FOREST RESEARCH REPORT

Contents

Report FOR 2018-3 No. 101

Crop Tree Release in Tolerant Hardwoods

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Introduction

With the advent of the Sustainability Regulations in the late 90's early 2000's crop tree release became a funded silvicultural option and therefore garnered more attention (NSDNR, 2010). This prompted the Nova Scotia Department of Natural Resources to initiate research trials on crop tree release starting in 2001.

Trials initially tested the applicability of crop tree release in mature hardwood stands in conjunction with group selection harvests. Subsequently, trials in pole-sized stands were initiated to investigate whether crop tree release could be applied in younger, smaller sized stands. This report discusses ten year results of these trials and provides recommendations for implementation of crop tree release in tolerant hardwoods.

Crop Tree Release Description

Crop tree release (CTR) of hardwood stands in the Eastern United States has been described by Perkey *et al*. (1993). This treatment focuses on increasing the growth rate of individual high quality trees. While Perkey *et al*. (1993) discuss releasing trees for a wide variety of benefits; this report will concentrate on using CTR for the production of high value sugar maple, yellow birch, and white ash sawlogs. CTR is suited to situations where;

- There are a limited numbers of trees that have high value potential.
- Sugar maple, yellow birch, red oak and white ash[1] are intermixed with low quality species.
- Only the best quality trees are released as opposed to all leave trees. This treatment serves as an alternative to traditional thinning techniques (Figure 1).

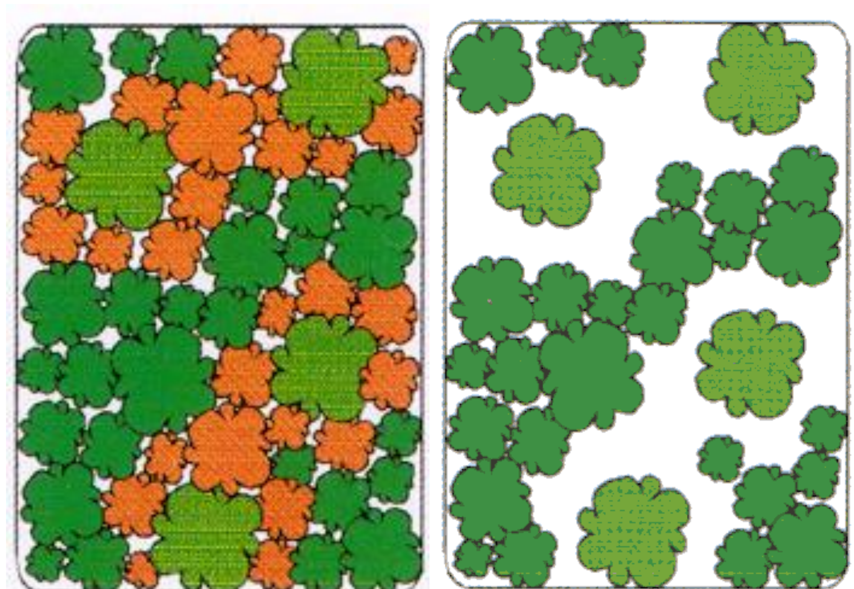

Figure 1. Typical spatial configuration of trees in a crop tree release treatment (adapted from Perkey *et al*. 1993).

CTR results in released high quality trees intermixed with areas of unreleased lower quality stems. The unreleased parts of the stand provide protection for the released trees, reducing the chance of crown die-back and epicormic branching (OMNR, 2004). The following are recommendations for implementation of crop tree release;

- Crop trees are released on at least three sides.
- Cut lower quality trees that have crowns touching crowns of crop trees.
- Crop trees should be a minimum of 6-9m (20-30 feet) apart to provide space for crown development.
- Crop trees must be healthy with full crowns (greater than 1/3 live crown). Suppressed trees with small crowns will be slow to respond and prone to die-back, epicormic branching, stem breakage and windthrow.
- Trees that have clean butt logs should be released.

[1] sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula alleghaniensis* Britton), red oak (*Quercus rubra* L.), white ash (*Fraxinus Americana* L.)

Crop tree release can be used to reduce the time it takes to grow a tree to sawlog size. Other studies have shown increased growth when crop trees are released (Perkey *et al*. 1993). BANTIC (Mills and Lamson, 1999), a model that predicts financial return based on local specifications, can be used to evaluate the financial return from growing sawlogs.

Trials

Locations

Six trials were established across Nova Scotia to test crop tree release treatments in tolerant hardwood stands (Figure 2).

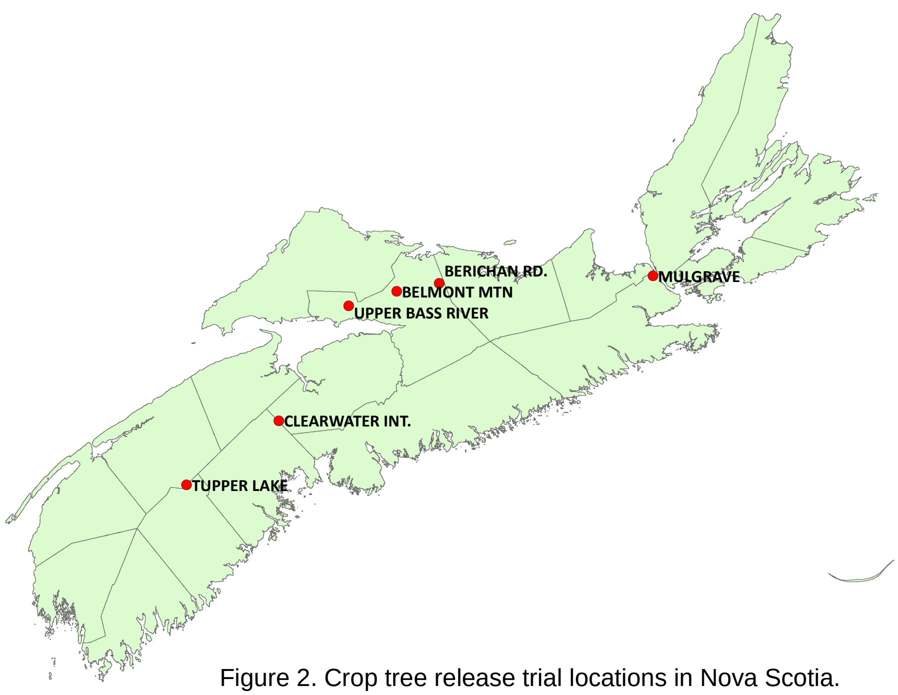

Figure 2. Crop tree release trial locations in Nova Scotia.

Descriptions

The trials were measured at the five and ten-year mark following treatment. The trials at Upper Bass River and Berichan were initiated in 2001-2003 as part of group selection trials in mature tolerant hardwood stands (Table 1). The best quality trees 15 to 37 cm (6 to 15 inches) in diameter at breast height (dbh) were released in-between harvested patches, while un-released trees of similar size and condition were selected for comparison. Tupper Lake, Belmont Mountain and Clearwater Intersection were selected to compare crop tree release (CTR) treatments to pre-commercial thinning (PCT) and un-treated controls (CON), when initiated in smaller diameter stands. Diameters ranged from 3 to 15 cm (1-6 inches). Mulgrave spans both the pole and mature stages of maturity with diameters ranging between 7-37 cm (3-15 inches).

The main species present included sugar maple, yellow birch, white ash, white birch, and red maple[2]. Tupper Lake, Mulgrave, Upper Bass River and Berichan are growing on an ecosite AC13, while Belmont Mountain and Clearwater Intersection are growing on an ecosite AC10 (Table 1).

Table 1. Crop Tree Release Trials

Location, County	Stand #	Year Initiated	Maturity/ Dbh Range, cm (inches)	HT when treated	Treatments*	Forest Ecosystem Classification (FEC)** Veg. Type	Soil Type	Eco-site	Planning LC
Tupper Lk., Queens Co	0426	2004	Pole 3-10 cm (1-4”)	9m	CTR PCT CON	TH3	ST2	AC13	3.00
Belmont Mtn., Colchester Co	0501	2005	Pole 7-15 cm (3-6”)	11m	CTR PCT CON	TH2	ST2	AC10	2.75
Clearwater Int., Hants Co.	0502	2005	Pole 7-15 cm (3-6”)	13m	CTR PCT CON	TH2	ST2	AC10	2.75
Mulgrave, Guysborough Co.	0601	2006	Pole-Mature 7-37 cm (3-15”)	16m	CTR CON	TH3	ST8***	AC13	3.00
Upper Bass River, (Fig. 3) Colchester Co	0101	2001	Mature 15-37 cm (6-15”)	16m	CTR CON	TH1	ST2L	AC13	3.00
Berichan, Colchester Co.	0301	2003	Mature 18-35 cm (7-14”)	19m	CTR CON	TH3	ST8	AC13	3.00

*CTR: Crop Tree Release, PCT: Pre-commercial Thinning, CON: Un-treated Control.
**Forest Ecosystem Classification (Neily *et al*. 2013).
***Mulgrave: ST8 with inclusions of ST2L

Vegetation Type (refers to the vegetation type potential of the sites; Tupper Lk. is presently an IH6 but has the potential to become a TH3).
TH1: Sugar maple/ Hay-scented fern.
TH2: Sugar maple/ New York fern – Northern beech fern.
TH3: Sugar maple – White ash/ Christmas fern.

Soil Type
ST2: Fresh – medium to coarse textured (L= loamy phase)
ST8: Rich fresh – medium to coarse textured

Ecosite
AC10: Fresh moisture regime – Medium fertility
AC13: Fresh moisture regime – Rich fertility

Planning LC: Land Capability (m^3/ha/yr)

[2]white birch (*Betula papyifera* Marsh.), red maple (*Acer rubrum* L.)

Figure 3. The photos show trees that were crop tree released at Upper Bass River. The photos were taken in 2017 (16 years after crop tree release).

Results

The trees at all trials were measured for Dbh, condition and crown characteristics. In addition, pole sized stands were measured for branching characteristics. Data were examined to compare the diameter growth rates, basal area growth rates, and tree quality between crop tree released, pre-commercial thinned and un-thinned control trees. See appendix 1 for additional data.

The dead, damaged or unhealthy trees were eliminated from the data set for the analysis portion of this report (pages 5-17), see page 18 and appendix 1 for information related to mortality and damages.

<u>Diameter Growth</u>
<u>Sugar Maple</u>

Figure 4 compares the differences in diameter growth resulting from the different treatments (CTR, PCT, Control) after 5 years and 10 years. Sugar maple has the greatest sample size with 312 CTR trees, 149 Control trees, and 94 PCT trees. The average diameter growth for this species across all six sites for control trees was 2.1 cm, while paired CTR trees grew 3.9 cm over the first 10-year period after release. This amounts to an increase of 86% in Dbh growth and a reduction in the time to grow an inch in Dbh from 12 to 7 years.

PCT was performed on a subset of sites including Tupper Lake, Belmont Mountain, and Clearwater Intersection. On these three sites, control trees grew on average 2.4 cm, PCT 3.9 cm, and CTR 4.5 cm over the first 10-year period after release. An average increase of 63% was realized for PCT and 88% for CTR relative to controls.

