Coarse Woody Debris in Harvested and Unharvested Areas at the Aleza Lake Research Forest: Volume and Attributes

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Coarse woody debris (CWD) has a variety of ecological functions in forested ecosystems. As well, it is valuable to society as a renewable source of bioenergy. Under some circumstances, coarse woody debris can cause problems by increasing the risk of wildfire, reducing the availability of plantable spots in harvest blocks, and interfering with movement of humans or wildlife. To manage CWD appropriately, forest managers require more knowledge about amounts and attributes of CWD in unharvested ecosystems, as well as the impacts of various management practices on amounts and attributes of CWD.

The Aleza Management Plan (2005-2010) states that "CWD management will focus on leaving a wide range of piece sizes well distributed on harvested sites, but a key focus will be on CWD pieces greater than 30 cm in diameter at the largest end." The post-harvest CWD target in the Northern Uplands and West Bear Management Units, where all harvest blocks to date have been located, was set at 20 m^3/ha, with an acceptable range of 0-40 m^3/ha**.**

Monitoring of CWD levels and attributes was undertaken by the Aleza Lake Research Forest in summer 2009 to evaluate compliance with the current management plan, to provide an information base for setting better targets in the next management plan, and to evaluate how CWD is affected by the removal of logs for the pulp market. Specific objectives of the project were:

- To compare total CWD volumes in harvest blocks logged when there was a market for pulp (P), harvest blocks logged when there was no market for pulp (NP), and unharvested areas (UN);
- To compare volumes of large pieces of CWD (those greater than 30 cm in diameter at the largest end) in P blocks, NP blocks, and UN areas;
- To compare piece sizes (length and diameter at stump height) in P blocks, NP blocks, and UN areas;
- To compare the occurrence of attributes (decay class and wildlife habitat attributes) in P blocks, NP blocks, and UN areas; and
- To compare the occurrence of wildlife habitat attributes in pieces $\geq$ 30 cm vs. pieces < 30 cm at the largest end.

METHODS

Coarse woody debris sampling was done in the Northern Uplands and West Bear Management Units at the Aleza Lake Research Forest in June and July 2009. Harvest blocks for sampling were selected according to the following criteria:

- The silvicultural system used must be clearcut with reserves.
- The preharvest stand must be Age Class 8, with no history of previous logging.
- The block must be either logged for sawlog or sawlog/peeler market only, or logged for sawlog and pulp market.
- Travel time to access the block must not be excessive.

Plots in the harvest blocks were laid out along transects located outside the roadside harvesting zone (the area within 30 m of main access routes). Each plot was composed of two 24-m (horizontal distance) transects. The azimuth for Transect 1 was randomly selected. The azimuth for Transect 2 was the first azimuth + 90. The actual number of plots varied from one block to another, depending on the size and shape of the block, but was never fewer than four.

Samples in the unlogged areas were associated with preexisting Permanent Sample Plots. Each of the four cornerposts was used as the Point of Commencement for one transect. Random azimuths were constrained to avoid entering the Permanent Sample Plots, so that the plots would not be subjected to the disturbance of extra foot traffic. The transects in the unlogged areas are permanent, and the endpoints were marked with metal angle iron painted yellow.

A line intercept sampling method was used, following the Northern Wetbelt sampling protocol (Stevenson et al. 2000), with the following differences:

- There was no minimum length for pieces to be included.
- Changes in the criteria for identifying CWD Types (Keisker 2000) developed in 2009 were applied. The 2009 criteria are provided in Appendix 1.
- Instead of measuring Diameter at Stump Height, the diameter of each piece > 1m in length was measured at the widest end. (This change was instituted after the first three blocks [Blocks 9, 15, and 16] were sampled.)

CWD volume was calculated according to Van Wagner (1982), except that volume of odd-shaped pieces was calculated according to Marshall et al. (2000). The distributions of the volume data were skewed right, and the variances were heterogeneous. A cube root transformation greatly improved the distributions (Figures 1 and 2). Analysis of variance was done on transformed volume data.

The distributions of the length and diameter at widest end (DWE) data were also skewed right. These distributions were normalized by a natural log transformation for statistical analysis (Figures 3 and 4).

