Appendix B – Consolidated Summary of Literature Describing the Effects of Riparian Management on Stream Shade and Stream Temperature

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Project	*Buffer/Harvest*	Vegetation Response	"Shade" Response	Water Temperature Response
1.1 and 1.2 - Variable Buffer Widths and Water Quality Ripstream Project – 1 and 2 Oregon Coast Range *Groom et al., 2011a* *and* *Groom et al., 2011b*	*18 "Private" Sites – Average "no-touch" buffer of **26m**, and clearcut harvests were generally outside of this zone. Four sites had harvest only on one bank of the river. Average treatment length for "Private" sites was 600 m.* *15 "State" Sites - Average "no-touch" buffer of **47m**, and thinning was the dominate harvest activities outside of this zone. Thirteen sites had harvest on only one bank of the river. Average treatment length for "State" sites was 800 m.* *Two years of pre-harvest and two years of post-harvest data was used in this analysis.*	Average "Private" site post-harvest basal area were reduced by around half (i.e., Pre-harvest levels were 43 m^2/ha and post-harvest levels were 25 m^2/ha). Average post-treatment buffer basal area (m^2/ha) for "State" sites was 42, which is an increase over pre-harvest levels (i.e., Pre-harvest levels were 41 m^2/ha).	"Private" site post-harvest stream shade values differed significantly from pre-harvest values (mean change in Shade from 85% to 78%); however, very little difference was found for "State" site stream shade values (mean change in Shade from 90% to 89%). The shade model BasalXHeight which included parameters for basal area per hectare (BAPH), tree height, and their interaction was best-supported: Its model weight (ω = 1.00) indicated strong relative support for this model and virtually no support for the remaining models. Accordingly, stream shade conditions were shown to be a function of tree height and stand density (i.e., basal area - BAPH). Sites with wider uncut buffers, or fewer stream banks harvested had greater basal area (i.e., BAPH). Sites with higher basal area within 30 m of the stream resulted in higher post-harvest shade.	Authors observed an increase in maximum temperature pre-harvest to post-harvest for sites that exhibited an absolute change in shade of > 6%; otherwise, directionality appears to fluctuate. "Private" sites pre-harvest to post-harvest temperatures increased on average by 0.7 °C with an observed range of response from −0.9 to 2.5 °C. In addition, mean temperatures increased by 0.37 C, minimum temperatures by 0.13 C, and diel fluctuation increased by 0.58 C. Timber harvested on "Private" sites had a 40.1% probability that the daily maximum temperature response will be >0.3 C (i.e., exceed the Protect Cold Water (PCW) criteria). "State" forest riparian stands did not exhibit exceedance rates of the PCW criteria that differed from preharvest, control, or downstream rates (i.e., 5%). Observed temperature changes at "State" sites were as frequently positive as negative: The average observed maximum change at "State" sites was 0.0 °C, however there were several sites with temperature increases near 1.5 °C due to harvest activities.

Project	Buffer/Harvest	Vegetation Response	“Shade” Response	Water Temperature Response
1.3 - Vegetation Buffers and Water Quality Coast Range of Washington Study Coast Range of Washington State *Jackson et al., 2001*	Four stand conditions: (1) No adjacent harvest (reference stream), (2) standard clearcut, (3) full riparian buffer, and (4) a non-merchantable harvest (There was very little non-merchantable vegetation so these effectively became clearcut harvest.). Widths of buffers applied to the buffered streams were dictated by operational considerations and the widths of the linear buffers ranges from 8 to 10 meters on each side of the channel. The stream length harvested was not presented. It appears that there was two years of water temperature data collect - one year of pre-harvest data and one year of post-harvest data.	Not Presented	Not Presented	Streams with no buffer did not have a statistically significant temperature response as a result of the streams being buried by a layer of slash that was deposited over these streams. Four of the five buffered streams became warmer (+2.0, 2.6, 2.8 and 4.9 C), and one became slightly cooler (-0.5 C) (Site 17E). The year following harvest at Site 17E had blowdown of some of the riparian vegetation, which buried 29% of the sample reach. This covering up of the stream channel confounded the temperature response for this sample reach (added additional shade), and thus it could be expected that the response temperature may have been warmer without the blowdown vegetation lying on top of 29% of the stream reach length. Temperature recovery is not observable because there was only one year of post harvest data. However, “significant” blowdown was observed in the year following this study period (2000), indicating that temperatures may have increased due to potentially elevated solar loading from the low shade levels following blowdown of the riparian vegetation.

