Remnant old trees enhance large woody debris loading in low-order streams at the Hubbard Brook Experimental Forest

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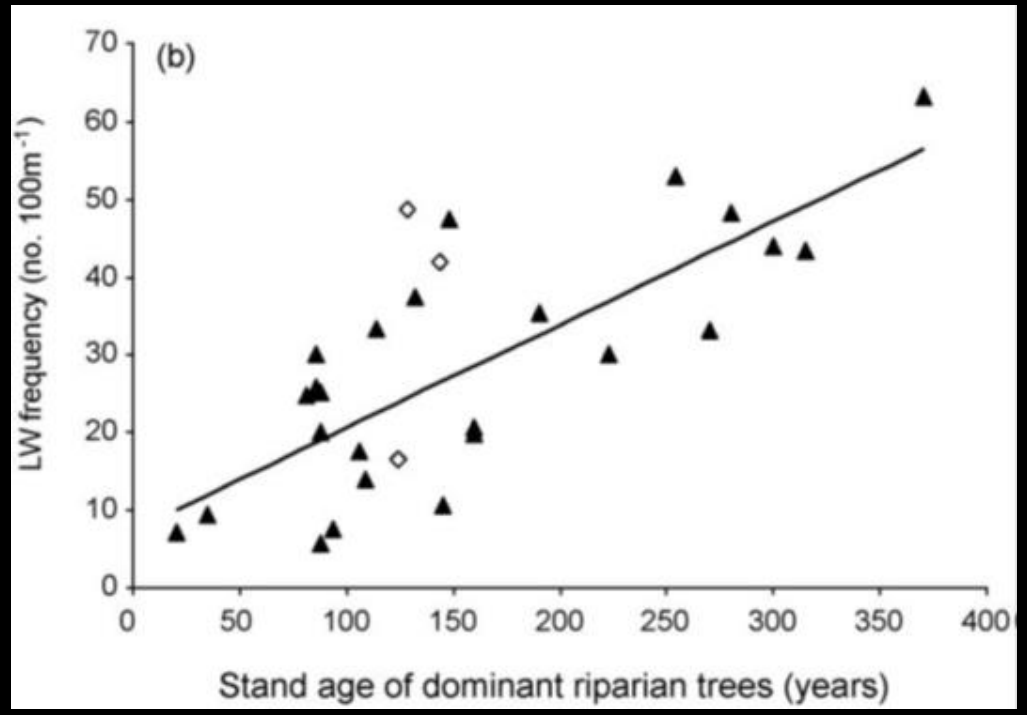
Background

Large woody debris has many important ecological functions:
Habitat complexity, nutrient processing sites, and “roughness” related to flood resilience

Large wood recruitment in streams is positively correlated with forest age and structural development (Keeton et al. 2007; Warren, Keeton et al. 2009)

Recruitment mechanisms include density-dependent mortality (self-thinning) and density independent mortality (e.g. disturbance gaps)