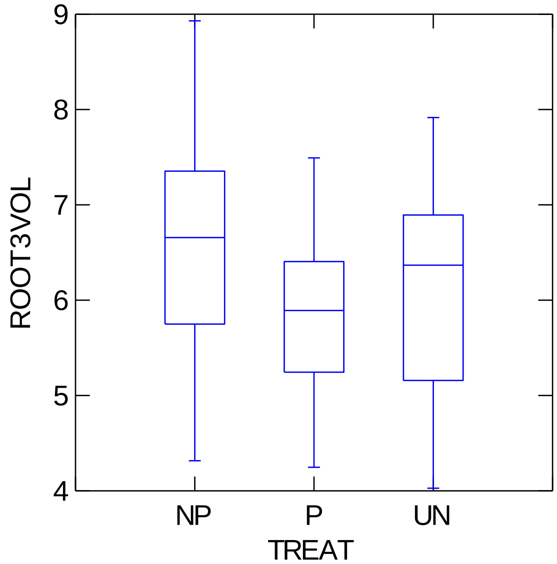

Figure 1. Boxplot showing distribution of total CWD volume data after cube root transformation.

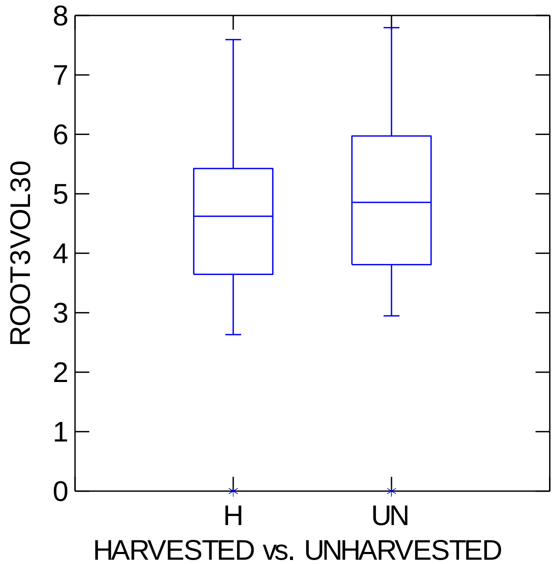

Figure 2. Boxplot showing distribution of volume data for CWD $\geq$ 30 cm at the largest end after cube root transformation.

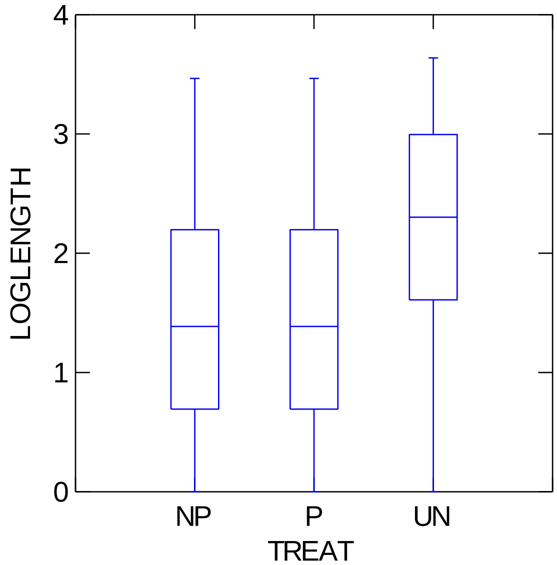

Figure 3. Boxplot showing distribution of piece length data after natural log transformation.

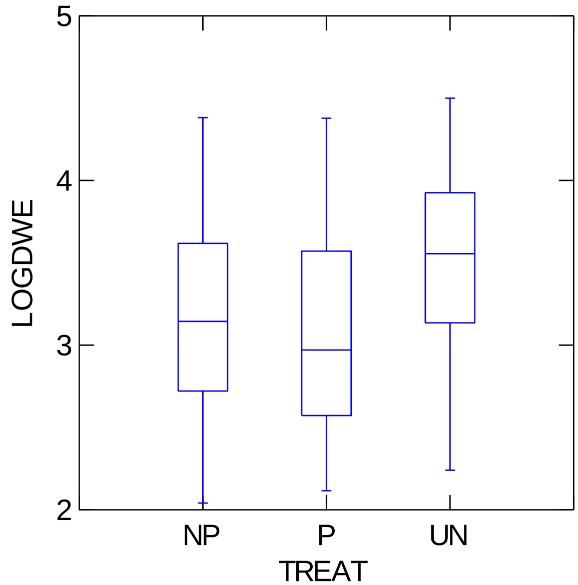

Figure 4. Boxplot showing distribution of piece diameter at the widest end (DWE) data after natural log transformation.

