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Cover photo: Stand conditions after the final removal harvest using a feller buncher and grapple skidder.

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Abstract

Logging damage during a final removal cut in a red and white pine dominated stand was assessed. Logging was conducted using two different logging methods. A feller buncher and grapple skidder (mechanical logging) was used in a major part of the cut block and a chain saw harvest and cable skidder (conventional logging) was used in the remainder of the block. Damage to residual stems immediately after logging was significantly below the allowable standard of 15% of the residual tree basal area. The damage was 5.2% (±3.0) major damage to residual basal area from the mechanical logging operation and 1.4% (±1.4) major damage from the conventional logging system. Skid trail coverage for conventional logging was 29% of the total area, just below the accepted limit of 30%, while mechanical logging was over the limit at 39%. 20% of the established regeneration was lost during the logging operation; however, the residual stocking of spruce, pine and oak seedlings was above the minimum limit. Four years after harvest, the residual seedlings showed improved vigour as height and root collar diameters increased substantially.

Résumé

Nous avons examiné les dommages causés pendant une dernière coupe dans un peuplement dominé par des pins rouges et blancs. Deux méthodes de coupe avaient été utilisées pour la récolte : une abatteuse-groupeuse et un débardeur à pince (la méthode mécanique) dans une grande partie de la parcelle de coupe; une scie mécanique et un débardeur à câble (la méthode conventionnelle) dans le reste de la parcelle. Les dommages causés aux arbres laissés sur pied tout de suite après les travaux étaient d'un degré considérablement inférieur au degré admissible (15% de la surface terrière des arbres résiduels). Les dommages importants avaient représenté 5.2% (± 3) de la surface terrière pour la méthode mécanique et 1.4% (± 1,4) pour la méthode conventionnelle. Avec la méthode conventionnelle, l'aire de débardage avait représenté 29% de la superficie totale, soit juste au-dessous de la limite acceptable de 30%. Avec la méthode mécanique, elle avait représenté 39%, soit 9% de plus que la limite acceptable. Notons que 20% de l'aire en voie de régénération avait été perdue lors des travaux forestiers. Toutefois, la surface toujours occupée par les semis d'épinette, de pin et de chêne était au-dessus du minimum. Quatre ans après la récolte, les semis résiduels manifestaient une vigueur accrue, leur hauteur et le diamètre de leur collet ayant augmenté considérablement.

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Background

Partial harvest operations are common in central Ontario's Crown forests. However, there are many challenges related to partial harvest operations because of the potential for site and stem damage due to entering and exiting of logging equipment. Careful logging practices must be applied by operators in order to limit logging damage to residual trees and regeneration (OMNR 1998).

The *uniform shelterwood system* is the preferred operating system for harvesting and regenerating white pine (*Pinus strobus*) and occasionally red pine (*Pinus resinosa*). The shelterwood system allows natural regeneration to grow under the protection of the older trees by a series of partial cuts over the entire rotation of the stand (OMNR 1998). In Ontario, most pine shelterwood harvests are at the *regeneration cut* stage (OMNR 2004), when a canopy reduction creates the proper micro-environment conditions for germination and establishment of seedlings (OMNR 1998). The second most common treatment is a *first removal cut* where additional overstory trees are removed to enable the regenerating trees to continue growing while protecting white pine regeneration from white pine weevil infestations. Stands with red pine regeneration do not require a first removal cut and may be prescribed a *final removal cut* (OMNR 1998). Currently the least common shelterwood cut in pine dominated stands is the final removal cut.

Figure 1. Feller buncher used in the final removal harvest

A final removal cut provides complete release of the understory and improves growing conditions for the advanced and established regeneration. However, an average of 25 living or dead trees (≥ 10 centimetre [cm] diameter at breast height [dbh] and > 3 metres [m] in height) per hectare must be retained following the final removal cut in order to maintain special habitat features (OMNR 2004). Included in the 25 trees or snags left in the final removal cut, at least 10 trees must be large dominant pine trees. These trees, called veteran trees, are retained for ecological reasons (Pinto et al.1998).

In 1998 mechanized logging (i.e. feller buncher and grapple skidder) accounted for a small percentage of timber harvesting in the partial harvest systems (OMNR 1998); it's now becoming more common. Since mechanized logging is a fairly new practice in Ontario, we wanted to observe its impact on harvesting operations; specifically damage to residuals and well-established regeneration.

In 2002, a large Pembroke District pine stand with significant red pine regeneration was scheduled for a shelterwood final removal cut using mechanical and conventional logging systems. Staff from the Ministry of Natural Resources (MNR) Pembroke District and Ottawa Valley Forest SFL (Sustainable Forest Licence), with the aid of the MNR Southern Science and Information Section initiated a study to look at this operation. Our concerns were:

- the mechanized logging system
- the limited experience of performing final removal cuts in Ontario
- the potential damage to advanced and established regeneration by feller buncher operations

The main objectives of this study were to examine the effects of a mechanical logging operation on advanced and established regeneration, and to determine what damage could be expected from similar operations. We compared conventional and mechanical operations to determine any differences in logging damage between the two systems. We also looked at how well each system followed the standards suggested in the conifer silvicultural guides (OMNR 1998).

