales tax	**Taxes on production** property tax	**Labour income**	**Gross operating surplus**	**Output**	**GDP**	**Jobs** avg FTE
	Base Case															
0	*Business as usual*	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	0.0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	0.0
	Immediate Protection (>250-year OG definition)															
1	*30% OG Protection*	($145.14)	($2.82)	($2.91)	($38.08)	($27.55)	($170.21)	($68.97)	(1.8)	($3.02)	($3.93)	($33.19)	($31.82)	($169.09)	($69.40)	(1.9)
2	*50% OG Protection*	($239.54)	($4.65)	($4.81)	($62.85)	($45.46)	($280.91)	($113.82)	(3.2)	($4.99)	($6.49)	($54.77)	($52.51)	($279.06)	($114.54)	(3.4)
3	*70% OG Protection*	($332.70)	($6.45)	($6.68)	($87.30)	($63.14)	($390.17)	($158.09)	(4.3)	($6.93)	($9.01)	($76.07)	($72.93)	($387.59)	($159.09)	(4.6)
4	*100% OG Protection*	($511.40)	($9.92)	($10.27)	($134.19)	($97.06)	($599.74)	($243.00)	(6.7)	($10.64)	($13.86)	($116.93)	($112.11)	($595.77)	($244.54)	(7.1)
	Immediate Protection (>140-year OG definition)															
5	*30% OG Protection*	($157.16)	($3.05)	($3.15)	($41.24)	($29.83)	($184.30)	($74.68)	(2.1)	($3.27)	($4.26)	($35.93)	($34.45)	($183.08)	($75.15)	(2.2)
6	*50% OG Protection*	($256.98)	($4.99)	($5.16)	($67.43)	($48.77)	($301.37)	($122.11)	(3.4)	($5.35)	($6.96)	($58.76)	($56.34)	($299.38)	($122.88)	(3.6)
7	*70% OG Protection*	($359.67)	($6.98)	($7.22)	($94.38)	($68.26)	($421.80)	($170.91)	(4.8)	($7.49)	($9.75)	($82.24)	($78.85)	($419.01)	($171.99)	(5.1)
8	*100% OG Protection*	($516.76)	($10.03)	($10.37)	($135.59)	($98.08)	($606.02)	($245.55)	(6.8)	($10.76)	($14.00)	($118.15)	($113.28)	($602.01)	($247.10)	(7.2)
	Transitional Protection (>250-year OG definition)															
9	*50% to 75% Transition (10yrs)*	($366.96)	($7.12)	($7.37)	($96.29)	($69.65)	($430.36)	($174.37)	(5.3)	($7.64)	($9.94)	($83.90)	($80.45)	($427.51)	($175.47)	(5.6)
10	*50% to 100% Transition (4yrs)*	($453.86)	($8.81)	($9.11)	($119.09)	($86.14)	($532.26)	($215.66)	(6.5)	($9.45)	($12.30)	($103.77)	($99.49)	($528.74)	($217.02)	(6.9)
11	*50% to 100% Transition (10yrs)*	($454.86)	($8.82)	($9.13)	($119.35)	($86.33)	($533.43)	($216.14)	(5.9)	($9.47)	($12.32)	($104.00)	($99.71)	($529.90)	($217.50)	(6.2)
12	*50% to 100% Transition (20yrs)*	($534.01)	($10.36)	($10.72)	($140.12)	($101.35)	($626.26)	($253.75)	(7.6)	($11.12)	($14.47)	($122.10)	($117.07)	($622.12)	($255.35)	(8.1)
	Transitional Protection (>140-year OG definition)															
13	*50% to 75% Transition (10yrs)*	($592.95)	($11.50)	($11.90)	($155.59)	($112.54)	($695.38)	($281.76)	(6.2)	($12.34)	($16.07)	($135.58)	($129.99)	($690.78)	($283.54)	(6.6)
14	*50% to 100% Transition (4yrs)*	($520.36)	($10.10)	($10.45)	($136.54)	($98.76)	($610.25)	($247.26)	(7.4)	($10.83)	($14.10)	($118.98)	($114.07)	($606.21)	($248.82)	(7.8)
15	*50% to 100% Transition (10yrs)*	($707.15)	($13.72)	($14.20)	($185.55)	($134.21)	($829.31)	($336.02)	(8.7)	($14.72)	($19.16)	($161.69)	($155.02)	($823.82)	($338.14)	(9.3)
16	*50% to 100% Transition (20yrs)*	($723.98)	($14.05)	($14.53)	($189.97)	($137.41)	($849.05)	($344.02)	(9.3)	($15.07)	($19.62)	($165.53)	($158.71)	($843.43)	($346.19)	(9.9)
	No Harvest															
17	*No harvesting of any timber*	($1,046.99)	($20.31)	($21.02)	($274.72)	($198.71)	($1,227.86)	($497.50)	(13.3)	($21.79)	($28.37)	($239.39)	($229.52)	($1,219.73)	($500.65)	(14.2)

Summary of Key Findings from the Supplementary Economic Impact Assessment

- Depending on the scenario, and using the open model (direct and indirect effects only), old growth protection will result in the following losses to the BC economy due to **reduced timber harvest**:
    - Employment losses of between 2 and 9 full-time equivalent (FTE) jobs
    - A decrease in contributions to the provincial GDP by between $69 and $344 thousand annually
    - A decrease in economic output by between $170 and $849 thousand annually
    - A reduction in tax revenues by between $3 and $14 thousand annually from taxes on products (e.g., sales tax) and $3 and $14 thousand annually from taxes on production (e.g., property tax)
    - A reduction in labour income (e.g., salaries/wages) by between $38 and $190 thousand annually
    - A reduction in gross operating surplus by between $28 and $137 thousand annually

- The tourism sector will partially compensate for the above losses due to increased visitation encouraged by the presence of old growth forests. The following gains are expected from this sector depending on the scenario:
    - Employment gains of between almost 2 and 7 FTEs
    - An increase in contributions to the provincial GDP by between $36 and $162 thousand annually
    - An increase in economic output by between $69 and $313 thousand annually
    - An increase in tax revenues by between $1 and $6 thousand annually from taxes on products (e.g., sales tax) and $1 and $6 thousand annually from taxes on production (e.g., property tax)
    - An increase in labour income (e.g., salaries/wages) by between $25 and $112 thousand annually
    - An increase in gross operating surplus by between $9 and $42 thousand annually

Eden Grove Old Growth by TJ Watt, n.d., Ancient Forest Alliance

ESSA