RESULTS

CWD volumes

Mean CWD volume at the block level ranged from 146 to 379 m^3/ha for harvest blocks, and from 230 to 265 m^3/ha for unharvested sites (Table 1). Under block means in Table 1, N indicates the number of plots (1 plot = 2 24-m transects) for the P (pulp market) and NP (no pulp market treatments, but number of 24-m transects for the UN (unlogged) treatment. Under treatment means, N indicates number of cutblocks for P and NP, but number of Permanent Sample Plots for UN.

Table 1. Mean volume (m^3/ha) and standard errors of total CWD and CWD $\geq$ 30 cm at the largest end at the block level.

ALRF CWD volume data summer 2009

Block means

			total			30cm	
Treat	**Block**	**n**	**volume**	**SE**	**n**	**volume**	**SE**
NP	1	6	234.8	39.6	6	83.7	30
NP	4B	4	376.8	48.9	4	203.1	48.8
NP	4	4	378.9	64.7	4	276	71.9
NP	6	4	237.7	54.5	4	67.5	55.5
NP	9	8	349.7	67.3	8		
NP	11	5	190.1	59.6	5	97.3	39.2
NP	20	5	363.8	31.8	5	133.1	10.5
P	12	9	265.6	28.5	9	68.3	10.7
P	14	5	272.3	27.4	5	145.8	51.1
P	15	8	159.1	19.3	8		
P	16	4	145.9	36.1	4		
UN	103	4	230.2	60.0	4	87.6	51.8
UN	107	4	264.9	63.8	4	146	66.1
UN	112	4	265.5	101.8	4	195.8	98.2
UN	115	4	257.1	79.6	4	185.7	76.9
UN	116	4	242.4	35.3	4	141.3	21.3

Treatment means

NP		7	304.5	30.4	6	143.5	33.0
P		4	210.8	33.8	2	107.1	38.8
UN		5	252.0	6.9	4	167.2	13.8

Analysis of variance at the plot level indicated that the grouping effect of blocks was not statistically significant ($p = 0.080$), but that differences among treatments were significant ($p = 0.020$). Bonferroni-adjusted pairwise comparisons indicated a significant difference (p = 0.019) between NP (no pulp market) and P (pulp market) treatments. No other pairwise differences were significant.

To examine the effect of treatment on the volume of large logs (> 30 cm at the widest end), we lumped the two harvested treatments together, because we had DWE data for only two of the pulp market blocks. Analysis of variance at the plot level indicated that neither the effects of harvesting (p = 0.814) nor of blocks within treatments (0.093) were statistically significant. It appears, from examination of the data sheets, that DWE may not have been recorded in the field for all logs that met the sampling criteria. It is unclear why this occurred, or whether or not it biased the results, but it did result in a small sample size for pieces with DWE data.

CWD size in relation to treatment

Sampled CWD pieces were approximately twice as long in the unharvested areas as in the harvest blocks, and mean diameter at the widest end was also noticeably greater in the unharvested areas (Table 2).

Table 2. Piece length of CWD (mean and SE) and diameter of CWD at the widest end (DWE) at the block level.

Block means

Treat	Block	n	length	SE	n	DWE	SE
NP	1	72	4.4	0.5	27	35.6	3.5
NP	4B	116	6.5	0.5	77	27.4	1.5
NP	4	89	7.8	0.7	64	30.6	2.2
NP	6	69	5.7	0.7	39	24.5	2
NP	9	167	5.1	0.4			
NP	11	85	7.8	0.7	60	24	1.7
NP	20	113	5.6	0.5	45	26.8	2.7
P	12	194	7.4	0.5	109	23.5	1.3
P	14	88	8.4	0.8	47	32.4	2.4
P	15	126	3.5	0.4			
P	16	69	5.1	0.6			
UN	103	33	12.5	1.5	16	39.4	3.6
UN	107	31	12.2	1.4	16	38.2	5
UN	112	28	12.6	2.0	19	36.9	4.4
UN	115	22	18.7	2.2	14	54.5	5.7
UN	116	33	9.6	1.3	20	27.9	2.5
Treatment means							
NP		711	6.1	0.2	312	27.7	0.9
P		477	6.6	0.3	156	26.2	1.2
UN		147	12.7	0.8	85	38.4	2