Warren, Keeton et al. 2009

Structural development occurs over multiple pathways

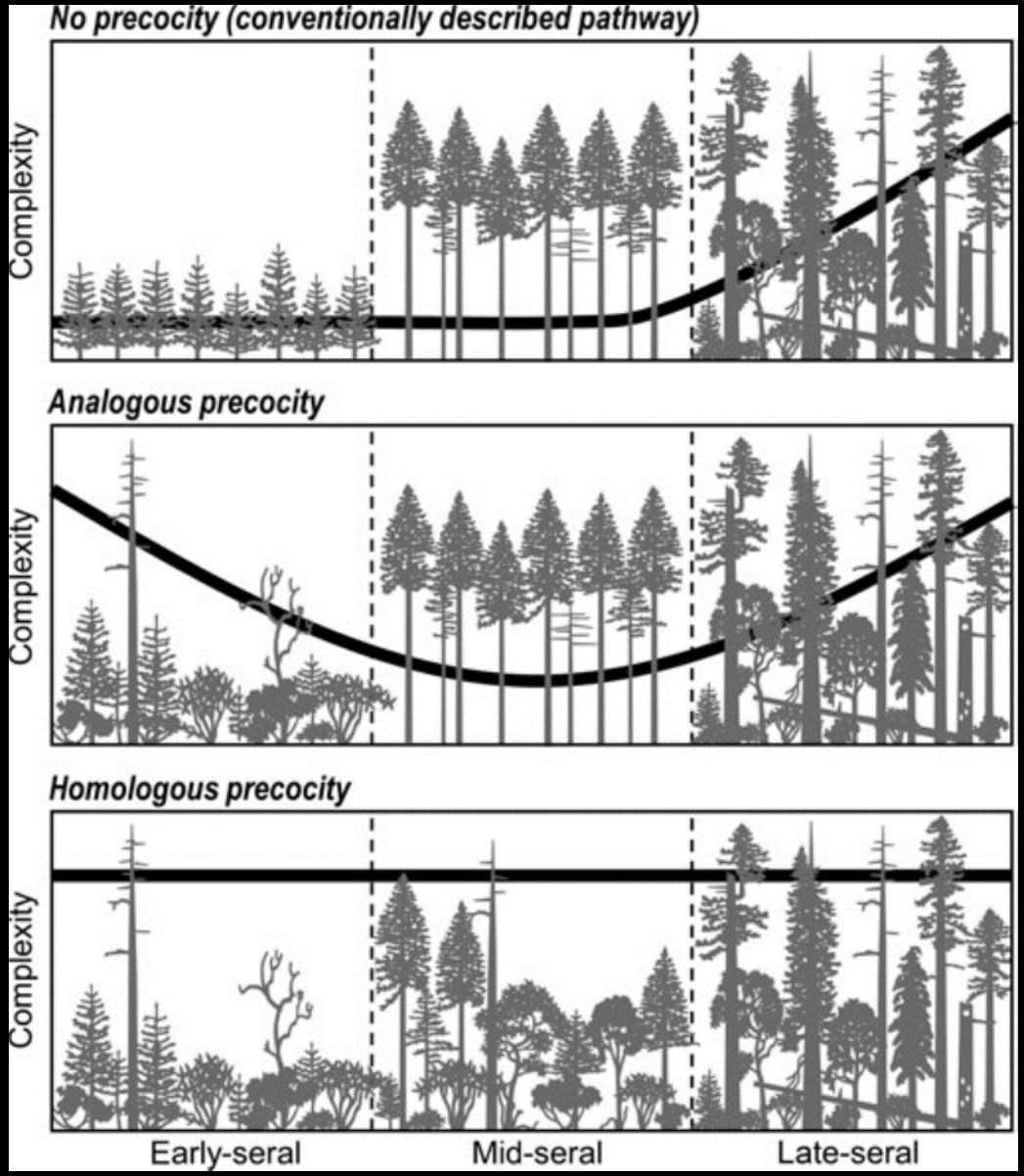
But these pathways of stand development are poorly described in northern hardwood-conifer forests

One unique pathway is playing out in the Hubbard Brook Experimental Forest (HBEF), NH

Partial harvests in the early 1900s left remnant trees

Research Question

How does stand development associated with partial harvesting and retention of large trees influence large woody debris recruitment in streams?



Donato et al. 2012

Study Area:

Hubbard Brook Experimental Forest (HBEF)

Mature forest, multi-aged structural development pathway

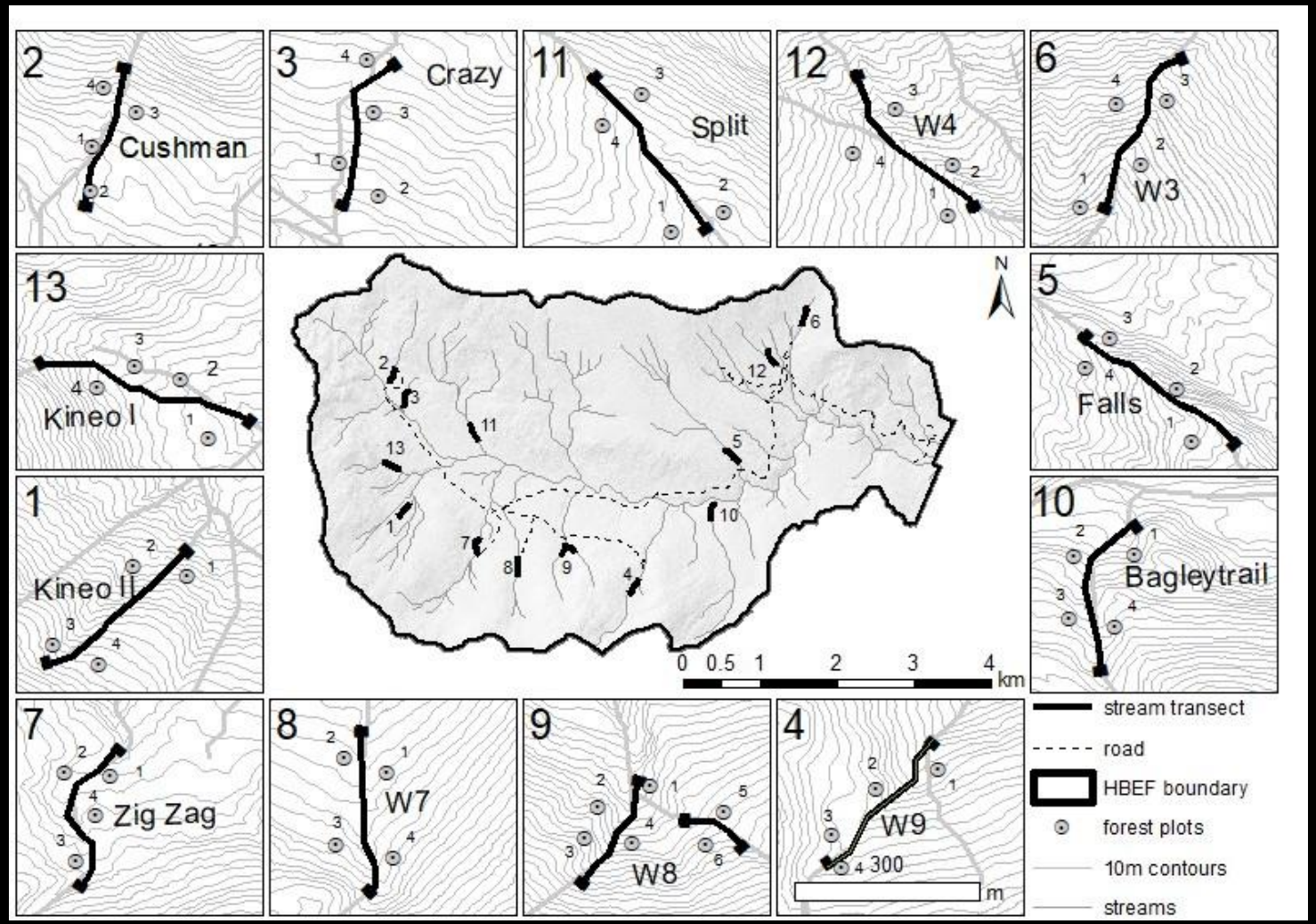
History of partial harvests and high-grading