Tupper Lake was the only site where PCT'ed trees out-performed CTR, this could be explained by this stand's young age and high initial density (15,200 stems/ha) compared to the other stands (Belmont Mt.=5,400 stems/ha, Clearwater Int.=3,850 stems/ha). Tupper Lake was the youngest, densest stand initially, therefore the PCT treatment resulted in a greater relative release due to the removal of a larger number of trees when compared to the older less dense stands.

All sites responded to the crop tree release treatment with increased Dbh growth relative to controls. The richer TH3 (Sugar maple - White ash / Christmas fern) stands growing on ST8 soils (Rich fresh – medium to coarse textured) showed superior growth relative to their controls (Mulgrave 156%, Berichan 76%).

Yellow Birch

Sufficient numbers of yellow birch trees occurred at Tupper Lake and Clearwater Intersection to compare diameter growth rates between the different treatments. There are 52 Control, 38 PCT, and 47 CTR yellow birch trees (Figure 4). The trends for yellow birch are similar to that of sugar maple, but growth rates are greater (Table 2). Yellow birch control trees averaged 3.0 cm, PCT 5.2 cm, and CTR 5.9 cm growth over the first 10-year period after release, while sugar maple control trees averaged 2.5 cm, PCT 4.6 cm, and CTR 5.0 cm. For yellow birch, an average increase of 97% was realized for CTR and 73% for PCT trees relative to controls across the two sites.

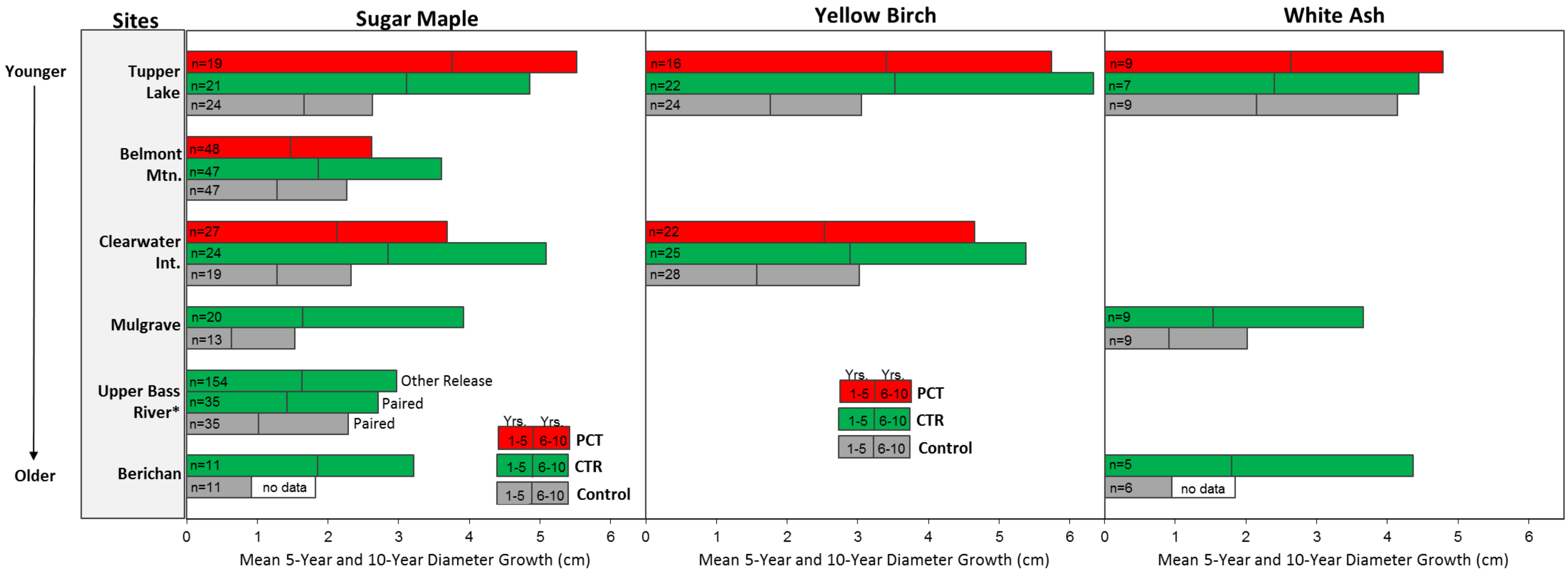

Figure 4. Comparing the diameter growth resulting from different treatments (pre-commercial thinning (PCT), crop tree release (CTR), and control) at different stages of maturity across a range of tolerant hardwood sites in Nova Scotia. Graphs show 5-year and 10-year post-treatment results for sugar maple, yellow birch and white ash. The sites are organized from youngest to oldest starting from the top (n=sample size).

*Upper Bass River: "Paired" CTR and Control contain trees of similar size and condition that were selected for comparison. "Other Release" contains additional trees that were crop tree released at this location, but no controls were paired with these trees (does not include paired trees).

Table 2. The 10-year post-treatment diameter growth following CTR and PCT for sugar maple and yellow birch at Tupper Lake and Clearwater Intersection.

	Diameter Growth (cm/10 years)					
	Tupper Lake		Clearwater Int.		Average	
	Sugar Maple	Yellow Birch	Sugar Maple	Yellow Birch	Sugar Maple	Yellow Birch
Control	2.6	3.1	2.3	3.0	2.5	3.0
Pre-Commercial Thin	5.5	5.7	3.7	4.7	4.6	5.2
Crop Tree Release	4.9	6.3	5.1	5.4	5.0	5.9

White Ash

There were few white ash trees on the trial sites (24 Control, 9 PCT, and 21 CTR). At the younger Tupper Lake site, the control white ash trees are growing well without treatment (4.1 cm/10 years) so there was not much gained by treating them (PCT=4.8 cm/10 years, CTR=4.4 cm/10 years) (Figure 4 and Table 3). Across the subset of sites that contain white ash (Tupper Lake, Mulgrave, and Berichan), the control white ash trees averaged 2.7 cm/10 years compared to 4.2 cm/10 years for CTR which is an increase of 56%.

Table 3. The 10-year post-treatment diameter growth following CTR and PCT for sugar maple and white ash at Tupper Lake, Mulgrave, and Berichan.

	Diameter Growth (cm/10 years)							
	Tupper Lake		Mulgrave		Berichan		Average	
	Sugar maple	White Ash	Sugar Maple	White Ash	Sugar Maple	White Ash	Sugar Maple	White Ash
Control	2.6	4.1	1.5	2.0	1.8	1.9	2.0	2.7
Pre-Commercial Thin	5.5	4.8	-	-	-	-	-	-
Crop Tree Release	4.9	4.4	3.9	3.7	3.2	4.4	4.0	4.2

Diameter Growth (individual trees by site)
Sugar Maple

Figure 5 shows the diameter growth by site based on the tree's initial diameter. Tupper Lake, Belmont Mountain and Clearwater Intersection were pre-commercial thinned (Figure 5 a,b,c). In all cases both PCT and CTR were superior to controls and for the most part CTR showed superior diameter growth compared to PCT. Tupper Lake was the only site where PCT'ed trees out-performed CTR (Figure 5a). Unfortunately, PCT'ed trees at Tupper Lake had more branch retention and adventitious twig sprouting (Figure 13) compared to CTR trees presumably because of more light penetration in the PCT treatment.

At Clearwater Intersection the mid-sized trees are growing the best. The smaller trees are likely suppressed and do not respond as well and the larger trees are already dominant, therefore release results in a relatively smaller increase in diameter growth (Figure 5c).

Mulgrave is intermediate in age and spans the pole to mature stage of development. At Mulgrave the greatest diameter growth after CTR was achieved for trees with an initial diameter less than 16 cm (6 inches) (Figure 5d).

Upper Bass River was mature at the time of release and growing on a vegetation type TH1, which is a drier and less fertile tolerant hardwood site. These factors may explain the minimal difference between CTR and the unthinned control trees (Figure 5e).

Berichan was mature at the time of release and growing on a vegetation type TH3, which is a fresh to moist nutrient rich tolerant hardwood site. At this site increased growth rates were maintained for CTR trees in excess of 20 cm (8 inches). The site richness may explain the maintenance of growth of the larger diameter trees despite being older. Caution should be used when interpreting the results for this site as there is a limited sample size and only 5 years of data for controls (Figure 5f).

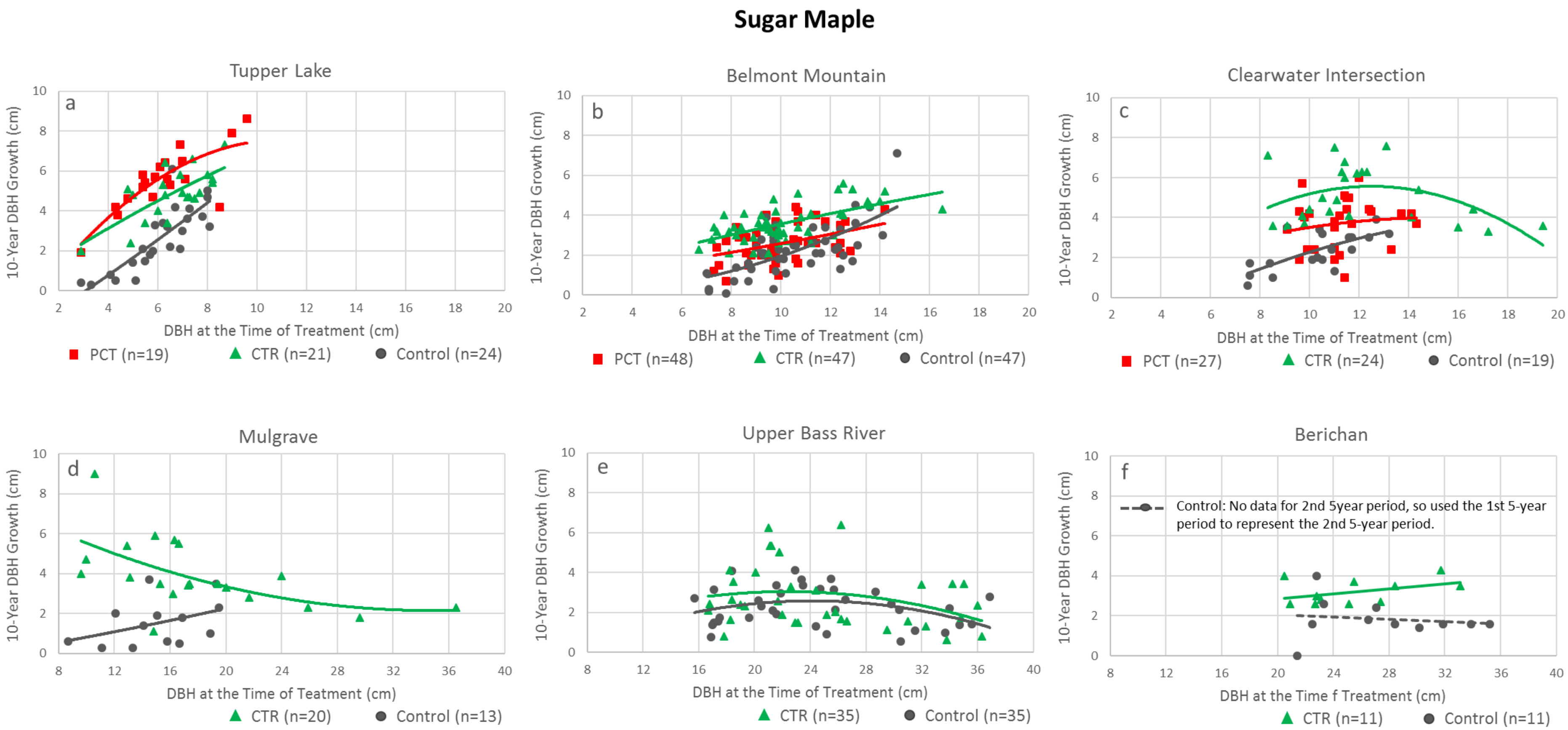

Figure 5. Comparing the 10-year diameter growth in relation to the tree's initial diameter when released. The graph shows the response of sugar maple to three treatments (pre-commercial thinning (PCT), crop tree release (CTR), and control) at Tupper Lake (a), Belmont Mountain (b), Clearwater Intersection (c), Mulgrave (d), Upper Bass River (e), and Berichan (f).
Sites are arranged from youngest to oldest top left to right (n=sample size).