Methods

Regeneration Assessments

Resources to complete a comprehensive study were unavailable; therefore we had to prioritize our work. Since mechanized logging equipment is a fairly new method in shelterwood and selection cuts and the effects of logging damage to established sapling sized regeneration is unknown, we decided that the mechanically harvested site would be studied more intensely than the conventionally harvested site. Therefore, we established regeneration assessment plots in the mechanical site only.

Our plot design and assessment was conducted according to the STARS (Silvicultural Treatment Assessment and Reporting System) method (Pinto et al. 2003):

• a series of 10 clusters laid out randomly, each cluster oriented in a north to south direction within the harvest area
• each cluster measured 32 metres squared (m^2) and consisted of 8 subplots measuring 4 m^2
• plots were numbered from 1 to 8 starting in the southwest corner of the cluster, Figure 2 illustrates the plot layout

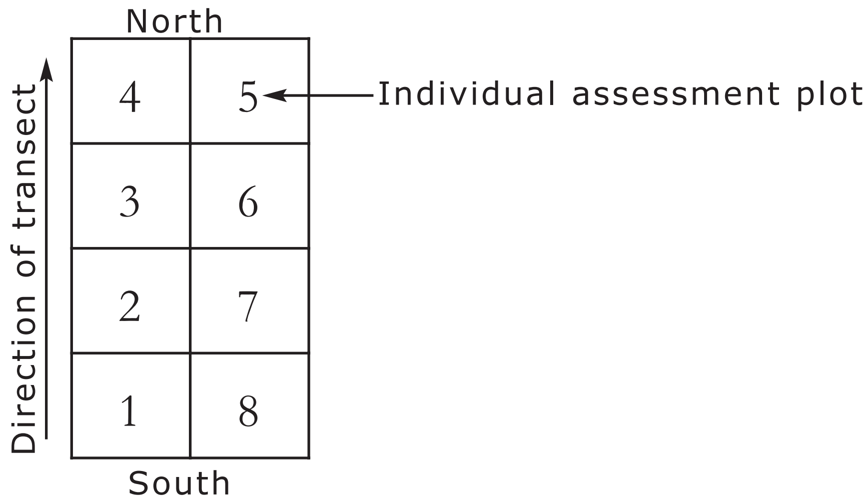

Figure 2. Typical cluster layout identifying plot numbers and direction of transect.

Prior to the January 2002 harvest, crews tallied all pine, spruce and oak seedlings greater than 30 cm and took the following measurements:

• total height
• root collar diameter
• health status

We recorded any evident dead seedlings found in the plots and tagged all seedlings with an individual number for re-measurement in the post-harvest state.

When harvest was completed in May 2002, we revisited each plot and:

• re-assessed all tagged seedlings
• recorded health status
• recorded logging damage that we deemed occurred as a result of the harvest

We used physical descriptors defined in the Ontario Growth and Yield Field Manual (Hayden et al. 1995). Missing seedlings were recorded as killed during the harvest operation. Four years later, in August 2006, we repeated the assessment; located tagged seedlings and tallied height, root collar diameter, and health status.

We calculated stocking and density when all field tallies were completed. Stocking was based on the presence or absence of seedlings in the 4 m^2 plot, while density was estimated by the number of seedlings counted in the area covered by the cluster (Pinto et al. 2003).

Overstory Assessments

We conducted overstory prism sweeps for both logging systems (i.e. conventional and mechanical). However, we only performed pre-harvest prism sweeps for the mechanical logging system. Prior to harvest, crews conducted a series of 10 prism sweeps in the centre of each regeneration plot in the stand scheduled for mechanical operation and recorded for each tree:

- dbh
- quality class—based on the six-class system described in the Ontario Tree Marking Guide (OMNR 2004)
- marked status—marked or not marked for retention
- any logging damage from the regeneration cut

Crews recorded distance and azimuth from a known location on the road so plots could remain unidentifiable to harvest operators and hopefully eliminate any bias such as more careful maneuvering within the study plots.

Tree marking was conducted by certified tree markers and harvesting was conducted by a company that normally works within the Pembroke District and has a history of good harvest practices. During marking and harvesting, all required silvicultural guidelines relating to wildlife habitat and ecological processes were followed.

When the final removal cut was completed our crews revisited the study plots and reassessed all residual trees for new logging damage. The physical descriptors described in the Ontario Growth and Yield Field Manual were used for the residual trees (Hayden et al. 1995). We recorded height for all live residual trees and diameter was recorded at 30 cm on the stumps of cut trees. We recorded the amount of stump rot in order to determine if stump rot could be correlated with logging wounds (stem and butt injuries) from the previous regeneration cut harvest. Stumps were visually assessed by crews and considered to have rot if they were hollow or 'punky'. We took cross directional measurements to determine the diameter of rot within the stump.

Four years after harvest, we once again re-measured the residual trees for dbh, height, and health status.