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
1.4 - Variable Buffer Widths and Water Quality Malcolm Knapp Research Forest Study - 1 Coastal British Columbia (**49^{o} Latitude**) *Kiffney et al., 2003*	Riparian no-touch buffer widths were **10m** and **30m**. There were control (no harvest) and a zero meter buffer (clearcut to stream). Stream treatment length ranged from 215 to 650 meters. Appears to have pre-harvest data and one year of post-harvest data collection.	Not Presented	Mean solar flux (i.e., photosynthetically active radiation – PAR) reaching the stream with a clear-cut (zero meters), 10-m, and 30-m treatment buffers were 58, 16, and 5 times greater than compared with the control, respectively. This corresponds with an approximate reduction of 3 and 26 units of shade associated with the 30 m and 10 m buffers, respectively, as compared to the control. Authors concluded that "our observations suggest that additional light penetration comes through the sides of the buffer" and that there was a significant relationship between light levels and buffer width along small streams.	Compared with controls, mean daily maximum summer water temperatures increased by 1.6, 3.0, and 4.8 degrees Celsius for the 30 m, 10 m and zero meter (clearcut) harvest treatments, respectively.
1.5 - Variable Buffer Widths and Water Quality Malcolm Knapp Research Forest Study - 2 Coastal British Columbia (**49^{o} Latitude**) *Gomi et al., 2006*	Riparian no-touch buffer widths were **10m** and **30m**. There were control (no harvest) and a zero meter buffer (clearcut to stream). Stream treatment length ranged from 215 to 650 meters. **The sites used in this analysis were similar to that of Kiffney et al., 2003.** Time line was six years: Two years of pre- harvest, and post-harvest was four years.	Not presented for buffered streams.	Not Presented	The summer daily maximum temperature increased 4.1 C for the 10m buffer site, which indicated a significant treatment effect. The two 30 m buffer sites resulted in a 1.1 and 1.8 C increase of the daily maximum temperatures: 1.8 C treatment effect was statistically significant, but the 1.1 C treatment effect was not.

Project	Buffer/Harvest	Vegetation Response	“Shade” Response	Water Temperature Response
1.6 - Variable Buffer Widths and Water Quality Westside Type N Buffer Study – CEMR Western Washington *Schuett-Hames et al., 2011*	Eight sites had clear-cut harvest to the edge of the stream (clear-cut patches), thirteen had 50 foot wide no-cut buffers on both sides of the stream (50-ft buffers), and three had circular no-cut buffers with a 56 foot radius around the perennial initiation point (PIP buffers). An un-harvested reference reach was located in close proximity to each treatment site (not within 100 feet of the treatment site). Stream treatment length was a minimum of 300 ft. Standing tree data were collected in 2006 (three years after harvest), and in 2008 (five years after harvest).	In 50 ft buffered stands with minimum windthrow induced mortality (n=10), mean tree mortality for these buffers was 15%, and the mean density of live trees was 140 trees/acre five years after harvest (range 59-247). In 50 ft buffer stands with high windthrow induced mortality (n=3), mean tree mortality was 68.3% for these buffers over the five year period, and exceeded 90% in one case. The mean density of the remaining live trees was 62.8 trees/acre.	The first year following harvest stream shade decreased 13.4 shade units. In 50 ft buffered stands with minimum windthrow induced mortality (n=10), overhead shade in this group of buffers was 10-13 units of shade less than the reference reaches five years after harvest activities. In 50 ft buffer stands with high windthrow induced mortality (n=3), mean overhead shade five years after harvest was about 30 units of shade lower than the reference reaches five years after harvest activities.	Not Presented