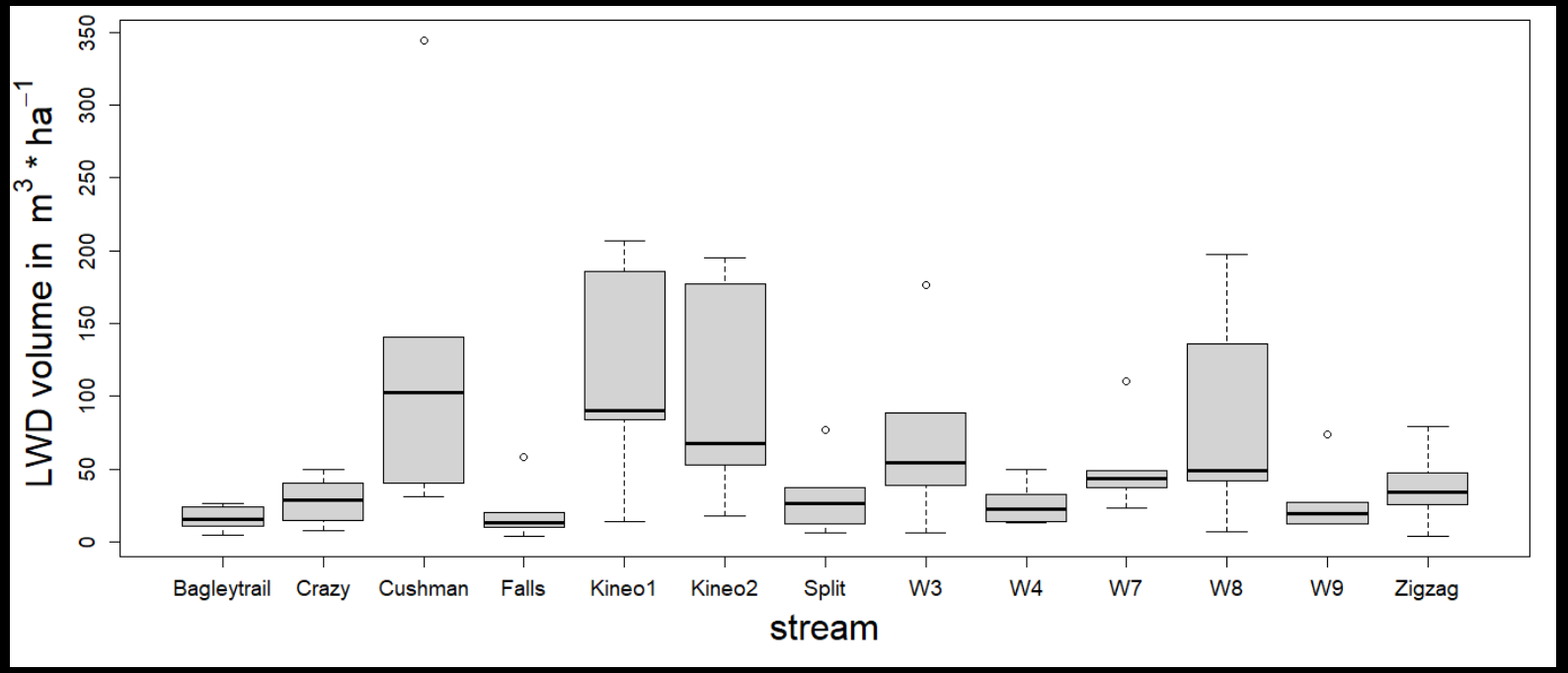
Heavy spruce removal early 20th century; release of secondary hardwoods