We established a series of transects for both logging systems upon completion of harvest. These transects were randomly located within each harvest block and measured just over 300 m in length. Crews conducted a series of 10 prism sweeps at 20 m intervals along each transect. Residual trees were tallied for dbh, height, health status, and any logging damage that occurred as a result of the harvest. We used growth and yield distance limiting tables (OMNR 2004) to determine which cut stumps were included in the prism sweeps. Stump diameter and the presence of rot was recorded for each cut stump. In the office, a stem taper equation (Honer et al. 1983) was used to determine the pre-harvest dbh of cut stumps in order to estimate pre-harvest basal areas.

Skid Trail Coverage

The post-harvest transects were used to determine the amount of skid trail coverage by logging system (conventional vs. mechanical). We determined percent skid trail coverage by calculating the length of transect covered by skid trails.

Site Description

The study site was located in Matawatchan Township, Pembroke District, see Figure 3. The conventional site has a mostly flat terrain while the mechanical site is gently rolling. Soil texture on both sites consists mostly of medium sands, with lesser amounts of fine and/or silty sands. Soil auguring revealed average soil depths of 100 cm for the conventional site and 40 cm for the mechanical site. Figure 4 illustrates the general layout of the study blocks.

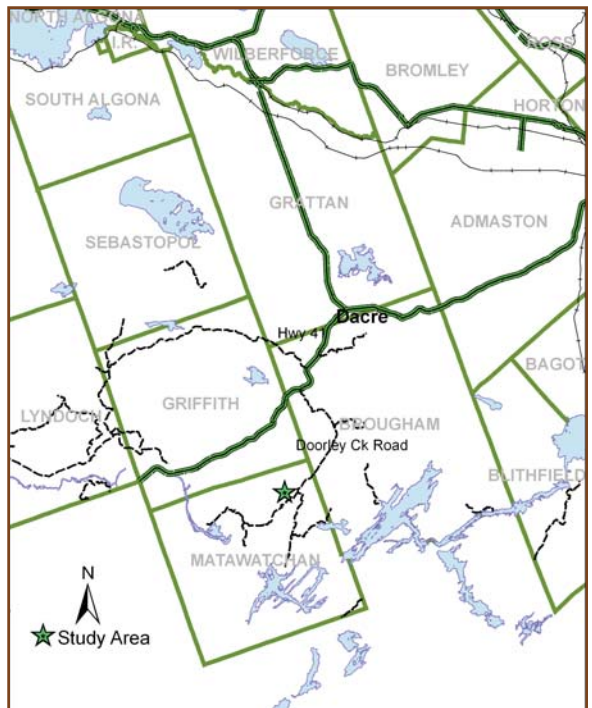

Figure 3. General location of the logging damage study.

Analysis

For the regeneration data, averages were computed from the means of each cluster. For the overstory data, averages were computed from the means of each prism sweep. For the mechanical operation, averages were based on 20 plots (10 plots from the transect and 10 plots from the regeneration plots) while for the conventional system, averages were based on 10 plots (10 plots from the transect). Means and standard error of the means were computed for each variable for comparison purposes. No statistics were computed because in many cases the sample size was too small and the variance was too great.