Yellow Birch

Figure 6 shows the diameter growth rates for yellow birch in relation to a tree's initial diameter at the time of release at Tupper Lake (a) and Clearwater Intersection (b). At both sites CTR and PCT were superior to controls in terms of diameter growth and CTR yellow birch showed slightly better diameter growth compared to PCT.

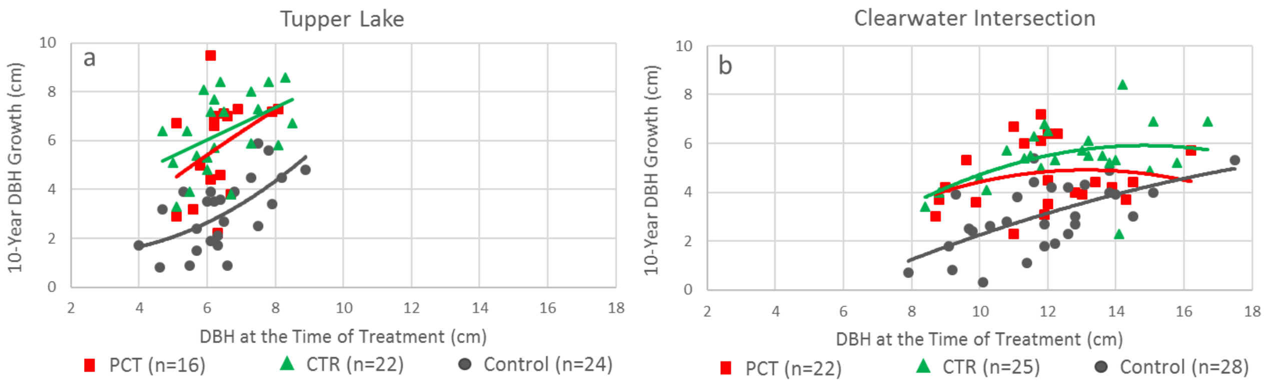

Figure 6. Comparing the 10-year diameter growth in relation to the tree's initial diameter when released. The graph shows the response of yellow birch to three treatments (pre-commercial thinning (PCT), crop tree release (CTR), and control) at Tupper Lake (a), and Clearwater Intersection (b). Sites are arranged from youngest to oldest left to right (n=sample size).

White Ash

Figure 7 shows the diameter growth rates for white ash in relation to a tree's initial diameter at the time of release at Tupper Lake (a), Mulgrave (b), and Berichan (c). Across the range of sites and diameters, trees that were CTR show superior diameter growth compared to controls. At Tupper Lake (Figure 7a), the magnitude of gains of the CTR trees over controls is not as great as with the other species (sugar maple Figure 5a) (yellow birch Figure 6a). White ash tends to grow fast when it is young regardless of release. At Mulgrave and Berichan, the growth of the CTR white ash trees averaged approximately 4 cm/10 years across the range of diameters (12-28 cm), and the average growth of controls was 2 cm/10 years (Figure 7 b,c). Caution should be used when interpreting the white ash results as there is a limited sample size (Figure 7 a,b,c).

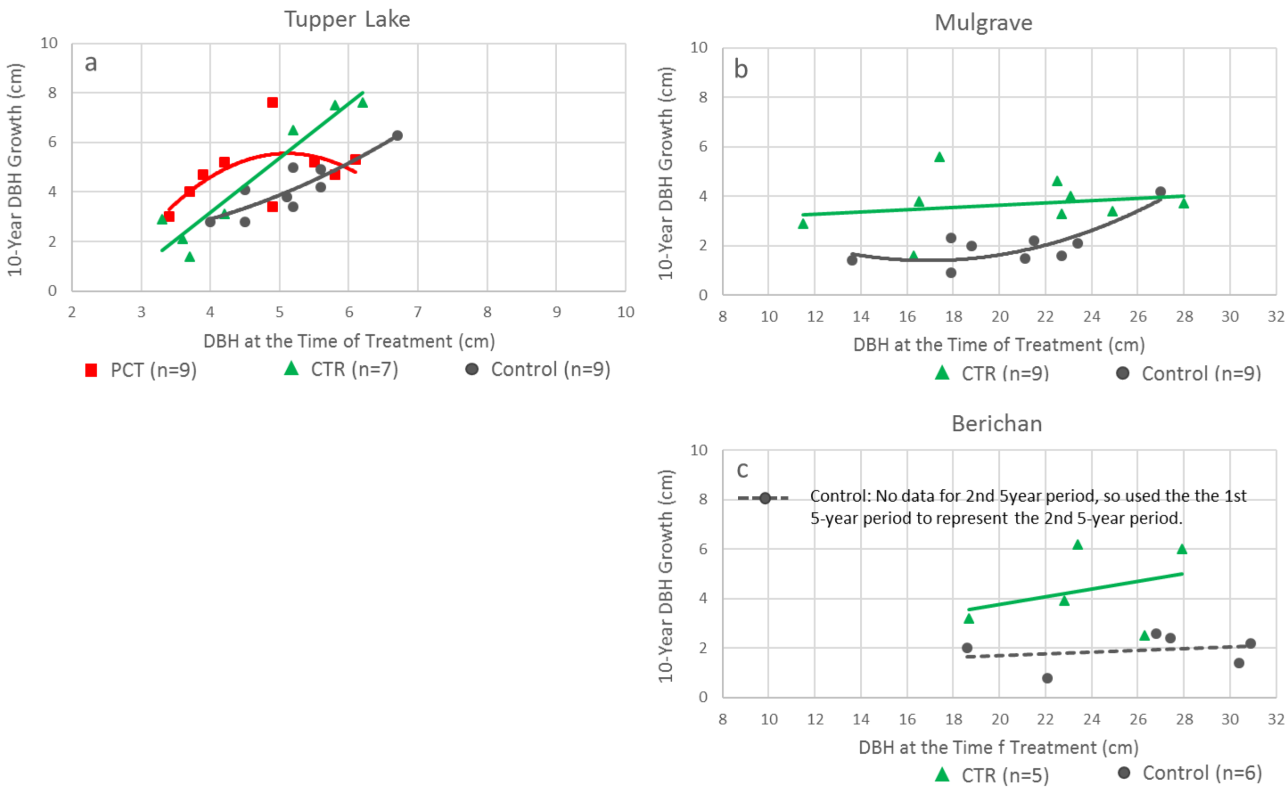

Figure 7. Comparing the 10-year diameter growth in relation to the tree's initial diameter when released. The graph shows the response of white ash to three treatments (pre-commercial thinning (PCT), crop tree release (CTR), and control) at Tupper Lake (a), Mulgrave (b), and Berichan (c) (n=sample size).

Basal Area Growth

In addition to diameter growth, basal area growth was analyzed as it provides another measure of growth that reflects the amount of fibre produced, particularly by larger trees. For example, to produce an equivalent diameter increment a larger tree has to produce significantly more wood than a smaller tree (Figure 8)

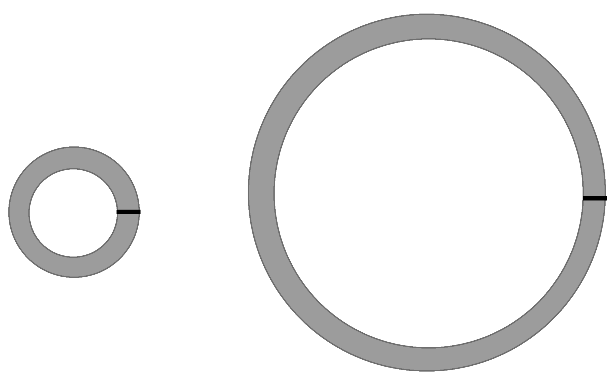

Figure 8. Comparing the difference in basal area produced (shaded region) between small and large trees for an equivalent diameter increment. —

On average trees that received a CTR or PCT treatments had more basal area growth compared to controls (Figure 9). The average basal area growth for sugar maple across all six sites for control trees was 56 cm^2, while CTR trees grew 104 cm^2 over the first 10-year period after release. This amounts to an increase of 86% in basal area growth. The older sites which had larger trees produced more basal area.

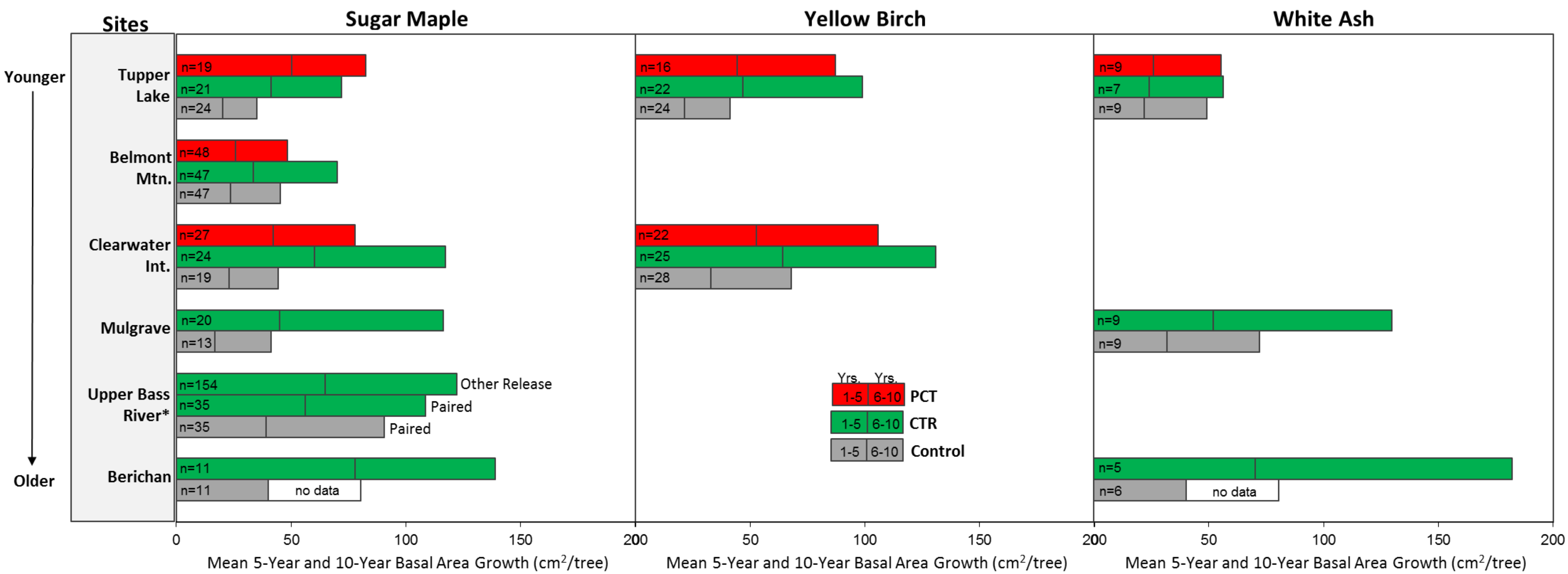

Figure 9. Comparing the basal area growth per tree resulting from different treatments (pre-commercial thinning (PCT), crop tree release (CTR), and control) at different stages of maturity across a range of tolerant hardwood sites in Nova Scotia. Graphs show 5-year and 10-year post-treatment results for sugar maple, yellow birch and white ash. The sites are organized from youngest to oldest starting from the top (n=sample size).