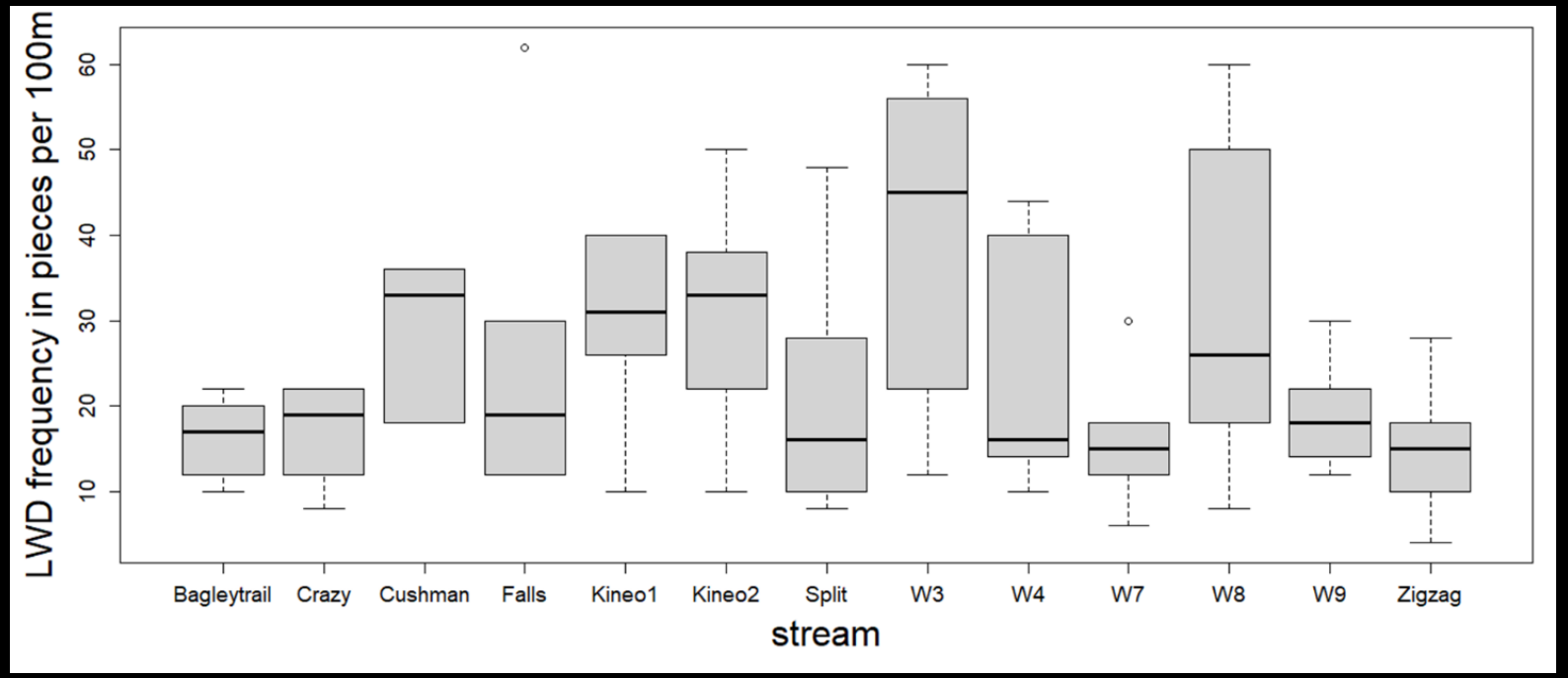
Carryover of remnant (or legacy) old-growth trees

Hypothesis: Forest structure and legacy trees are influencing variability in stream wood loading

Study Sites and Data Collection







Large Woody Debris (LWD) loading is highly variable both within (50 m long subsections) and among stream reaches (300 m length)

Statistical Methods

Descriptions and units of forest structure parameters		
forest structure parameter	**unit**	**description**
forest type	category	forest type that most closely matches species composition of overstory after NED2 Reference Guide
canopy closure	%	mean percentage of canopy closure
basal area total	m^3*ha^{-1}	mean basal area of live and dead trees
basal area live	m^3*ha^{-1}	mean basal area of live trees
basal area dead	m^3*ha^{-1}	mean basal area of dead trees
relative density	%	mean trees per area ratio after Sollins 1987
quadratic mean dbh	cm	mean quadratic mean dbh of trees in stand
big tree density	$stems*ha^{-1}$	mean density of trees with dbh ≥ 50cm
total tree density	$stems*ha^{-1}$	mean density of living and standing dead trees
live tree density	$stems*ha^{-1}$	mean density of living trees
dead tree density	$stems*ha^{-1}$	mean density of standing dead trees
basal area conifers	m^3*ha^{-1}	mean basal area of conifer trees
percent conifers	%	mean percentage of total basal area made up by conifer trees
AGB total	$t*ha^{-1}$	mean above ground biomass including living and standing dead trees
AGB live	$t*ha^{-1}$	mean above ground biomass of living trees
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sd of canopy closure	%	standard deviation of canopy closure
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Bayesian Generalized Linear Mixed Models (GLMMs) with Stan