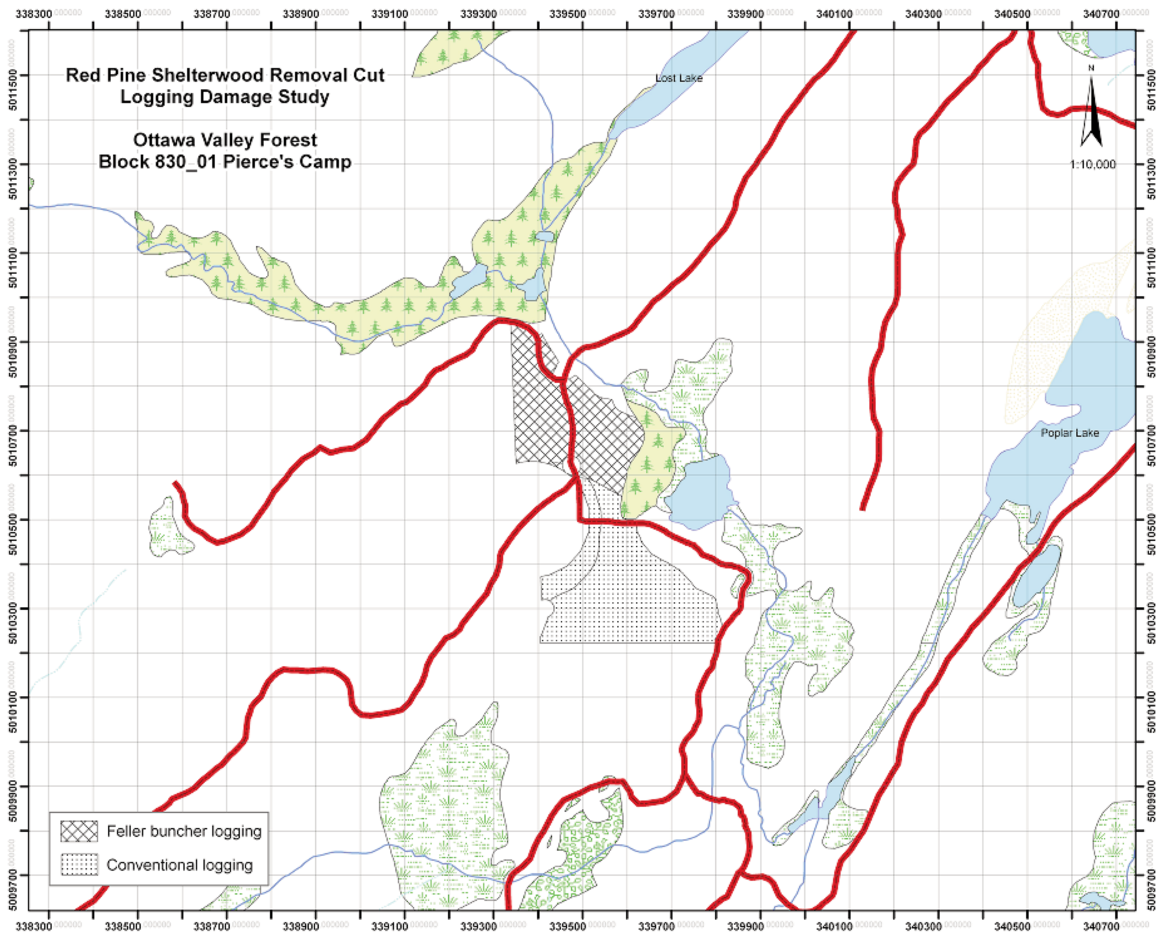

Figure 4. Detailed location and arrangement of the logging damage study blocks.

Results and Discussion

Advanced and Established Regeneration

Stocking, Density and Species Composition

Although damage to advanced and established regeneration is a concern in all harvest operations, shelterwood removal cuts are especially sensitive because the majority of the overstory is being removed and the stocking standards of the regeneration must be maintained following the harvest (OMNR 1998). According to the current forest management plan for the Ottawa Valley Forest for red pine shelterwood harvest there should be a minimum of 40% stocking to red pine, white pine, red oak, white spruce, black spruce, or jack pine with a minimum of 30% stocking made up of red pine. The desired stocking is 80%, made up of red pine, white pine, red oak (*Quercus rubra*), white spruce (*Picea glauca*), black spruce (*Picea mariana*), or jack pine (*Pinus banksiana*) with a minimum of 60% stocking made up of red pine (From: FMP-10, pg PR1-7, Van Dyke 2006).

We calculated stocking and density of the regeneration cohort at pre-harvest and post-harvest stages of the mechanical operation. For all pine, spruce, and oak stems pre-harvest there were 11594 stems per hectare (stems/ha) and post-harvest the number dropped to 10250 stems/ha (Table 1). For free-to-grow (FTG) height (stems ≥ 1 m tall), there were 7031 stems/ha prior to the cut, and afterwards the number dropped to 6438 stems/ha. However, the number of FTG seedlings remained well above the minimum suggested in OMNR (1998) of 1000 stems/ha. Four years after harvest, many seedlings that were less than 1 m in height before the final removal cut had grown to over 1 m in height.

Table 1. Density of white pine, red pine and red oak for the pre- and post-harvest stage, and the 4th year after the final removal cut. Values (±1 standard error) are presented for all stems and FTG stems.

	Density (# stems/ha)					
	Pre-harvest		Post-harvest		4th Year after final removal cut	
Species	All	FTG	All	FTG	All	FTG
Pw	2031 (±866)	1031 (±457)	1781 (±778)	938 (±435)	1750 (±780)	1375 (±688)
Pr	9094 (±2177)	5875 (±1280)	8156 (±2310)	5375 (±1389)	6344 (±1864)	5663 (±1720)
Or	469 (±215)	125 (±69)	313 (±123)	125 (±69)	1219 (±261)	469 (±125)
Total	11594 (±1994)	7031 (±1211)	10250 (±2080)	6438 (±1207)	9313 (±1845)	7406 (±1622)
Note: FTG (free-to-grow) = regeneration ≥ 1 m tall						

Regeneration standards for a red pine dominated shelterwood harvest state that there must be at least 40% stocking of acceptable species (pine, spruce, oak) with 30% stocking of red pine ≥ 1 m tall. Results from this study illustrate that prior to harvest stocking standards were above the minimum (Table 2). Even after harvest, stocking levels remained well above the minimum standard at 64%. Four years later, stocking for seedlings reaching FTG height had reached pre-harvest levels.

Table 2. Percent stocking of white pine, red pine and red oak for the pre- and post-harvest stage, and the 4th year after the final removal cut. Values (±1 standard error) are presented for all stems and FTG stems.