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
1.7 - Variable Buffer Widths and Water Quality Rogue River Siskiyou National Forest Study Rogue River Siskiyou National Forest, Oregon *Park et al., 2008*	Thinning maintained the dominate trees and removed 80 to 100 stems per acre. Various "no-touch" buffer widths were maintained (i.e., 20, 40, 60, and 80 feet) with thinning occurring outside of this zone to distance of 180 ft from the stream. Stream treatment length for each treatment was 100 ft. It appears that Angular Canopy Density (ACD) values were collected soon after thinning activities	Reduced the stems per acre from around 220 to between 120 and 140 within the "thinned" zone.	Thinning the stand from 220 stems per acre to around 120 to 140 stems per acre increased the Angular Canopy Density (ACD) over the stream by 14% in one plot and 24% in another plot (Each treatment had two reported plot values). ACD reductions were observed for at least one plot at each of the "no-touch" buffer widths (up to 80 feet). The magnitude of decrease was lower as the "no-touch" buffer width increased, with average reductions in ACD near zero with a "no-touch buffer" of 60 feet.	Not Presented

Project	Buffer/Harvest	Vegetation Response	“Shade” Response	Water Temperature Response
1.8 - Variable Buffer Widths/Thinnings and Water Quality Stuart-Takla Fisheries-Forestry Interaction Study Interior sub-boreal forests of northern British Columbia (**55° Latitude**) *Macdonald et al., 2003*	Three harvest conditions: 1) Low Retention Buffer – remove all merchantable timber (>15 cm and >20 cm dbh for pine and spruce-pine respectively) within **20 m** of stream, 2) High Retention Buffer – Remove all large merchantable timber > 30 cm dbh within the **20-30m** zone and 3) Patch cut – a high-retention along the lower 60% of the stream and removal of all riparian vegetation in the upper 40% of the watershed. Forest harvest actions outside of these buffer areas were not presented. Stream treatment length ranged from 185 to 810 meters. There are two reaches for the low and high retention buffers, and three control (unharvested) reaches. There was around 2 years of pre-harvest data, and 5 years of post harvest data.	Not Presented	Canopy density conditions over the stream were shown to decrease following harvest activities, from an average condition of 76 in the control group, to 17 and 9 percent canopy density for “High” Retention buffer (B3) and “Low” Retention buffer (B5), respectively.	The authors concluded that summer stream temperatures clearly increased following forest harvesting and found that water temperatures were still elevated 5 years following treatment for all riparian buffers used in the analysis. Summer maximum mean weekly temperature increased by an average of 2.4*C and 5 *C for the “low” retention buffers. For the “high” retention buffers, summer maximum mean weekly temperature increased by an average of 0.3*C and 1.7 *C. Several years of blowdown associated with the second listed high retention buffer and patch retention buffer increased the temperature response from this treatment. Before the blowdown event, this buffer had a temperature increase of over 1 C for the weekly average temperature condition, and it increased to near 2 C following the blowdown events. The other high retention buffer in this study had around a 0.5 C temperature increase following harvest: This reach was the largest stream, and had very little stream length exposed to cutblocks (375 m). No temperature recover was observed after five years.

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
1.9 - Variable Buffer Widths/Thinnings and Water Quality Western Maine Project Western Maine (45° Latitude) *Wilkerson et al., 2006*	Fifteen streams were assigned to one of five treatments: (1) clearcut with no stream buffer (less than 6.8 m^2/ha residual basal area); (2) a thinned 11-m buffer (thinning target of 13.7 m^2/ha) and clearcut outside of this zone; (3) a thinned 23-m buffer (thinning target of 13.7 m^2/ha) and clearcut outside of this zone; (4) partial cuts with no designated buffer (retaining at least 13.7 m^2/ha residual basal area in the harvest zone); and (5) un-harvested controls. Stream treatment length was 300m and was on both sides of the stream. There were three replicates of each treatment. Time line was 3 years: one year of pre-harvest data and two years of post-harvest data.	Basal area values associated with "clearcut harvest" stands in this study were reduced to levels well below the minimum target (retain at least 6.9 m^2/ha). The basal associated with the partial-harvest treatment ranged from 14.0 to 18.9 m^2/ha. Thinning targets associated with the buffered streams (11 m and 23-m) exceeded the 13.8^2/ha target in 5 of the 6 streams (only one was slightly below 13.5^2/ha).	Canopy closure measured in the middle of the stream channel was reduced by average of 11% in the 11m group (i.e., average canopy cover was 94 before treatment and 84 following treatment), and 4% the 23m group (Average canopy cover was 94 before treatment and 90 following treatment.).	The temperature increase associated with the 11m buffer ranged from 1.0 to 1.4 C. They did not report a temperature increase associated with the 23 m and partial harvest buffers. They speculated that high subsurface groundwater flow significantly mitigated the effects of canopy removal by slowing temperature increases. No apparent temperature recovery was observed after 3 years.