Analyzed streams at the 50m sub-reach scale

78 stream sub-sections across 13 streams

28 forest structure and stream geomorphology predictor variables

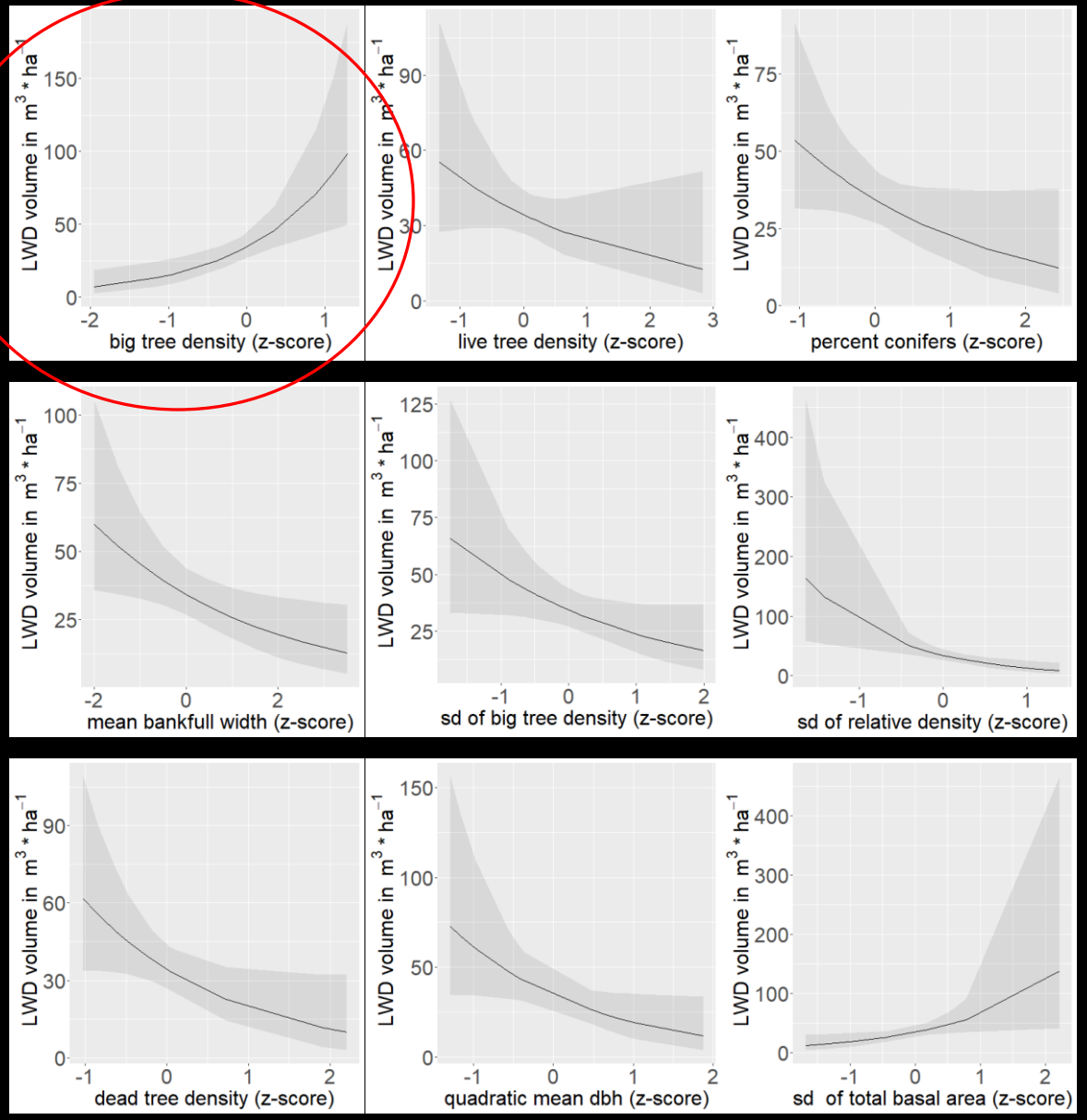
Collinear variables removed

Most parsimonious model selected using expected log predictive density

Big trees (>50 cm dbh) strongly related to LWD volume

Std. dev. of basal area also related. Measure of patch complexity?