Analysis of variance of (log-transformed) length at the plot level indicated that both the grouping effect of blocks and the effect of treatment were statistically significant (p = 0.000 for both effects). Bonferroni-adjusted pairwise comparisons showed that the unlogged areas differed from both the P and the NP blocks (p = 0.000 for both comparisons). The P and NP blocks did not differ from one another.

The P and NP blocks were grouped for analysis of variance of (log-transformed) DWE data because DWE data are available for only two P blocks. Both the grouping effect of blocks and the effect of harvesting were statistically significant (p = 0.000).

CWD attributes in relation to treatment

The distribution of decay classes differed significantly among the three treatments (likelihood ratio chi-square test; p = 0.000) (Table 3).

Table 3. Distribution of decay classes (percent occurrence) among treatments

Decay class (percent occurrence by treatment)

	n	**1**	**2**	**3**	**4**	**5**
NP	711	27.8	40.8	19.3	10.7	1.4
P	476	35.7	28.2	15.1	17.6	3.4
UN	147	8.2	46.3	27.9	15	2.7

For all 5 CWD Types having enough occurrences to test, the distribution of occurrences (i.e. presence or absence of a given Type) differed significantly by treatment (again using the likelihood ratio chi-square test).

Table 4. Distribution of CWD Types (percent of pieces exhibiting attribute) among treatments and probability of differences among treatments

CWD Types (percent of pieces exhibiting attribute)

	n	**CWD1**	**CWD2**	**CWD3**	**CWD4**	**CWD5**	**CWD6**	**CWD7**
NP	711	15.8	63.3	2.0	28.6	11.7	0.7	0.4
P	477	14.7	54.9	0.4	34.0	8.2	0.2	0.0
UN	147	24.5	65.3	10.9	40.1	22.4	0.7	0.5
p		0.023	0.007	0.000	0.011	0.000	N/A	N/A

Another way of looking at habitat quality is to compare the mean number of Types per piece in each treatment (Table 5). The distributions of number of Types per piece differed significantly among treatments (likelihood ratio chi-square test; p = 0.000).

Table 5. Distribution of Number of CWD Types per piece (percent of pieces) by treatment

Number of Types per piece (percent of pieces)

		Number of Types				
	n	**0**	**1**	**2**	**3**	**>3**
NP	711	20.7	49.4	20.0	8.2	1.8
P	477	27.7	43.8	18.7	8.6	1.3
UN	147	15.6	42.2	19.7	12.9	9.5

To analyze the occurrence of CWD Types further, we could make the following independent comparisons:

- UN vs. NP and P together
- NP vs. P

CWD attributes in relation to piece size

The occurrence of CWD Types in pieces $\geq$ 30 cm in diameter at the largest end (L) was compared with the occurrence of Types in pieces < 30 cm in diameter at the largest end (S).

Table 6. Percent occurrence of CWD Types in pieces < 30 cm in diameter at the largest end (S) and in pieces $\geq$ 30 cm in diameter at the largest end (L), all treatments combined

CWD Types by size class (percent of pieces exhibiting attribute)

	n	**CWD1**	**CWD2**	**CWD3**	**CWD4**	**CWD5**	**CWD6**	**CWD7**
S	357	5.9	62.7	0.8	38.9	10.6	0	0
L	230	44.8	73.5	4.8	66.5	32.2	1.3	3
p		0.000	0.007	0.002	0.000	0.000	N/A	N/A

For all 5 Types having enough occurrences to test, the frequency of occurrence (i.e. presence or absence of a given Type) was significantly greater in large pieces than in small pieces, using the likelihood ratio chi-square test.

The distribution of the number of Types per piece also differed significantly between large and small pieces (likelihood ratio chi-test; $p = 0.000$) (Table 7).