*Upper Bass River: "Paired" CTR and Control contain trees of similar size and condition that were selected for comparison. "Other Release" contains additional trees that were crop tree released at this location, but no controls were paired with these trees (does not include paired trees).

Growth Related to Initial Diameter

CTR and PCT treatments both show greater diameter and basal area growth relative to controls across the range of initial diameters (Figure 10 and Figure 11). Younger trees with smaller initial diameters had greater diameter growth rates after crop tree release compared to older larger trees (Figure 10). However, basal area growth tended to increase with initial diameter (Figure 11).

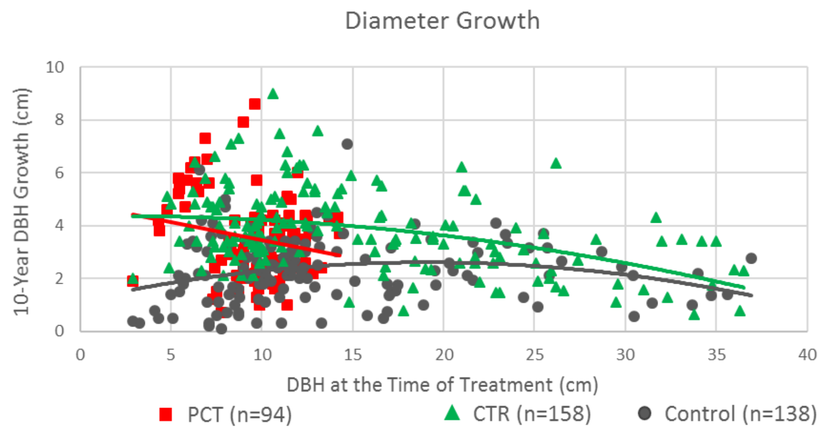

Figure 10. Comparing the 10-year diameter growth in relation to the tree's initial diameter when released. The graph shows the response of sugar maple to three treatments (pre-commercial thinning (PCT), crop tree release (CTR), and control) across a range of tolerant hardwood sites (6 sites) in Nova Scotia.
(n=sample size)

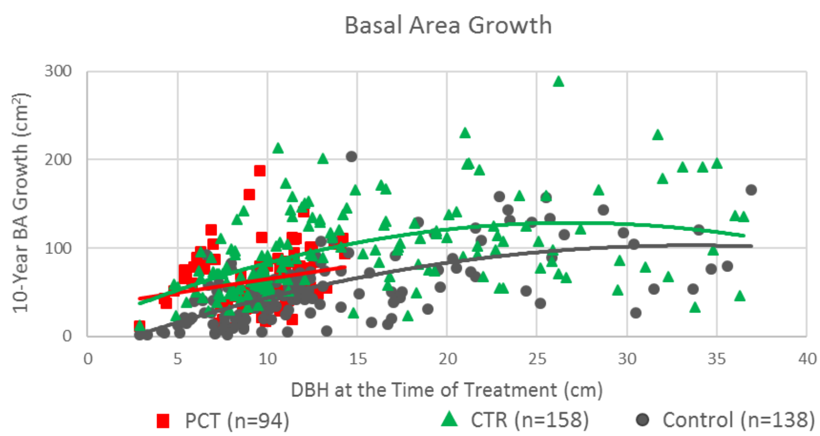

Figure 11. Comparing the 10-year basal area growth in relation to the tree's initial diameter when released. The graph shows the response of sugar maple to three treatments (pre-commercial thinning (PCT), crop tree release (CTR), and control) across a range of tolerant hardwood sites (6 sites) in Nova Scotia.
(n=sample size)

Table 4 shows the number of years it would take to grow an inch in diameter or 50cm^2 of basal area based on the tree's initial diameter at the time of CTR. A sugar maple tree that is 20 cm (8 inches) at the time of CTR takes 7 years to grow an inch compared to 10 years if it was not treated, and 5 years to grow 50cm^2 compared to 7 years if it was not treated; that is approximately 1/3 less time.

Table 4. The effect of the tree's initial DBH at the time of release on diameter and basal area growth of sugar maple. Comparing crop tree release (CTR) versus no treatment (Control) using the trendlines from Figures 10 and 11. This table assumes the release is maintained over the entire period.

	Diameter				**Basal Area**			
	Diameter Growth (cm/10 years)		**# Years to grow 1"**		**Basal Area (cm^2/10 years)**		**# Years to grow 50cm^2**	
Initial DBH	Control	CTR	Control	CTR	Control	CTR	Control	CTR
5 cm	1.8	4.3	14	6	15	52	34	10
10 cm	2.3	4.2	11	6	44	83	12	7
15 cm	2.6	4.0	10	7	66	106	8	5
20 cm	2.6	3.6	10	7	83	121	7	5
25 cm	2.5	3.2	10	8	95	128	6	4
30 cm	2.2	2.6	12	10	102	127	5	4
35 cm	1.6	1.9	16	13	103	118	5	5

<u>Quality</u>

Superior growth can be achieved when trees are released at a young age; however, this can adversely affect product quality, especially in hardwoods. Trees that are released too early, before they've had a chance to self-prune, tend to retain more branches and twigs for a longer period of time which in turn can reduce quality. A prior report (Nicholson *et al*., 2010) investigated this topic but with the focus on pre-commercially thinned hardwood stands in Nova Scotia. The same assessment procedures for quality were used in this report; where the following features were used as indicators of quality (Figure 12).

- The number of live branches within the first 5m (16 ft) section.

- The number of dead branches within the first 5m (16 ft) section.

- The number of live adventitious twigs[3] within the first 5m (16 ft) section.

- The height of the lowest live branch wherever it occurs (could be greater than 5m).

The first 5m (16ft) section of the stem is the focus as this area usually contains the most suitable portion of the tree for sawn products.

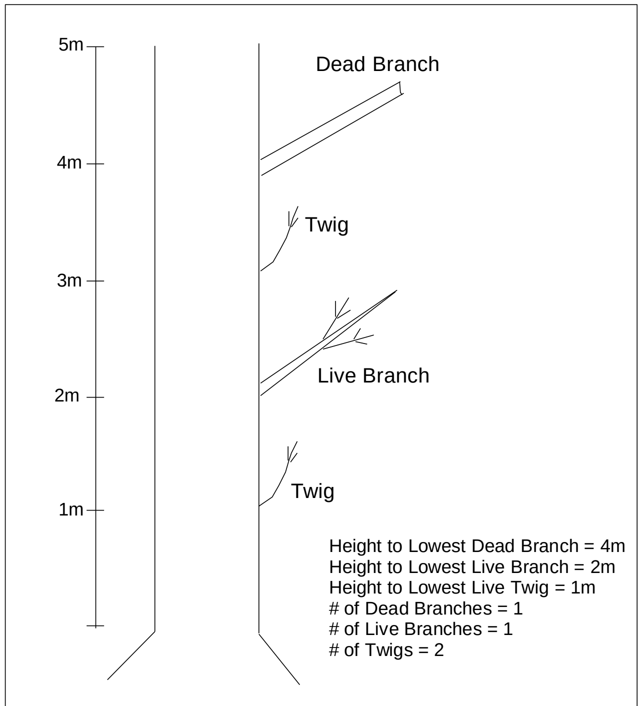

Figure 12. Sketch showing the features used to assess/quantify quality.

Figure 13 shows the effect of CTR and PCT treatments on sugar maple branching at various stages in stand development. The CTR treatment has little to no impact on branching across the range of sites, even on the younger sites. At Tupper Lake the PCT treatment appears to affect quality as trees that were PCT'ed have more branches, slightly more twigs, and have less clear bole compared to the CTR and controls (Figure 13 a,b,c)(Table 5). More shade is presumably being kept on the CTR trees which reduces branch retention and twig sprouting when compared to the PCT treatment (Figure 13a,c).

Twig development spiked 5 years after release but quickly died back by year 10. This phenomenon appears to be common when sugar maple is released as it was observed at three sites (Tupper Lake, Belmont Mtn., and Clearwater Int.) for both release treatments (PCT, and CTR) (Figure 13 c,f,i). Twig flushing in this study was not considered a long-term quality issue as twig numbers reverted back to near pre-treatment levels within 10 years.