Large, remnant yellow birch

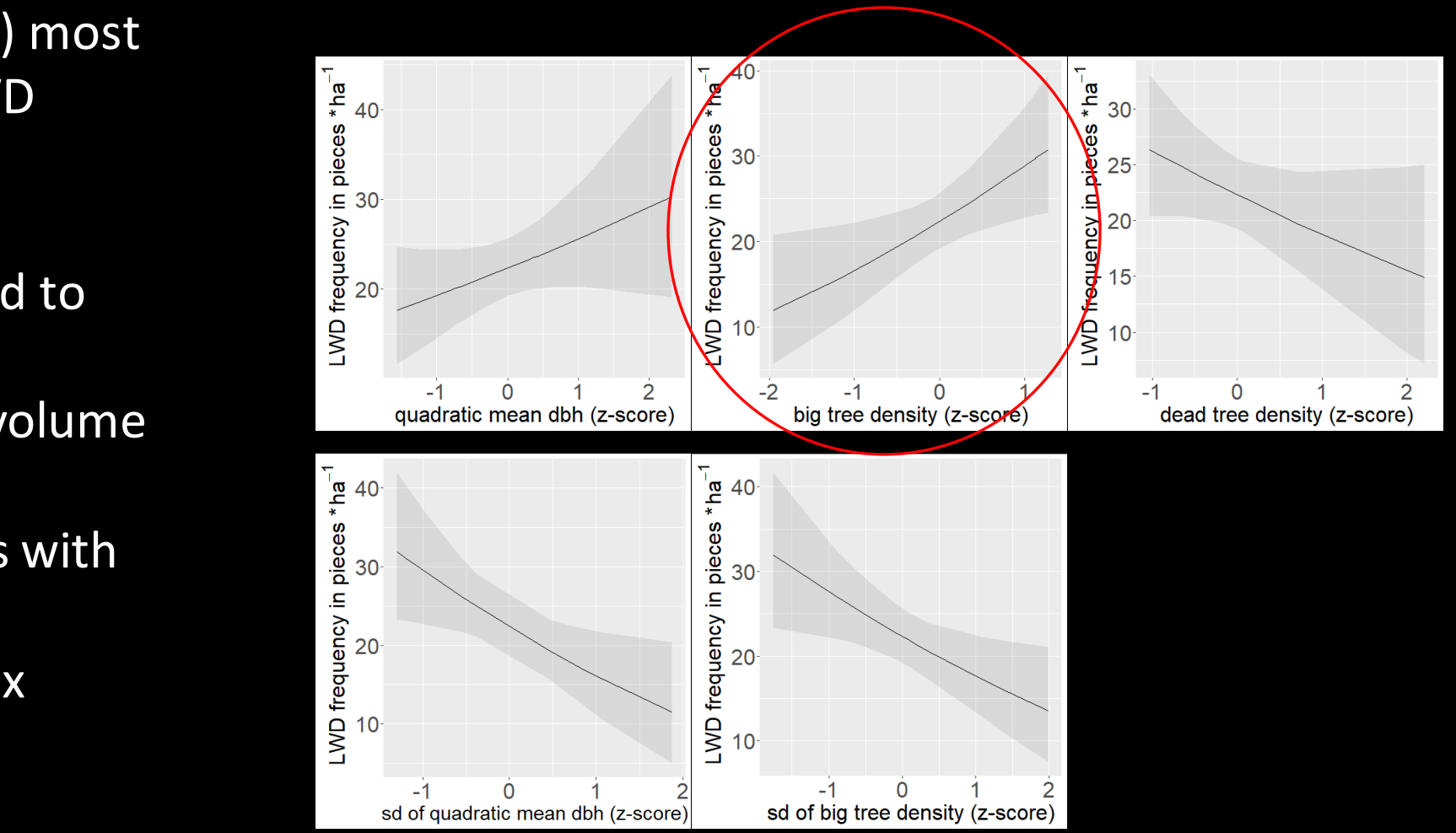


Marginal effect plots for parameters included in the most parsimonious model describing the relationship between in-stream LWD volume and forest structure. Parameters have been standardized (z-score).

Big trees (>50 cm dbh) most strongly related to LWD frequency

QMD positively related to LWD frequency but negatively related to volume

Negative relationships with dead tree density → intriguing and complex



Marginal effect plots for parameters included in the most parsimonious model describing the relationship between in-stream LWD frequency and forest structure. Parameters have been standardized (z-score).