	Density (# stems/ha)					
	Pre-harvest		Post-harvest		4th Year after final removal cut	
Species	All	FTG	All	FTG	All	FTG
Pw	35 (±8)	25 (±9)	33 (±8)	23 (±8)	31 (±7)	25 (±7)
Pr	63 (±10)	51 (±9)	56 (±11)	48 (±10)	49 (±10)	45 (±11)
Or	15 (±6)	5 (±3)	11 (±4)	5 (±3)	33 (±5)	15 (±4)
Total	80 (±7)	66 (±9)	76 (±7)	64 (±8)	80 (±6)	66 (±9)
Note: FTG (free-to-grow) = regeneration ≥ 1 m tall						

Prior to harvest, species composition of advance and established regeneration was 78% red pine, 18% white pine and 4% red oak (Table 3). When looking at stems reaching FTG height (≥ 1 m tall), 84% was red pine, 15% was white pine and 2% was red oak. Post-harvest, composition remained roughly the same. However, four years after harvest, the percentage of red oak increased to 13%, red pine decreased to 68% while white pine remained roughly the same at 19%. The same trend was observed for the regeneration reaching FTG height.

Table 3. Species composition of white pine, red pine and red oak by harvest stage.

	Density (# stems/ha)					
	Pre-harvest		Post-harvest		4th Year after final removal cut	
Species	All	FTG	All	FTG	All	FTG
Pw	18	15	17	15	19	18
Pr	78	83	80	83	68	76
Or	4	2	3	2	13	6
Note: FTG (free-to-grow) = regeneration ≥ 1 m tall						

Survival

Although approximately 20% of the regeneration was lost in this harvesting operation, there were still enough stems remaining after the harvest to consider the stand adequately stocked. Percent survival of all regeneration after the mechanical logging operation averaged 89% (±6.1%) (Figure 5). White pine survival was the highest at 91% (±4.1%) followed by red pine and red oak at 85% (±10.3%) and 82% (±11.9%), respectively. For stems reaching FTG height, survival averaged 93% (±4.5%) for all stems. Survival among stems reaching FTG height was highest for red oak at 100%, followed by white pine at 90% (±6.0%) and red pine at 86% (±10.2%). These results are consistent with those of Dunne and Corbett (1992) in Algonquin Park, and Table 2 revealed that stocking standards were indeed maintained after the harvest.

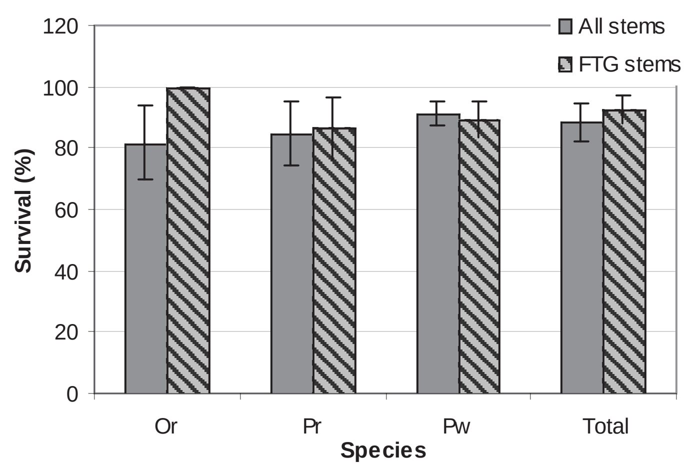

Figure 5. Percent survival (±1 standard error) by species for all stems and for those reaching FTG height (≥ 1 m tall).

Height and Diameter

The average height of FTG regeneration prior to the mechanical harvest was 215 cm (±28) tall. By species, red oak was the tallest at 465 (±85) cm, followed by white pine at 232 cm (±32) and red pine at 149 cm (±5) (Figure 6). Post-harvest heights remained relatively the same, even though there was some mortality. Four years later, the average height of all regeneration was 246 cm (±27). In order of height by species, white pine measured 302 cm (±51), red oak was 258 cm (±67) and red pine was 188 cm (±9) tall. The decrease in red oak height in 2006 was probably due to the large number of red oak seedlings growing into the FTG height category.

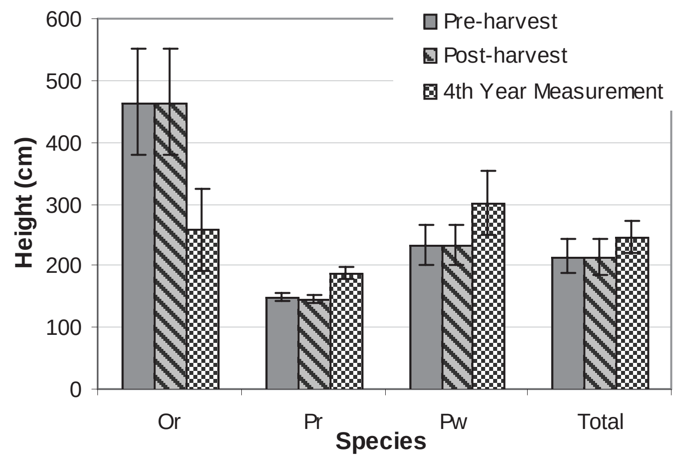

Figure 6. Average height (±1 standard error) by species and harvest stage for stems reaching FTG height (≥1 m tall).