[3] *Adventitious twigs are small branches originating from dormant buds on the stem of a tree. They are defined as being 1 cm (3/8 inch) or less in diameter, once they reach a diameter greater than 1 cm (3/8 inch) they are tallied as branches (Calvert and Petro 1993).*

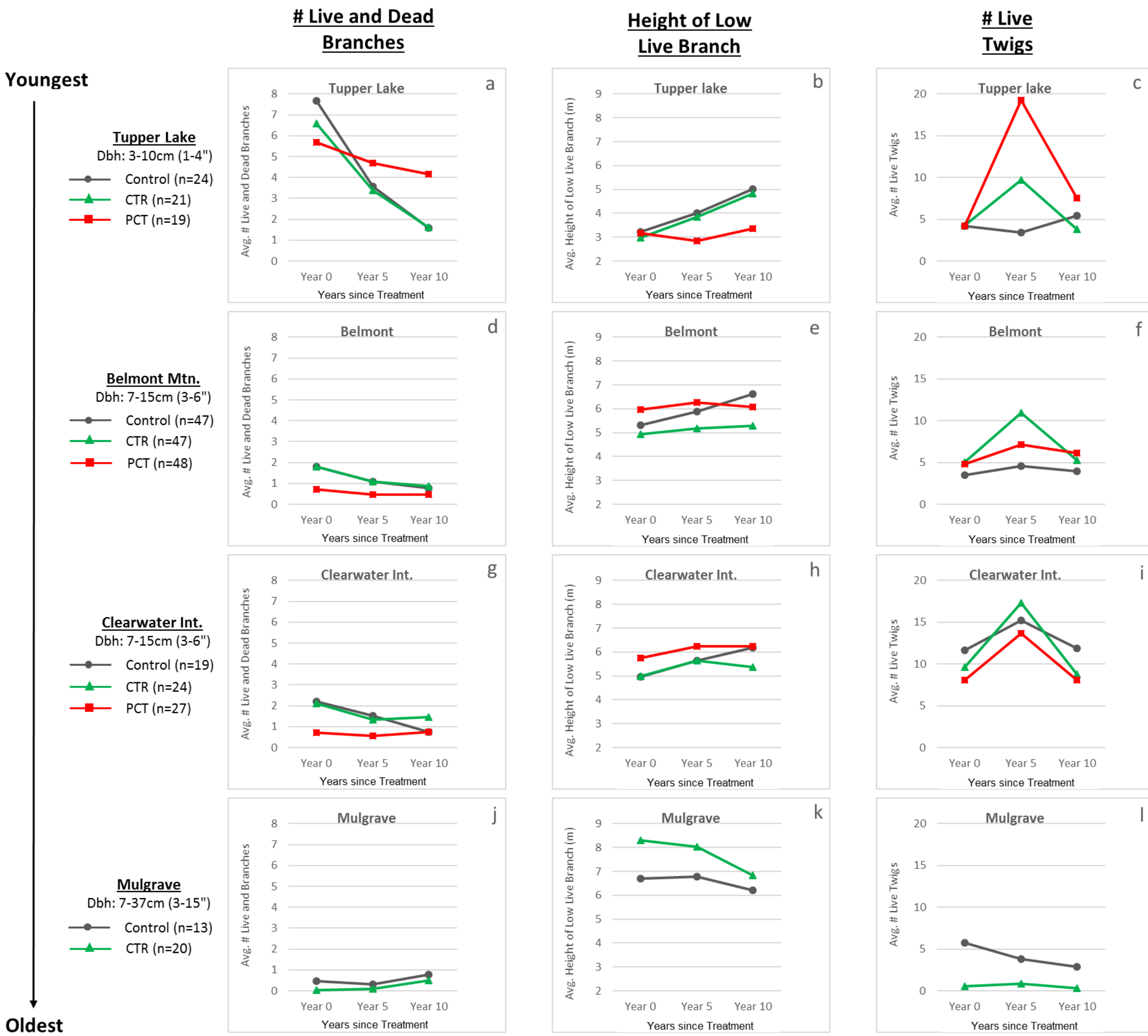

Figure 13. The number of live and dead branches, the height of the lowest live branch, and the number of live twigs on sugar maple after crop tree release (CTR), pre-commercial thinning (PCT), or leaving untreated (control) at four sites (Tupper Lake, Belmont Mountain, Clearwater Intersection, and Mulgrave). The sites are organized from youngest to oldest starting from the top. n=sample size.

Tupper Lake a,b,c: Trees were between 3-10cm (1-4") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Belmont Mountain d,e,f: Trees were between 7-15cm (3-6") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Clearwater Int. g,h,i: Trees were between 7-15cm (3-6") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Mulgrave j,k,l: Trees were between 7-37cm (3-15") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.

Table 5. Comparing the effect of different treatments (Control, CTR, PCT) on sugar maple tree quality. The results are 10-years post-treatment at four different site (Tupper Lake, Belmont Mountain, Clearwater Intersection, and Mulgrave).

	# Live and Dead Branches			**Height of Lowest Live Branch (m)**			**# Live Twigs**		
Location	Con.	CTR	PCT	Con.	CTR	PCT	Con.	CTR	PCT
Tupper Lake	1.6	1.6	4.2	5.0	4.8	3.4	5.4	3.8	7.5
Belmont Mtn.	0.8	0.9	0.5	6.6	5.3	6.1	4.0	5.3	6.2
Clearwater Int.	0.7	1.5	0.7	6.2	5.4	6.2	11.8	8.8	8.1
Mulgrave	0.8	0.5		6.2	6.8		2.8	0.4	

The PCT treatment when applied at Belmont Mtn., and Clearwater Int. had little to no impact on quality when compared to controls (Table 5). The PCT treatment when applied in the shortest, youngest stand (Tupper Lake) appears to affect quality in the short-term (10 years); however, longer-term studies (Nicholson *et al.* 2010) show that quality indicators tend to reach acceptable levels over time prior to the trees reaching sawlog size.

See appendix 2 for additional quality and growth related results with graphs showing trends over time at each individual site by species (sugar maple, yellow birch, white ash).

<u>Mortality/Damages</u>

Figure 14 shows the mortality and lists the damages that occurred at each site, by treatment and species.

<u>Tupper Lake</u>

Damage/mortality sustained at Tupper Lake was mainly due to porcupine (Erethizon dorsatum) feeding. Porcupine severely damaged and killed 21% of the sugar maple, and none of the yellow birch and white ash, in the pre-commercially thinned area. No trees were damaged by porcupine in the control or CTR areas.

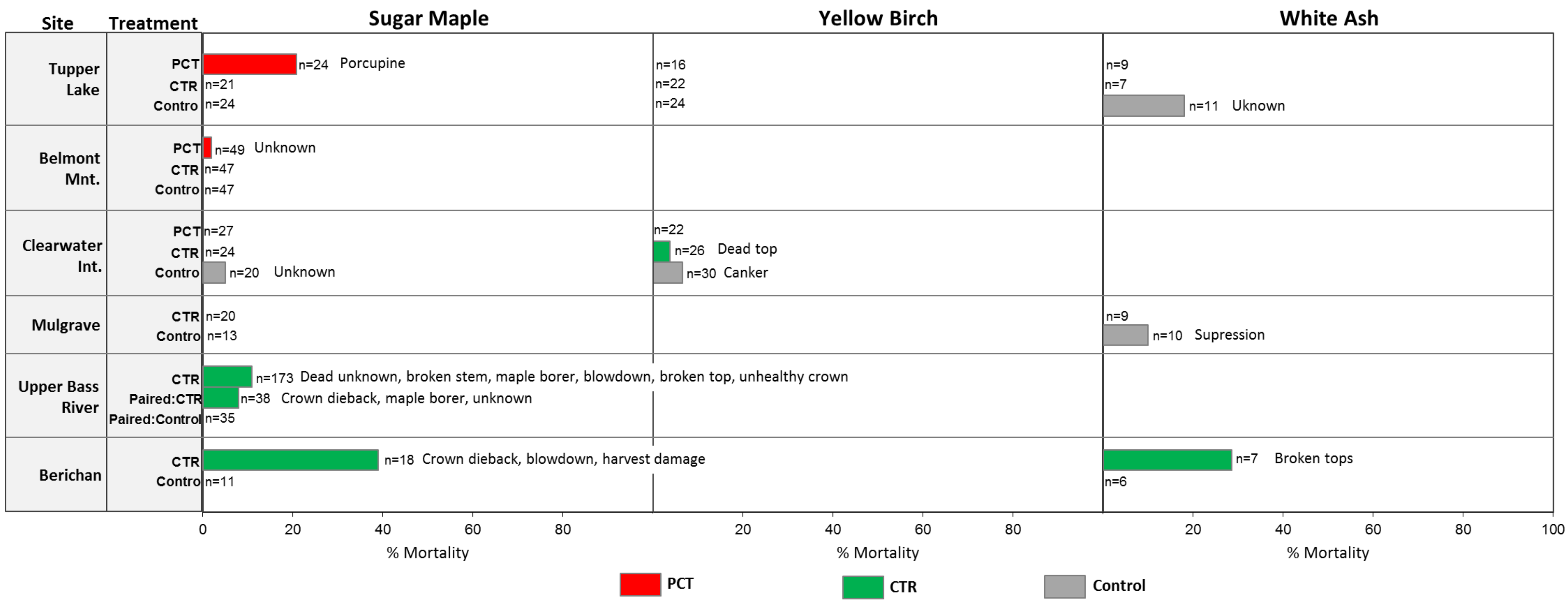

Figure 14. The mortality at each site by treatment (pre-commercial thinning (PCT), crop tree release (CTR), and control) and species. The graph shows the 10-year post-treatment results for sugar maple, yellow birch, and white ash. Sugar maple was present at all six sites. Yellow birch was present at Tupper Lake and Clearwater Intersection. White ash was present at Tupper Lake, Mulgrave, and Berichan. The sites are organized from youngest to oldest starting from the top. Reasons for the mortality are listed in order of frequency following the trend bar (n=total number of trees at the beginning of the trial prior to mortality).

Upper Bass River – Paired CTR/Control

Ten years after treatment, 8% (3 of 38) of the paired CTR trees had died for various reasons; crown dieback (1), maple borer (1), and unknown (1). No trees incurred harvesting damage. Harvesting damage penalties were included in the harvesting contract.

Upper Bass River – CTR

An additional 173 trees were crop tree released at Upper Bass River, but no controls were paired with these trees. 11% (19 of 173) of CTR trees died for various reasons listed in order of frequency; dead unknown (6), broken stem (4), maple borer (3), blowdown (2), broken top (2), unhealthy crown (2). It was observed that sugar maple trees that were excessively exposed during crop tree release or had small crown initially (<1/3 live crown) were susceptible to damage. This draws attention to the damage that can occur when either releasing inappropriate trees or excessively exposing trees.

Berichan

39% (7 of 18) of CTR sugar maple trees were dead 10 years after release. 5 trees had severe crown dieback, one tree was uprooted after five years, and one tree had severe stem damage due to harvesting. 29% (2 of 7) of CTR white ash trees were dead 10 years after release due to broken tops. It was observed that released white ash were especially susceptible to crown damage when forked tops occurred in the crown. It should be noted that Berichan and Upper Bass River were battered by hurricane Juan and a severe winter storm referred to as "White Juan" during late 2003 and early 2004 after treatment.

Summary

- **Crop Tree Release (CTR)**: Across all sites, CTR resulted in an 86% increase in diameter growth for sugar maple which translates into a reduction in the time to grow an inch in Dbh from 12 to 7 years (Avg. from 6 sites: Control=2.1 cm/10 years, CTR=3.9 cm/10 years).

- **Pre-Commercial Thinning (PCT)**: CTR diameter growth rates (88%) were generally greater than PCT growth (63%), except at the youngest site (Avg. from 3 sites: Control=2.4 cm/10 years, PCT=3.9 cm/10 years, CTR=4.5 cm/10 years).

- **Site Richness**: There tended to be greater response to release in the stands growing on richer sites.

- **Yellow Birch**: For pole sized stands (3-15 cm), the trends for yellow birch and sugar maple were similar, but growth rates for yellow birch were slightly greater over the first 10-year period after release.

- Yellow birch: Control 3.0 cm, PCT 5.2 cm, and CTR 5.9 cm
- Sugar maple: Control 2.5 cm, PCT 4.6 cm, and CTR 5.0 cm

- **Basal Area**: The average basal area growth for sugar maple across all six sites for control trees was 56 cm^2, while CTR trees grew 104 cm^2 over the first 10-year period after release. This amounts to an increase of 86% in basal area growth.

- **Reduction in Time**: A sugar maple tree that is 20 cm (8 inches) at the time of crop tree release takes 7 years to grow an inch compared to 10 years if it was not treated. (average of all 20 cm dbh trees across all the sites).