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
1.10 - Vegetation Buffers and Water Quality Washington Headwater Stream Study Western Washington (46.5^{o} Latitude) *Janisch et al., 2012*	In small forested watershed (< 9 ha) the following three treatments were applied: (1) clearcut (n=5); (2) continuous buffered (n= 6); and (3) patch-buffered streams (n=5). In all three treatments, the upland portions of the catchments were clearcut harvested so that these treatments differed only in the way the riparian zone was harvested. The buffer width associated with the continuous buffer treatment was 20 meters on both side of the stream. The average stream treatment length for continuous buffer streams was 279 m, however only 43% of the stream length (on average) was observed to be flowing in the first post harvest year. There were 6 continuous buffer treatment sites, each with a paired reference site. A seven year monitoring period (2002-2008), with three years of post harvest temperature data collection activities.	Not Presented	Stream shade was calculated from hemispherical photography, and included both canopy and topography. Stream shade averaged 94% over the stream channel before logging and did not differ significantly between reference and treatment reaches. Stream shade in reference sites did not change substantially (average = 94%) after logging activities occurred in the other sample reaches. Stream shade decrease to 86% on average for the continuous buffer treatment reaches. This corresponds to an average reduction of 8 units of stream "shade" associated with this treatment.	For continuous buffered catchments, temperature changes were significantly greater than zero ($\alpha = 0.05$) in the first two post-treatment years. In the third post-treatment year, the magnitude of the temperature change estimated from the statistical model was significantly different for most of the monitoring period, however it was shown to not be significantly different from zero after Julian day 228 (≈15th August) (It is important to point out that the absolute temperature response is still greater than zero during this last two week period). Temperature response was highest at the start of the evaluation period (i.e., July) and decreased in latter parts of the summer. The July-August average temperature change for the three post-treatment years for the continuous buffered streams was 0.8 ^{o}C, and the estimated average July 1st temperature change for the three post-treatment years was 1.1 ^{o}C. The authors concluded that overall, the area of surface water exposed to the ambient environment best explained aggregated temperature response. Shorter stream segment lengths were associated with coarse-substrate channels and shorter exposure lengths, and these streams tended to be thermally unresponsive to management activities.

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
1.11 - Vegetation Buffers and Water Quality Oregon Department of Forestry Stream Shade Study Coast Range of Oregon (45^{o} Latitude) *Allen and Dent, 2001*	The 13 sites in the Coast Range managed with a "no-cut" buffer had an average "no-cut" buffer width of 49.6 feet (15 m). Clearcut harvest occurred outside of this no-cut zone. The average stream width for these sites was 6.6 feet, and ranged from 3.2 to 12.8 feet. The plot had a minimum length of 500 feet and maximum length of 1000 feet. Unharvested stand data were collected at sites adjacent, or in close proximity, to harvested stands in order to sample shade conditions that may have existed prior to entry. A time line was not presented	Not Presented	The average shade measured at the unharvested sites in the Coast Range was 89 % (i.e., 95, 85, 89, 93, and 83). The average difference in shade conditions associated with the 13 no-cut streams in the Oregon Coast Range was 14.5 units of shade, ranging from 4 to 27 units.	Not Presented

