Analyses of 27 years of stand structure development and basal area growth response to a range of initial basal area density levels, 1992-2019

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# Methods

## Analysis

### Tree-level growth responses

To test the hypothesis that tree-level radial growth response over the 1992-2019 period varied with interactions between (i) tree diameter at the time of treatment (1992); (ii) treatment; and (iii) species, we fit linear mixed effects models with log-transformed 1992-2019 diameter increment as the response variable, and treatment, species and log-transformed 1992 diameter as interacting fixed effects, and plot as a random intercept effect. We also fit a similar model with the 1992-2019 diameter increment expressed as a percentage of 1992 diameter. Plots of residuals and fit lines with orginal data were examined to evaluate model goodness of fit. Variance explained for each model are reported using the approach described in Nakagawa et al. (2013), as implemented in the MuMIn package for R (**???** later).

### Stand structure and growth dynamics

#### Stand-level volume and basal area estimates

Total and merchantable volumes were estimated for trees using species- and region-specific equations (Nigh 2016) based on tree height and DBH. Consistent with forest management practices in British Columbia, we only estimated volumes for trees meeting a minimum diameter utlization limit of 18.5cm DBH. For trees lacking a tree height measurement, We estimated height by fitting a single diameter-height model developed with a linear mixed effects model, with log-transformed DBH as a fixed effect, and tree nested within plot as a random effect. Trees with broken tops were omitted from diameter-height models. We summed tree-level estimates of volume and basal area to generate stand-level estimates.

#### Stand growth

To test the hypothesis that stand volume and basal area growth from 1992-2019 varied by treatment, we fit separate linear mixed effects models using periodic annual volume and basal area increments as response variables, treatment as a fixed effects, and plot as a random effect. Periodic annual increment was calculated for the four measurement periods by dividing increment over the measurement period by the number of complete growing seasons within that period (Appendix 1).

Number of growing seasons between measurement periods

| Measurement Year | Growing Seasons |
| --- | --- |
| 1992 | NA |
| 1994 | 3 |
| 1997 | 3 |
| 2009 | 11 |
| 2019 | 11 |

### Changes in tree density over time

We qualitatively assessed changes in tree density over time through density diagrams that displayed tree density (stems per hectare) by diameter class, faceted by measurement period, species and treatment unit. The effects of tree density changes on basal area was also qualitatively evaluated by summarizing basal area per hectare by diameter class, species and treatment unit.

### Stand-level basal area and volume growth

Nakagawa, S., and Schielzeth, H. 2013. A general and simple method for obtaining R2 from generalized linear mixed-effects models. Methods in Ecology and Evolution **4**(2): 133–142. doi:[10.1111/j.2041-210x.2012.00261.x](https://doi.org/10.1111/j.2041-210x.2012.00261.x).

Nigh, G.D. 2016. Total and merchantable volume equations for common tree species in British Columbia by region and biogeoclimactic zone. BC Tech. Rep. 106. www. for. gov. bc. ca/hfd/pubs/Docs/Tr/Tr106. htm.