- **Quality - CTR:** Comparing the CTR treatment to the corresponding controls shows little to no difference in quality across the range of sites.

- **Quality – PCT:** The PCT treatment when applied in the older stands (Belmont Mtn., Clearwater Int.) has little to no impact on quality when compared to controls. The PCT treatment when applied in the youngest stand (Table 6: Tupper Lake) appears to affect quality in the short-term. Ten years after release, trees that were pre-commercial thinned have significantly more branches, slightly more twigs, and have less clear bole compared to the CTR and controls. It will have to be tracked longer to determine the long-term effects on quality.

Table 6. Location: Tupper Lake

	Sugar Maple		
10 Years Post-Treatment	# Branches (live+dead)	# Twigs (live)	HT. to Low Live Branch (m)
Control	1.6	5.4	5.0
Crop Tree Release	1.6	3.8	4.8
Pre-Commercial Thin	4.2	7.5	3.4

- **Twigs**: Five years after the release (CTR and PCT) of sugar maple, twig development spiked but quickly died back. This phenomenon appears to be common when sugar maple is released as it was observed at the three youngest sites. Twig flushing in this study was not considered a long-term quality issue as twig numbers reverted back to near pre-treatment levels within 10 years.

- **Risks – Sugar Maple**: On mature sites, 13% (29 of 229 trees) of crop tree released sugar maple trees were dead 10 years after release for various reasons including crown dieback, maple borer, broken stems and tops, blowdown, and unknown. It was observed that sugar maple trees that were excessively exposed during crop tree release or had small crown initially (<1/3 live crown) were susceptible to damage.

This draws attention to the damage that can occur when either releasing inappropriate trees or excessively exposing trees.

- **Risks – Sugar Maple – Maple Borer:** At Upper Bass River, maple borer damage was present in 21% (Incidence = 44/211 trees) of crop tree released trees and 2% died due to maple borer damage (Dead = 4/211 trees). This number could be larger as the exact cause of death in many cases was unknown. It is unclear whether the treatment increased the incidence of maple borer damage or it would have been present regardless, this is worth further investigation.

- **Risks – White Ash**: It was observed that crop tree released white ash trees were especially susceptible to crown damage when forked tops occurred in the crown.

Value
Hardwood logs are some of the most valuable forest products we can grow in Nova Scotia. A tree must have adequate quality and must reach a minimum size before it qualifies as either a veneer or sawlog. Sugar maple, yellow and white birch, white ash, red oak, and red maple are most valuable. While white birch and red maple can achieve sawlog specifications they are less likely because of shorter life spans and susceptibility to rot. As illustrated in Figure 15, cutting a sugar maple tree that has veneer potential before it reaches the minimum size requirement significantly reduces the value.

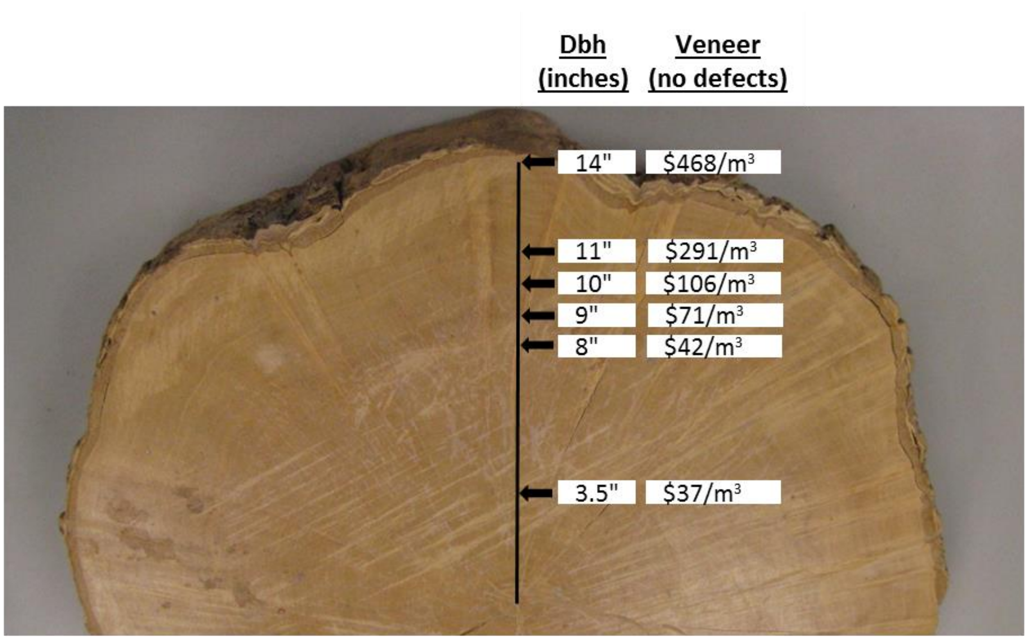

Figure 15. Illustrates the value of a sugar maple tree with veneer potential at different stages. Values shown reflect pricing/specifications for Nova Scotia in June 2018 (roadside pricing). Minimum inside diameter for products: Pulp = 3.5", Pallet = 8", Sawlog Grade 2 = 9", Sawlog Grade 1 = 10", Sawlog Prime = 10", Veneer = 11", Veneer = 14".

If the quality is present, the transition from pulp to sawlog (better than pallet grade) doubles or triples the value (2-3X) and from pulp to veneer values can increase anywhere from 6-13X (Table 7). The goal of a CTR is to reduce the time it takes to reach the higher product size requirements without compromising quality.

Table 7. Shows how the value of sugar maple changes depending on the size, product and quality. Values shown reflect pricing/specifications for Nova Scotia in June 2018 (roadside pricing).

Min. Diameter (inside bark)		Veneer		Sawlogs				
inches	cm	No Defects (1/3 heart) ($/m³)	1 Defect (1/3 heart) ($/m³)	Prime ($/m³)	Grade 1 ($/m³)	Grade 2 ($/m³)	Pallet Grade 4 ($/m³)	Pulp ($/m³)
14”	36	468	291	106	88	71	42	37
11”	28	291	207	106	88	71	42	37
10”	25	106	106	106	88	71	42	37
9”	23	71	71	71	71	71	42	37
8”	20	42	42	42	42	42	42	37
3.5”	9	37	37	37	37	37	37	37

Conclusion

- Trees of all sizes (dbh range 3-37 cm) responded to crop tree release with increased diameter growth. On average, trees experienced an 86% increase in diameter growth relative to controls in the first 10 years following crop tree release across six different tolerant hardwood sites in Nova Scotia. The diameter growth response ranged from 19% - 156% depending on the site. The richer sites tended to show greater response.

- On average, the crop tree release treatment (88%) showed superior diameter growth when compared to pre-commercial thinning (64%) (Control=2.4 cm/10 years, PCT=3.9cm/10 years, CTR=4.5cm/10 years), except in the densest stand.

- Release in hardwood stands must be balanced against the impact the treatment will have on branching and future quality potential for sawlogs. The following features were used as indicators of quality (# of branches, the height of lowest live branch, and the # of twigs). Comparing the crop tree release treatment to the corresponding controls shows negligible difference in terms of quality across the range of sites, even at the youngest site (Tupper Lake).

- Pre-commercial thinning when applied in older stands (Belmont Mtn. 11m tall, Clearwater Int. 13m tall) had little to no impact on quality when compared to controls. The pre-commercial thinning treatment when applied in the youngest stand (Tupper Lake 9m tall) affects quality in the short-term. Ten years after release, trees that were pre-commercial thinned have more branches, slightly more twigs, and have less clear bole compared to the crop tree release and controls. However, longer-term studies (Nicholson *et al.* 2010) show that quality indicators tend to reach acceptable levels over time prior to the trees reaching sawlog size. It will have to be tracked longer to determine the long-term effects on quality.

- Crop tree release can be used to reduce the time it takes to grow a tree to sawlog and veneer size. High quality trees that are undersized presently yield only 1/2 the price of a log with the same quality that meets size specifications for sawlogs and 1/6 to 1/13 the price for veneer.

- The most advantageous time to crop tree release is when trees are 3-10 cm (1-4 inches) less than sawlog specifications. This produces the best return on investment by reducing the time it takes to reach the higher value products without carrying the investment for an extended period of time. A sugar maple tree that is 20 cm (8 inches) at the time of crop tree release takes 7 years to grow an inch compared to 10 years if it was not treated. At this point it is unknown how long beyond the first 10 year period the release is sustained.

- Crop tree release efforts should be concentrated on the richer sites as they are more likely to respond. Mature stands particularly require site richness to maintain the growth of the larger diameter trees.

- In mature stands, care should be taken not to over expose sugar maple trees during a crop tree release treatment as this species is prone to crown dieback. Sugar maple trees with small crowns (<1/3 live crown) should not be released as they are prone to dieback and won't respond adequately.

- White ash with forked tops should not be released as they are susceptible to splitting crowns.

Recommendations

- To identify situations where CTR is appropriate, refer to Nova Scotia's Forest Management Guide (McGrath 2018).

- Release trees that are between 10-25 cm (4-10 inches) in diameter. Trees should be healthy, free of defects in the butt log and self pruned for at least 3m (10 feet), but preferably 5m (16ft). Live crown ratio should be greater than 1/3. Usually these trees would be co-dominant or dominant in crown class. Trees smaller than 10 cm dbh (4 inches) are not recommended for release due to detrimental impacts on quality; such as increased branching and wind and ice damage. Releasing at this early stage also results in a longer time to carry treatment costs before return is realized.

- Release only high valued long lived species such as sugar maple, yellow birch, red oak and white ash. Release white ash with caution as they are susceptible to stem breakage if they contain forked tops.

- Released trees should be at least 6 m (20 feet) apart to give room to grow large enough to meet size specifications for high valued products. If two high quality trees occur next to each other, they can be released as if their combined crowns were one.

- Release only the highest quality trees with potential for high value sawlogs. Do not release poor quality stems (release 125 trees/hectare or 50/acre at maximum).

- Release trees on 4 sides by removing all trees with crowns touching the crown of the tree to be released.

- Avoid excessive exposure to crop trees to protect from die back, epicormic branching, uprooting and stem breakage. Do not release trees at the edge of cleared areas. Where extra precaution is desired, release on only 3 sides, leaving trees to protect the south facing side of crop trees.

- Do not clear all trees between crop trees. This will result in excessive exposure and reduced stocking. Un-released pockets within a treated stand provide protection for high quality released trees and a reservoir of potential replacement trees if some crop trees are damaged due to pest, storms or other causes. These un-released trees could also provide sources for low quality fibre if markets justify their removal.

- Crop tree release is primarily a release/tending operation. The trees that are cut surrounding the crop trees can be utilized, however every effort should be made to protect the crop trees. The objective of this treatment is to increase growth and vigor of the highest quality trees. Trees to be cut should be lower quality and can be left on-site after cutting. They will add to biodiversity by providing habitat and nutrients when left.

- Care must be taken when cutting trees around crop trees. Treatment objectives will not be met if potential value and growth of crop trees are reduced by damaging stems or crowns.