Conclusions

Remnant old trees appear to enhance LWD volume and frequency in HBEF's low order streams

May translate into effects on debris dam formation and wood related in-stream processes

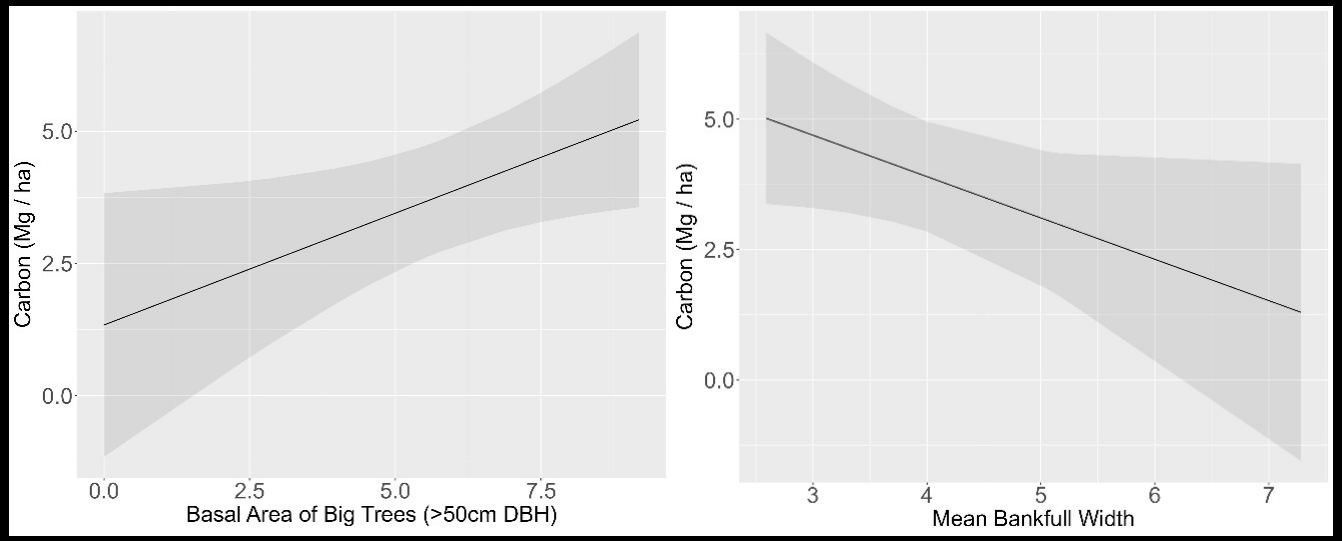
Atypical stand development pathways in some areas of HBEF?
→ Subject of Stephen Peters-Collaer's PhD work

Retention forestry practices intended to enhance riparian forest functionality may yield long-term stream function benefits

Investigating LWD functions: Stream LWD carbon storage

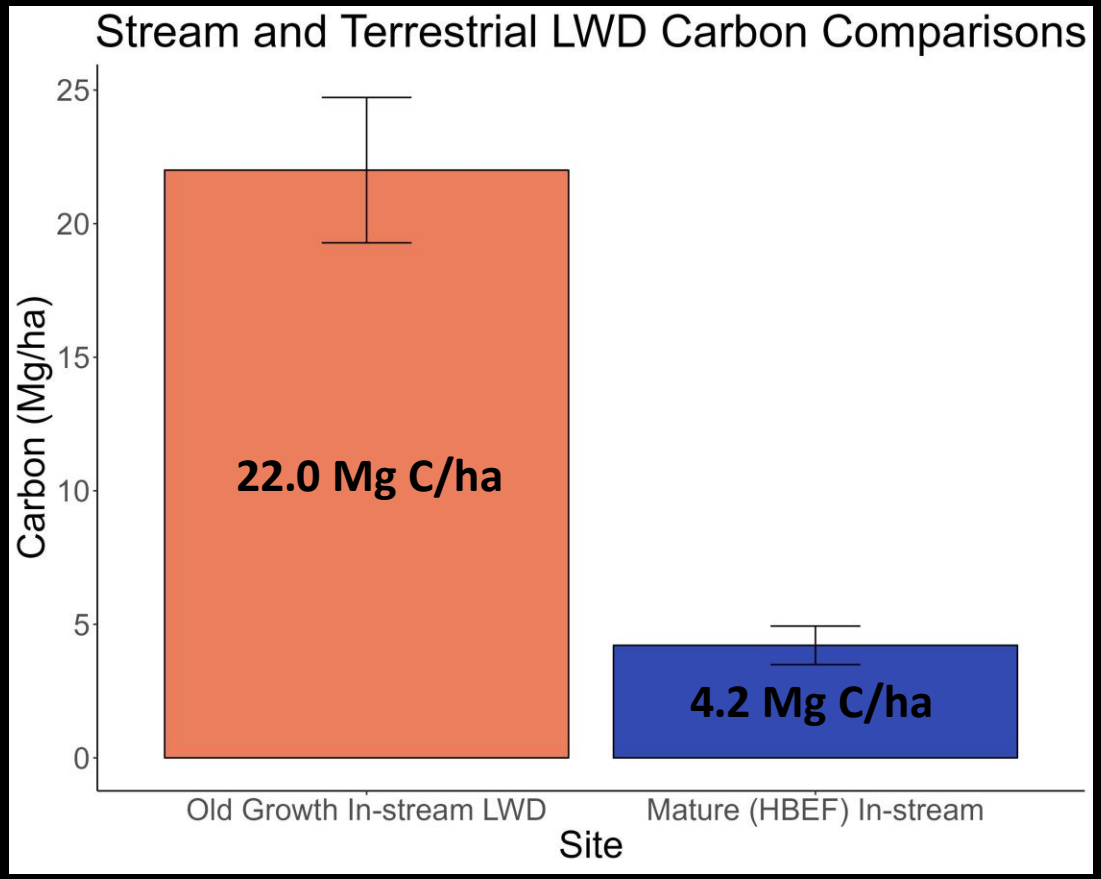
Which riparian forest structural parameters are most important for explaining in-stream LWD carbon storage?