Table 7. Distribution of Number of CWD Types (percent of pieces) in pieces < 30 cm in diameter at the largest end (S) and in pieces $\geq$ 30 cm in diameter at the largest end (L), all treatments combined

Number of Types per piece by size class (percent of pieces)

		Number of Types				
	n	**0**	**1**	**2**	**3**	**>3**
S	357	12.6	60.2	23.0	3.9	0.3
L	230	1.3	21.7	39.6	27.0	10.4

CONCLUSIONS AND RECOMMENDATIONS

Total volume of CWD after harvesting was significantly lower in blocks harvested for pulp and sawlogs than in blocks harvested when there was no pulp market. However neither mean differed significantly from the mean value in unlogged stands. CWD volumes ranged from 146 to 379 m^3/ha in harvest blocks, and from 230 to 265 m^3/ha at unharvested sites, far exceeding the target (20 m^3/ha) and the acceptable range (0-40 m^3/ha) specified in the Aleza Management Plan. Now that these data are available, an upward revision of the target and acceptable range is recommended for the next Aleza Management Plan.

CWD volumes in the unlogged sites were surprisingly uniform compared to those reported in other studies, such as Manning, Cooper and Associates, Ltd. (2007). This result may be an artifact of a small sample size. Although the initial sampling plan had called for a pair of transects commencing at each corner of the Permanent Sample Plots, only one transect at each corner was actually installed. Thus, the volume estimate for each unharvested site was based on a total of 98 m of transect length, whereas the minimum transect length for any one harvest block was 196 m, and most were greater. Future sampling efforts should include establishment of additional transects in unharvested areas.

Analysis of variance did not reveal any significant difference between volume of large ($\geq$ 30 cm DWE) CWD in harvested and unharvested areas. However, sample sizes for logs with measured DWE were small, and some DWE measurements that should have been recorded may have been missed.

Aside from volume, both measurements of piece size – piece length and DWE – showed that piece size on logged blocks was significantly lower than in unlogged areas. Differences in piece size are associated with habitat quality. The occurrence of individual CWD Types and the number of Types per piece were both significantly greater in large ($\geq$ 30 cm DWE) than small (< 30 cm DWE) pieces. This relationship probably explains, in part, the differences in occurrence of CWD attributes among treatments that was observed. Although the present analysis does not tell us whether 30 cm DWE is the best size threshold to use for management purposes, it appears to be a good one.

Literature cited

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APPENDIX 1. Criteria used for identifying CWD Types (Keisker 2000) at Aleza Lake Research Forest, summer 2009

CWD1: Large concealed spaces

Main functions: Reproduction, resting, escape. Also used for hunting and food caching.

Main users: Cat family, weasel family, grouse, Snowshoe Hare, Bushy-tailed Woodrat, Porcupine, dog family, Black Bear, amphibians

Log decay classes: 1, 2, 3

Recognizing CWD1:

Look for:

- Spaces under elevated logs
- Logs that are hollow or have very large cavities
- Spaces in, or at the base of, upturned rootwads
- Spaces within slash piles

Spaces must provide visual concealment when viewed from most angles. Other CWD or adjacent vegetation may contribute to the concealment.

Spaces must be large enough to accommodate a grouse or snowshoe hare – minimum entrance opening 8 cm (about the width of one closed fist); minimum internal dimensions 12 cm (about the width of two closed fists pressed together.

Optional subcategories:

CWD1a: space appears to be well-drained – no evidence of standing water
CWD1b: space has standing water, or evidence that standing water has been present in the past. Look for mud, mottled soil (red to gray patches of oxidized soil), or hydrophytic vegetation (e.g., horsetails)

CWD2: Small concealed spaces (or soft substrate allowing excavation of such spaces) at or below ground level beneath hard material

Main functions: Reproduction, resting, escape. Also used for food caching by some small mammals, and as hunting sites by predators.

Main users: Amphibians, snakes, shrews, voles, squirrels, mice, weasels

Log decay classes: 1, 2, 3

Recognizing CWD2:

Look for:
- Small spaces under CWD resting on the ground
- Logs with cavities at or below ground level.
- Loose bark on CWD resting on the ground
- Burrows in soft material under CWD
- Soft material under CWD. Soft material may be soft decaying wood, forest litter, humus, or fine loose soils.

Spaces must be small enough to effectively conceal the main users. Other CWD or adjacent vegetation may contribute to the concealment, but there must be hard material above the space.