Average root collar diameters followed the same general trend. Prior to harvest, average root collar diameters averaged 23.1 millimetre (mm) (±1.6), and by species they were 32.7 mm (±0.7) for red oak, 24.6 mm (±3.2) for white pine and 19.9 mm (±1.1) for red pine (Figure 7). After harvest, average root collar diameters remained relatively the same. Four years later, the average root collar diameter of all species doubled to 50.7 mm (±7.6). Because of the large in-growth of red oak into the FTG height category, average root collar diameter dropped to 24.4 mm (±9.7). Four years after harvest root collar diameters among red pine and white pine almost tripled to 63.8 mm (±10.7 and ±15.3, respectively).

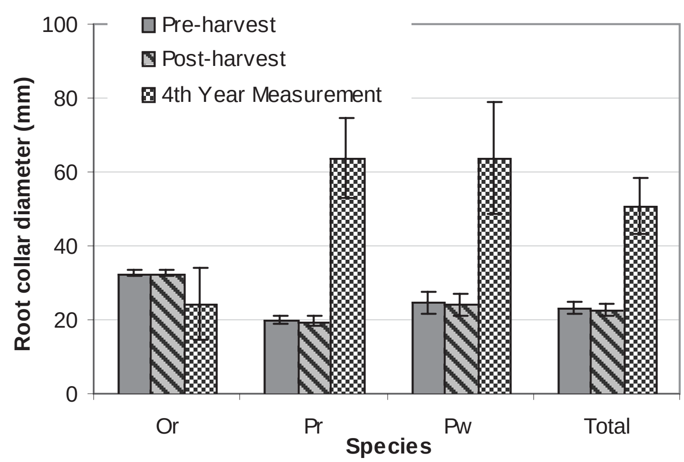

Figure 7. Average root collar diameter (±1 standard error) by species and harvest stage for stems reaching FTG height (≥ 1 m tall).

Health Status and Condition

Regeneration standards for a harvest operation are generally laid out in the silvicultural ground rules of a forest management plan, as there are no damage standards in the silvicultural guides. However, minimum stocking standards must be maintained after harvest (OMNR 1998).

The health status of all regeneration was assessed upon completion of the harvest. As stated earlier, 89% of all regeneration, and 93% of regeneration reaching FTG height survived the mechanical logging operation. Of the regeneration that was alive after the harvest, 69% was classed as healthy (i.e. no physical descriptors were recorded). For those considered to be unhealthy, the main causes were: logging damage (e.g. broken tops, stem wounding, pushed over/leaning) at 44%; diplodia shoot blight (*Sphaeropsis sapinea*) at 45%; other damage by insects, disease and wildlife at 9%; and other cases of physical damage (cause unknown) at 2% (Figure 8a). Of the seedlings that were dead, 32% was due to logging damage (stem wounding), 15% was from infection of diplodia shoot blight and 53% of seedlings had no discern-

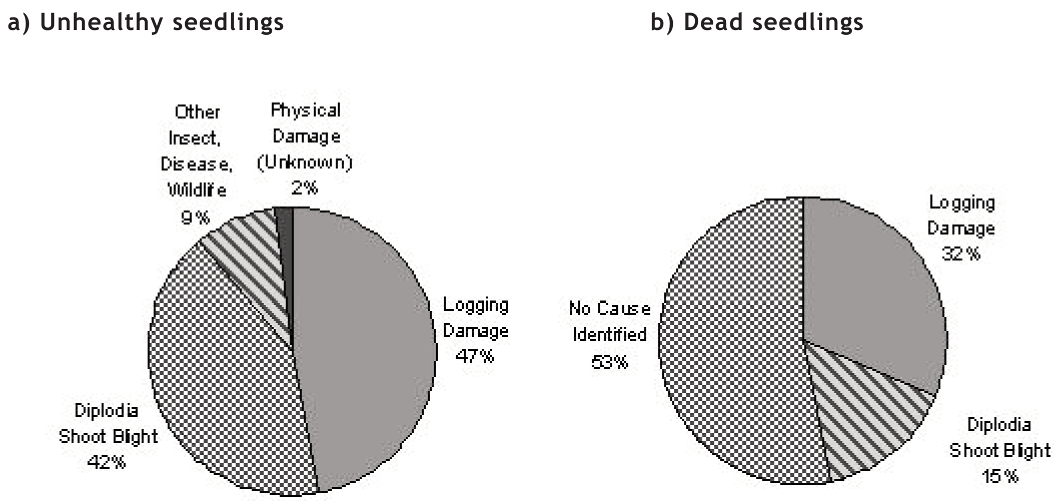

Figure 8. Main causes of seedlings classed as a) dead and b) unhealthy after the mechanical logging operation.

able cause of death (Figure 8b). Missing seedlings were considered to be dead with no identifiable cause.

A case of diplodia shoot blight on red pine seedlings was noticed during the pre-harvest tally; of the seedlings tallied in 2002, 6% were dead and assumed to have died due to the disease or its complications. When summarized by health status, 66% of the dead seedlings had died due to diplodia shoot blight and its complications, while another 13% of all live seedlings were infected with the disease. However, in 2006, less than 2% of the regeneration was infected with the disease.