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Appendix 1. Summary of results by species and site

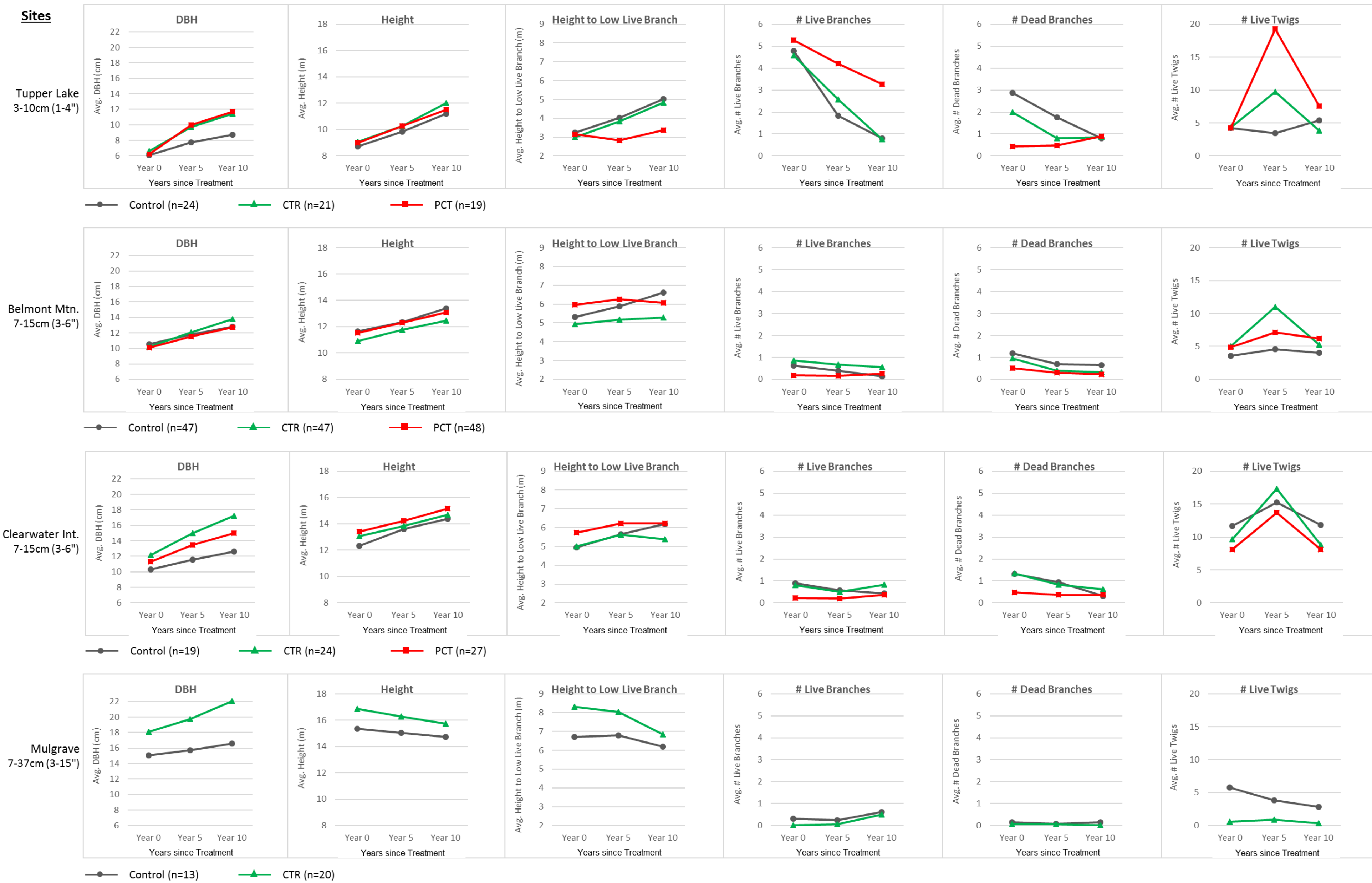
Species	Location	Stand #	Maturity when treated	DBH when treated (cm)	Yrs. Since treated	Stump Age	# Trees at the beginning			# Trees that Died (cumulative)[1]			Sample Size (dead/unhealthy trees removed)[2]			Density			Avg. Diameter (cm)			Avg. Height (m)			Avg. # of Live Branches			Avg. # of Dead Branches			Avg. # of Live Twigs			Avg. Ht of Lowest Live Branch (m)			Avg. Height of Crown (m)			Avg. Basal Area/Tree (cm^2/tree)		
							Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT	Control	CTR	PCT
Sugar Maple	Tupper	0426	Pole	3-10	0	24	24	21	24	-	-	-	24	21	19				6.1	6.6	6.2	8.7	9.1	9.0	4.8	4.6	5.3	2.9	2.0	0.4	4.2	4.3	4.2	3.2	3.0	3.2	4.2	4.6	4.0	31	36	32
	Lake				5	29				-	-	-	24	21	19	15,200		2,120	7.7	9.7	10.0	9.8	10.3	10.3	1.8	2.6	4.2	1.8	0.8	0.5	3.5	9.7	19.3	4.0	3.8	2.8	5.7	5.0	5.0	51	77	83
					10	34				-	-	5	24	21	19	12,200		2,120	8.7	11.4	11.7	11.2	12.0	11.5	0.8	0.8	3.3	0.8	0.9	0.9	5.4	3.8	7.5	5.0	4.8	3.4	6.6	6.6	5.2	66	108	115
	Belmont	0501	Pole	7-15	0	35	47	47	49	-	-	-	47	47	48	5,400		1,750	10.5	10.2	10.1	11.7	10.9	11.5	0.6	0.9	0.2	1.2	1.0	0.5	3.5	5.1	4.9	5.3	4.9	6.0	7.8	7.1	8.0	90	85	82
	Mountain				5	40				-	-	-	47	47	48	4,900		1,700	11.8	12.0	11.6	12.3	11.7	12.3	0.4	0.7	0.2	0.7	0.4	0.3	4.6	11.0	7.1	5.9	5.2	6.3	7.6	6.7	7.6	114	119	108
					10	45				-	-	1	47	47	48	3,400		1,650	12.8	13.8	12.7	13.4	12.4	13.1	0.1	0.6	0.3	0.7	0.3	0.2	4.0	5.3	6.2	6.6	5.3	6.1	7.8	6.7	7.5	135	155	130
	Clearwater	0502	Pole	7-15	0	30	20	24	27	-	-	-	19	24	27	3,850		1,150	10.3	12.2	11.3	12.3	13.1	13.4	0.9	0.8	0.2	1.3	1.3	0.5	11.6	9.7	8.1	5.0	5.0	5.7	7.6	8.2	8.7	86	122	102
	Intersection				5	35				-	-	-	19	24	27	3,350		1,100	11.6	15.0	13.5	13.6	13.9	14.2	0.6	0.5	0.2	0.9	0.8	0.4	15.2	17.3	13.7	5.6	5.6	6.2	7.4	7.3	8.2	109	182	144
					10	40				1	-	-	19	24	27	2,850		1,025	12.6	17.2	15.0	14.4	14.7	15.2	0.4	0.8	0.4	0.3	0.6	0.4	11.8	8.8	8.1	6.2	5.4	6.2	7.6	6.8	7.7	130	239	180
	Mulgrave	0601	Pole-	7-37	0		13	20		-	-		13	20					15.1	18.1		15.3	16.8		0.3	0.0		0.2	0.1		5.8	0.6		6.7	8.3		10.1	11.2		186	292	
			Mature		5					-	-		13	20					15.7	19.8		15.0	16.3		0.2	0.1		0.1	0.1		3.8	0.9		6.8	8.0		9.2	9.7		203	337	
					10					-	-		13	20					16.6	22.0		14.7	15.7		0.6	0.5		0.2	0.0		2.8	0.4		6.2	6.8		8.3	8.2		228	408	
	Upper Bass	0101	Mature	15-37	0		35	38		-	-		35	35					24.5	24.9		16.0	15.5																	500	515	
	River				4					-	-		35	35					25.3	26.0																				531	560	
	Paired Control and Release Trees				9					-	2		35	35					26.6	27.3																				582	612	
					14					-	3		35	35					27.4	28.7																				616	674	
	Upper Bass	0101	Mature	15-37	0			173						154						24.9																					504	
	River				5						1			154						26.5																					569	
	Release Trees Only				10						12			154						27.9																					627	
					15						19			154						29.3																					689	
	Berichan	0301	Mature	18-35	0		11	18		-	-		11	11					27.6	25.6		20.0	18.8														11.6	11.4		613	526	
					5					-	4		11	11					28.5	27.4		cut	18.8														cut	10.9		653	604	
					10					-	7		11	11					29.4 [3]	28.8		cut	18.8														cut	10.4		cut	665	
Yellow Birch	Tupper	0426	Pole	3-10	0	24	24	22	16	-	-	-	24	22	16				6.4	6.5	6.4	8.5	9.0	8.7	5.9	4.1	5.6	2.5	1.2	0.7	20.4	15.8	12.7	3.3	3.6	3.4	4.3	4.9	4.0	33	34	32
	Lake				5	29				-	-	-	24	22	16				8.2	10.0	9.8	10.4	10.8	10.2	1.3	1.9	5.4	1.3	0.9	0.5	8.8	5.8	4.3	4.5	4.3	3.2	5.9	5.7	4.5	55	81	77
					10	34				-	-	-	24	22	16				9.5	12.8	12.1	11.8	12.9	12.0	0.7	0.4	2.9	0.5	0.5	1.3	5.0	2.6	1.9	5.2	5.4	3.8	7.2	7.2	5.4	75	133	119
	Clearwater	0502	Pole	7-15	0	30	30	26	22	-	-	-	28	25	22				11.9	12.4	11.9	12.4	12.5	13.1	1.3	0.1	0.0	1.4	1.1	0.6	2.9	2.3	2.0	4.8	6.2	6.8	7.7	8.2	9.1	114	125	114
	Intersection				5	35				-	-	-	28	25	22				13.4	15.3	14.4	13.8	13.6	13.8	0.3	0.1	0.1	0.7	0.4	0.1	2.8	4.2	3.2	6.4	6.0	6.7	8.7	8.0	8.8	147	189	166
					10	40				2	1	-	28	25	22				14.9	17.8	16.5	15.1	14.8	15.0	0.1	0.6	0.5	0.4	0.2	0.0	3.3	1.3	1.5	7.5	5.4	5.9	9.1	7.5	7.7	182	256	219
White Ash	Tupper	0426	Pole	3-10	0	24	11	7	9	-	-	-	9	7	9				5.2	4.6	4.7	8.5	8.3	7.9	5.3	3.7	4.8	4.4	2.3	4.0	2.0	1.6	8.3	3.6	3.9	3.5	4.4	4.2	4.0	21	17	18
	Lake				5	29				1	-	-	9	7	9				7.3	7.0	7.3	10.5	9.3	9.2	0.9	1.6	2.3	2.4	1.0	1.6	0.0	1.3	1.4	5.0	4.4	4.1	6.2	5.3	4.8	43	41	44
					10	34				2	-	-	9	7	9				9.3	9.0	9.5	12.8	11.3	11.4	0.0	0.4	0.7	0.8	0.6	1.6	0.0	1.1	0.1	7.2	5.7	4.8	8.5	6.4	6.2	70	73	74
	Mulgrave	0601	Pole-	7-37	0		10	9		-	-		9	9					20.4	20.3		16.9	18.5		0.0	0.0		0.4	0.0		0.0	0.0		8.4	10.4		10.8	12.5		338	343	
			Mature		5					1	-		9	9					21.3	21.9		17.1	18.2		0.0	0.0		0.4	0.0		0.1	0.9		8.4	10.4		10.6	11.8		370	395	
					10					1	-		9	9					22.5	24.0		17.3	17.9		0.0	0.1		0.2	0.0		0.6	0.7		8.6	9.8		10.5	11.1		411	473	
	Berichan	0301	Mature	18-35	0		6	7		-	-		6	5					26.0	23.8		20.3	18.6														13.2	12.7		547	454	
					5					-	-		6	5					27.0	25.6		cut	18.9														cut	12.7		588	524	
					10					-	2		6	5					cut	28.2		cut	19.2														cut	12.7		cut	636	

[1]# Trees that died (cumulative): The mortality from the prior measurement is added on to the current. For example at Berichan/sugar maple/CTR: 0 trees died the first measurment period, 4 trees died the second measurement period, and 3 trees died the third measurement period for a total of 7 trees.