Big trees (again)!



Compared carbon stored in in-stream LWD at the mature HBEF with a comparable old-growth forest

Old growth streams stored ~5 times as much carbon as mature forest streams



Acknowledgements

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Hubbard Brook Ecosystem Study


Questions?

Statistical analysis of forest structure – LWD relationships

Bayesian Generalized Linear Models (GLMs)

Nested study design, large number of parameters, relatively small sample size per group

78 stream sections, 13 streams

28 forest structure and stream geomorphology predictor variables

R language packages MuMln, bayesplot, and loo for model selection; ggeffects for marginal effects; ggpubr for visualization

Forest and stream parameters as fixed effects, site as random effect

Collinearity checked using Pearson's r; parameter selection accordingly; scaled and zero-centered

Model selection process: expected log predictive density used to select most parsimonious model from candidate model sets

Residuals checked for normal distribution; compared Bayesian R^2 and mean leave-one-out (LOO) R^2; marginal effects plots for all parameters included in best fitting model

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USDA McIntire-Stennis Forest Research Program

University of Vienna, Austria

Stream Characteristics

- 1st and 2nd order headwater streams
- Unmanipulated north and western facing sub-watersheds at HBEF
- 300 m stream reaches
- Bankfull widths 2.7 to 5 m
- Stream gradients 6 to 20%

Stream characteristics

site	area m^2	mean bankfull width m	mean gradient %	LIM - LWD Volume m^3*ha^{-1}	TWC - LWD Volume m^3*ha^{-1}	LIM - LWD frequency stems*100m^{-1}	TWC - LWD Frequency stems*100m^{-1}	Debris dam frequency dams*100m^{-1}	Pool frequency pools*100m^{-1}
Bagleytrail	1488.50	4.96	13.92	15.05	16.32	4.33	16.33	8.00	9.00
Crazy	814.25	2.71	9.33	30.84	28.48	7.33	17.00	10.33	6.00
Cushman	864.00	2.88	12.33	65.14	127.10	9.00	29.00	12.67	4.33
Falls	2283.75	7.61	12.92	47.13	19.85	7.33	25.67	8.67	7.33
Kineo1	876.75	2.92	10.50	69.04	111.78	12.00	29.67	12.67	2.33
Kineo2	919.25	3.06	20.67	50.79	96.22	10.33	31.00	12.00	9.33
Split	1531.50	5.11	5.83	17.52	31.01	4.67	21.00	4.67	1.00
W3	1234.50	4.12	19.92	61.69	69.75	13.00	40.00	18.00	2.67
W4	926.75	3.09	17.33	28.38	25.76	10.33	23.33	12.33	1.67
W7	1135.00	3.78	6.92	64.36	51.00	8.00	16.00	3.33	8.00
W8	923.90	3.20	12.08	74.64	80.19	9.50	31.33	12.67	0.00
W9	990.75	3.30	13.50	27.26	27.38	5.67	19.00	7.67	8.33
Zigzag	1448.25	4.83	7.17	24.21	37.32	1.67	15.00	4.67	2.67

Background

- Large woody debris in low order streams provides many important ecological functions, such as habitat complexity, nutrient processing sites, and “roughness” related to flood resilience.
- Previous research shows that large wood recruitment in streams is positively correlated with forest age and structural development (Keeton et al. 2007; Warren, Keeton et al. 2009).
- Mechanisms include both density-dependent mortality (self-thinning) and density independent mortality (e.g. disturbance gaps).
- But the multiple pathways of stand development are poorly described in northern hardwood-conifer forests
- One such pathway is playing out in upper portions (never manipulated) of the Hubbard Brook Experimental Forest, NH
- There a history of partial harvesting in the early 20th century left abundant remnant trees. 100+ years later these biological legacies are the size and age of dominant trees found in old-growth forests.

Research Question

- How does stand development associated with partial harvesting and retention of large trees influence large woody debris recruitment in streams?