During the fourth year re-measurement, the tally crew noticed a large number of seedlings were being suppressed by competing vegetation so a competition factor was added to the tally. A tree was considered to be suppressed when the competing vegetation within a 1 m radius of the crop tree was greater than 30 cm taller than the crop tree. Results of the analysis revealed that four years after harvest 19% of all advance and established regeneration was suppressed by competing vegetation. Although this is not a harvesting concern, it does indicate that the trees might benefit from some vegetative release if they are to continue to grow and become the future stand.

Overstory

Stand Structure and Quality

Prior to harvest, species composition was similar between the two stands. The site scheduled for mechanical logging consisted mostly of white pine and red pine at 90%, with lesser amounts of red oak, eastern white cedar (*Thuja occidentalis*), white spruce, and poplar (*Populus tremuloides*) (Table 4). The two major species in the conventional site were once again white pine and red pine, totalling 96% of all species. Minor species included eastern white cedar, white spruce and white birch (*Betula papyrifera*). Post-harvest, species composition remained roughly the same on both sites. One notable exception is the decrease in white pine on the mechanical site; however, total conifer composition remained roughly the same.

Table 4. Species composition (based on percentage of basal area for each taxa) by logging system for both the pre-harvest and post-harvest stages.

	Species Composition			
	Mechanical Logging		Conventional Logging	
Species	Pre-harvest	Post-harvest	Pre-harvest	Post-harvest
Pw	69	62	83	79
Pr	21	20	13	15
Or	5	5	n/a	n/a
Other Conifer	3	12	3	4
Other Hardwood	2	1	2	2

Pre-harvest basal areas for the mechanical and conventional operations were 23.7 m^2/ha (±2.1) and 21.0 m^2/ha (±2.0), respectively. Because the final removal cut took place, a considerable amount of the overstory was removed, but a higher number of residuals were still left behind than required in the silvicultural guide (i.e. 10 live veteran trees/ha, 6 live cavity trees/ha and 8 mast producing trees/ha,). The amount of basal area removed during the harvesting operations was 66% (±3%) for the mechanical site and 43% (±5%) for the conventional site. Therefore, post-harvest basal areas for the mechanical and conventional operations were 7.6 m^2/ha (±0.8) and 11.6 m^2/ha (±1.2), respectively.

The silvicultural guide for the Great Lakes–St. Lawrence conifer forest in Ontario states that the proper use of the uniform shelterwood system will result in an increase in average diameter of forest stands after the preparatory and regeneration cuts (OMNR 1998). This is because at every cutting stage the larger and healthier trees are retained in the stand to provide shelter, a seed source and to increase in value. By the time the final removal cut is performed, the stand should consist of the healthiest and largest trees. A notable exception would be leaving smaller or less healthy trees behind to maintain special wildlife features (e.g. stick nests, cavity trees). Therefore, it would be expected that the stand dbh would remain fairly consistent after the final removal cut. The results from this study support that assumption, and Figure 9 illustrates how the average diameter (dbh) for the mechanical and conventional logging systems remained roughly the same from the pre-harvest to post-harvest stage. For the mechanical system the pre-harvest dbh was 35.6 cm (±0.8) and the post-harvest dbh was 35.5 cm (±1.4). For the conventional system, average dbh increased slightly from 47.9 cm (±0.9) to 50.3 cm (±0.7) for the pre- and post-harvest stages, respectively.

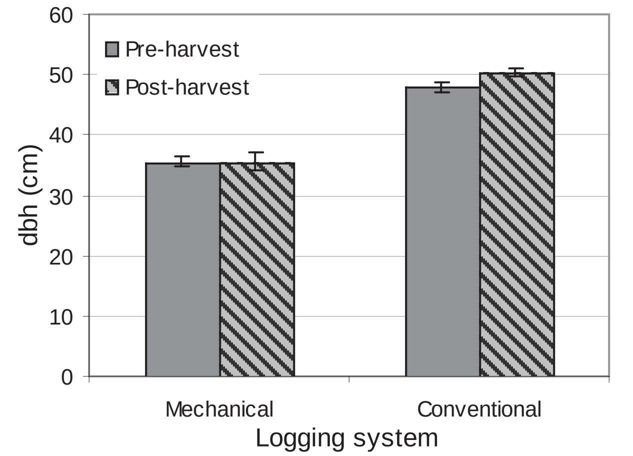

Figure 9. Average dbh (±1 standard error) of residual trees (10 cm+) by logging system for the pre-harvest and post-harvest stages.

Quality class was recorded for the mechanical logging operation only. Prior to harvest, the percentage of acceptable growing stock (AGS) was 83%, and upon completion of the harvest the amount of AGS dropped to 77%. The slight decrease in AGS could be a result of retaining poorer quality trees for special habitat features.