Optional subcategories:

CWD2a: spaces suitable for use by non-burrowing species are present
CWD2b: suitable spaces not present, but soft material present under CWD

CWD3: Small concealed spaces above ground level

Main functions: Reproduction, resting.

Main users: Winter Wren, Northern Waterthrush, Pacific Treefrog, flycatchers, other songbirds, Deer Mouse

Log decay classes: 1, 2, 3, 4?

Recognizing CWD3:

Look for:
- Cavities, depressions or ledges in upturned rootwads
- Cavities (including old excavated nestholes), depressions or ledges in logs, among stacked logs, or in stumps (if stumps are included in sampling)

Must be $\geq$ 10 cm above ground level; if below 10 cm, consider CWD2.

Optional subcategries:

CWD3a: shallow depression or ledge with little overhead cover
CWD3b: depression, ledge, or cavity with enough surrounding cover to largely conceal user or nest

CWD4: Long concealed spaces (or soft substrate allowing construction of runways)

Main functions: Travel along concealed runways; hunting sites (Marten, Fisher)

Main users: Long-toed Salamander, voles, shrews, Deer Mouse, squirrels, weasels

Log decay classes: 1, 2, 3?, 4 (4 for excavated runways)

Recognizing CWD4:

Look for:

- Concealed spaces under logs resting near the ground
- Concealed spaces along the edges of logs resting on the ground
- Spaces between log, ground, and moss hanging of edges of log
- Runways excavated in soft material in, under, or alongside logs
- Soft material under CWD suitable for the construction of runways. Soft material may be soft decaying wood, forest litter, humus, or fine loose soils.

Spaces must be small enough to provide effective concealment.

Minimum length 1 m

Optional subcategories:

CWD4a: concealed runways are present
CWD4b: concealed runways not present, but soft material suitable for the construction of runways present under CWD

CWD5: Large or elevated, long material clear of dense vegetation

Main functions: Travel along exposed, raised lanes

Main users: Squirrels, Marten

Log decay classes: 1, 2, 3 (3 only if large)

Recognizing CWD5:

Look for:

- Logs that are elevated or large enough that the upper surface of the log is above the surrounding vegetation, and that do not, themselves, have branches that obstruct travel or visibility
- Diagonal logs that provide access to the tree canopy, a pile of woody debris, or other habitat area

Unimpeded length of an isolated log must be at least 4 m. No length limit if the log is part of a larger system of travel lanes, or provides access to a habitat area.

CWD6: Invertebrates in wood, under bark or moss cover, or in litter/humus accumulated around CWD

Main functions: Foraging

Main users: Amphibians, woodpeckers, Winter Wren, shrews, Deer Mouse, Striped Skunk, bears

Log decay classes: All

Recognizing CWD6:

Look for:

- Evidence of an ant colony: frass, sawdust, galleries, or the ants themselves
- Evidence of recent feeding, generally by woodpeckers or bears
- Recently fallen trees containing live bark beetles

The following features are not reasons to classify a log as CWD6:

- A few invertebrates. Some invertebrates are present in all CWD, but to classify a piece as CWD6, we must see evidence of a concentration of invertebrates above background levels that makes the log an attractive food source for foraging vertebrates.
- Evidence of feeding that took place when the tree was still standing (unless the live invertebrates are still present).
- Old sapsucker holes. Sapsuckers drill small, uniformly-spaced holes in horizontal lines in the bark of living trees, but do not use these holes once the tree is dead.

CWD7: Diagonal logs creating access into the snowpack

Main functions: Travel

Main users: Marten, Fisher

Log decay classes: 1, 2

Recognizing CWD7:

Look for:

- Diagonal logs that are at least 20 cm in diameter at 60 cm above the ground surface, creating a break in the snowpack that gives Martens and Fishers access to resting and hunting sites below the snow.

Appendix 2. Sample data sheet used for CWD sampling at Aleza Lake, summer 2009.

Study area ____________ **Block** ______ **Plot** ____ **Transect** ______ **Azimuth**________ **Transect length** _______

Date_______________ **Observers**______________________**Notes**____

Piece No.	Dist	Sp	Diam (cm)	Tilt angle deg	Horiz length cm	Vert depth cm	Piece Length	Decay Class Piece	Orig	DSH	CWD Types 1	2	3	4	5	6	7	Comments