[2]Sample Size (dead/unhealthy trees removed): For analysis the dead and unhealthy trees were removed from the data set. The measurements that follow (avg. diameter, avg. height, avg. # live branches, ect..) are based on the sample size column.

[3]Berichan: Missing last diameter measurements for controls due to harvesting, so used the the 1st 5-year period to represent the 2nd 5-year period

Sugar Maple



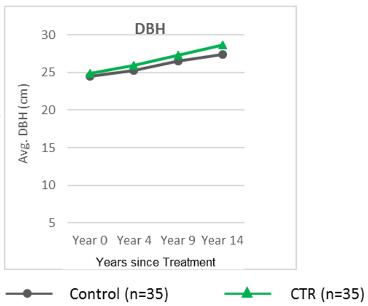
Appendix 2. Sugar Maple. The the diameter at breast height (DBH), the height, the height of the lowest live branch, the number of live branches, the number of dead branches, and the number of twigs on sugar maple after crop tree release (CTR), pre-commercial thinning (PCT), or leaving untreated (control) at four sites (Tupper Lake, Belmont Mountain, Clearwater Intersection, and Mulgrave).

Tupper Lake: Trees were between 3-10cm (1-4") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Belmont Mountain: Trees were between 7-15cm (3-6") diameter at the time of treatment (year 0), and 5 and 10 years after.
Clearwater Intersection: Trees were between 7-15cm (3-6") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Mulgrave: Trees were between 7-37cm (3-15") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.

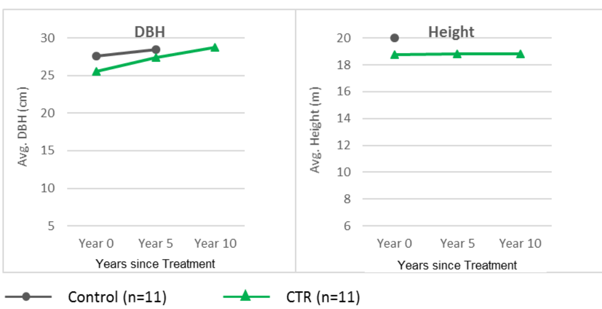
Sugar Maple

Sites

Up. Bass River
15-37cm (6-15")



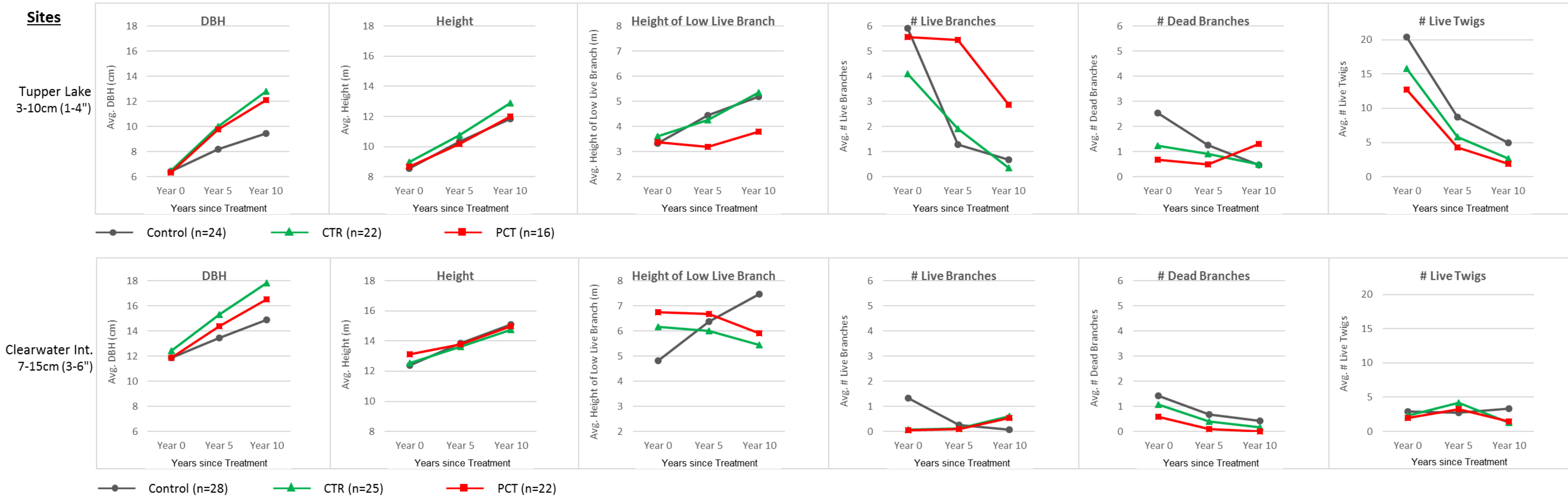
Berichan
18-35cm (7-14")



Appendix 2. Sugar Maple continued. The the diameter at breast height (DBH) and the height of sugar maple after crop tree release (CTR) or leaving untreated (control) at two sites (Upper Bass River, Berichan).

Upper Bass River: Trees were between 15-37cm (6-15") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Berichan: Trees were between 18-35cm (7-14") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.

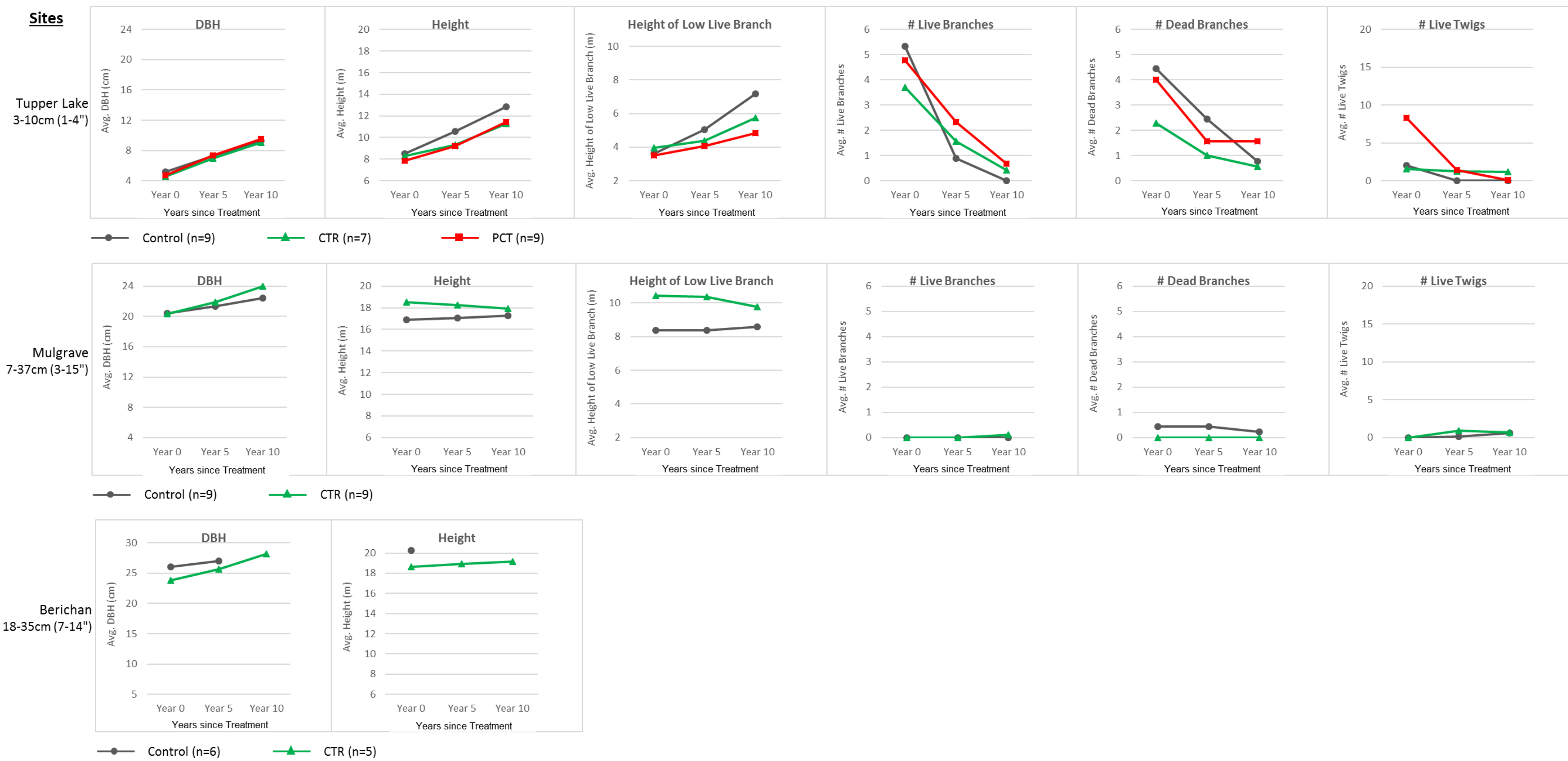
Yellow Birch



Appendix 2. Yellow Birch. The the diameter at breast height (DBH), the height, the height of the lowest live branch, the number of live branches, the number of dead branches, and the number of twigs on yellow birch after crop tree release (CTR), pre-commercial thinning (PCT), or leaving untreated (control) at two sites (Tupper Lake and Clearwater Intersection).

Tupper Lake: Trees were between 3-10cm (1-4") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Clearwater Intersection: Trees were between 7-15cm (3-6") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.

White Ash



Appendix 2. White Ash. The the diameter at breast height (DBH), the height, the height of the lowest live branch, the number of live branches, the number of dead branches, and the number of twigs on white ash after crop tree release (CTR), pre-commercial thinning (PCT), or leaving untreated (control) at three sites (Tupper Lake, Mulgrave, and Berichan).

Tupper Lake: Trees were between 3-10cm (1-4") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Mulgrave: Trees were between 7-37cm (3-15") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.
Berichan: Trees were between 18-35cm (7-14") diameter at the time of treatment. Sites were measured at the time of treatment (year 0), and 5 and 10 years after.