Logging Damage

Harvesting under partial-cut systems (i.e. shelterwood, single tree selection) will generally result in some degree of physical damage to residual stems and regeneration (OMNR 1998). Damage standards for the Great Lakes–St. Lawrence forest state that there should be less than 15% major damage to the total residual basal area and less than 10% major damage to residual AGS basal area (OMNR 1998). According to the silvicultural guide the following is considered major damage:

- tree was cut and not marked
- tree was flattened, killed, or broken off
- a tree stem wound greater than its dbh^2 (trees 10 to 30 cm dbh) or 1000 cm^2 (trees 32 cm+ dbh) or 60% of the size shown for all size classes if the wound was in contact with the ground
- greater than 25% root exposure
- greater than 33% crown loss (OMNR 1998)

Results from the analysis reveal 5.2% (±3.0) major damage to residual basal area from the mechanical logging operation and

1.4% (±1.4) major damage from the conventional logging system (Figure 10). Both harvest systems fell well below the maximum allowable standard of 15% of the residual basal area. Quality class was not assessed in prism sweeps from the transect tally, so a measure of major damage to AGS residual basal area could not be computed.

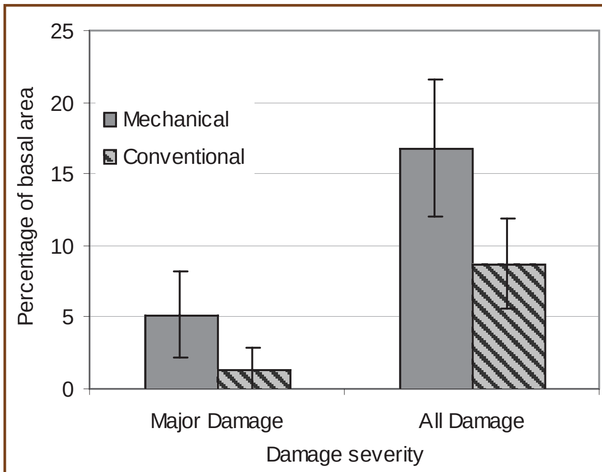

Figure 10. Percentage of residual basal area (±1 standard error) with major damage and total damage by logging system.

In terms of all damage severities, the mechanical logging operation resulted in 16.8% (±4.8) damage while the conventional operation resulted in 8.7% (±3.1) damage to residual basal area. All recorded damage on both sites was bark scrapes to the stem and butt of the trees due to felling and skidding. No cases of crown or root damage, or trees being pushed over, were recorded on either site. For the conventional harvest system, 60% (±25) of the wounds were in contact with the ground and for the mechanical system the percentage of wounds contact with the ground was 31% (±16). The occurrence of wounds in with ground contact is a concern because research suggests a greater likelihood of decay developing over time (Anderson 1994, Ohman 1970).

After examining all stumps, the results revealed that 50% of all cut stumps had some degree of rot. Past logging damage data from the 1976 harvest was available for 10 of the plots; however, the presence of rot could not be correlated with wounding from past harvests. In addition, the percentage of rot could not be correlated with the size of the wound. This could be due to the extremely small sample size.

Skid Trail Coverage

Current guidelines for the Great Lakes–St. Lawrence conifer forest state that there is to be no more than 30% skid trail coverage in shelterwood harvests (OMNR 1998). Results from this study reveal that skid trail coverage for the conventional system fell just below the standard at 29% while the mechanical system exceeded the standard at 39% (Figure 11).

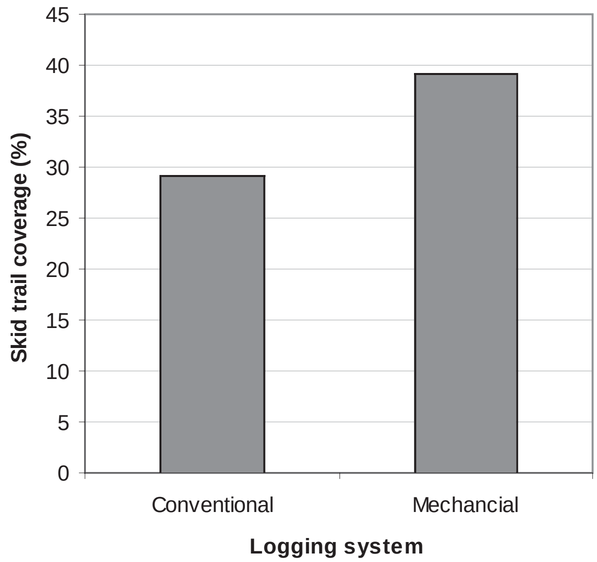

Figure 11. Percentage of skid trail coverage by logging system.

Conclusions

The results from this study indicate that even though some regeneration was lost due to harvesting, there were still plenty of seedlings remaining, and seedlings reaching FTG height were well above the minimum density and stocking standards for shelterwood harvests. And even though some seedlings were damaged due to the harvest, there were still plenty of healthy seedlings remaining that will contribute to the future stand. Because heights and root collar diameters of regeneration reaching FTG height remained consistent from the pre- to post-harvest stage, this indicates that seedling loss was not concentrated in any one size class (i.e. loss of seedlings was relatively random). In addition, one type of species of regeneration was not more susceptible to the effects of logging (i.e. seedling loss and/or damage).

Both logging systems fell well below the maximum allowable standard of 15% major damage to residuals. In addition, both logging systems produced the same types of damage. When looking at skid trail coverage, the mechanical logging system exceeded the standard of 30%.

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