Project	Buffer/Harvest	Vegetation Response	“Shade” Response	Water Temperature Response
2.1 - Riparian Thinning with “Warm” Headwater Conditions North Central British Columbia Project North-Central British Columbia (55^{o} – Latitude) *Mellina et al., 2002*	Three small, lake headed, forest streams. Two sites (118/16 and 118/48) had thinning out of all mature commercial timber (>15 cm dbh for lodgepole pine and >20 cm dbh for spruce and subalpine fir) within a 30 m buffer surrounding the stream and clearcut occurred outside of this zone. The third site was an unharvested control. Stream treatment length was 607 m and 372 m for the treatment reaches and 430 m for the unharvested reach. The time line was four years: One year of pre-harvest data, and three years of post-harvest data.	Harvesting removed around 50% of streamside vegetation.	Following harvest, canopy cover over the stream decreased from 88% to 48% and 51% for sites 118/16and 118/48, respectively.	Maximum stream temperatures and diurnal fluctuations increased as a result of harvesting, but the magnitude of change was lower than expected because the water entering the treatment reach was warm lake water discharge. Relative to pre-harvest patterns, maximum temperatures for the two treatment streams increased by a net average of 0.4 C, and diurnal fluctuations increase by a net average of 1.1 C. The authors concluded that these are modest changes (compared with literature values) may reflect the effect of headwater lakes on outlet stream temperature. The dominate downstream cooling observed both before and after harvest was attributed to the combination of warm source temperature associated with the lakes and the strong cooling effect of ground water inflow through the clear-cut, as well as the residual shade provided by the partially logged riparian buffer. No apparent temperature recovery was observed over three years.

Project	Buffer/Harvest	Vegetation Response	“Shade” Response	Water Temperature Response
2.2 - Riparian Thinning with “Warm” Headwater Conditions White River Riparian Harvesting Impacts Project Boreal Shield near White River, Ontario (**48° Latitude**) *Kreutzweiser et al., 2009*	Thirty to 100m wide riparian buffers were “thinned” to basal area reduction of 20.4% (Site WR1), 28.6% (WR2), and 10.8% (WR6). (It is important to note that the preharvest basal area volume was not presented.) There was a 5 m no entry zone. These levels were assessed by postlogging measurements of residual trees and stumps. Three sites had not been previously been logged and serve as reference conditions. Stream treatment length was 600 m (WR1), 840 m (WR2) and 550m (WR6). Site WR6 was harvested during the second year so there was only one year of preharvest data for this site, and three years of post-harvest data. The other two harvest sites (WR1 and WR2) had two years of pre-harvest data and two years of post-harvest data.	Thirty to 100m wide riparian buffers were “thinned” to basal area reduction of 20.4% (Site WR1), 28.6% (WR2), and 10.8% (WR6). (It is important to note that the preharvest basal area volume was not presented.)	Site WR1 (20.4% of basal area removed) had a 12% reduction of canopy cover but no increase in ambient light (PAR) reaching the stream surface. WR2 (28.6% of basal area removed) had no detectable change in canopy cover removed but average light reaching the stream surface increase (but not significantly). Canopy density and PAR were not measured for site WR6 because the “logging occurred in only small sections of one side of the stream, and mature streamside trees at WR6 tended to be further removed from the stream edges than at WR1 or WR2.”	All streams originated from beaver ponds and flowed downstream through the harvest or reference blocks. Accordingly, all sites exhibited as much as 6-8 C of cooling in the forested reaches over the 240-600m distances between upstream pond outflows and downstream locations during the monitoring period. This is an expected condition (Mellina et al., 2002: Story et al., 2003). The only site that had reduced cooling during the post harvest summer period was WR2 (28.6% of basal area removed). The authors inferred that is possible that shallow groundwater inflow temperatures were elevated by increase solar radiation and soil warming in the upland clearcut and parts of the riparian forest around this site. Instream temperature downstream of WR 2 (28.6% of basal area removed) increased by around 4.4 C in the first post-logging year. Temperatures returned to pre-harvest levels by the second post-harvest year. Stream temperatures at WR1 (20.4% of basal area removed) became more variable following harvest, but were within the range of “preharvest weekly temperatures”. Stream temperatures at WR6 (10.8% of basal area removed) were elevated in one of the three post-harvest monitoring years. The authors summarized that the temperature impacts were not observed on the second post harvest year.

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
2.3 - Riparian Buffer with "Warm" Headwater Conditions Copper Lake Watershed Study Western Newfoundland, Canada (48.5^o Latitude) *Curry et al., 2002*	19 ha were harvested in one stream without a buffer strip (Site T1-1). A harvest area of 33 ha with a 20 m buffer strip was applied to another stream. The 20m buffer strip was primarily on one side of the stream (Site T1-2). There was a control (no harvest) watershed. Time line was five years (1993 through 1997). Harvest occurred November 1994 through January 1995, along with June and July 1996.	Not Presented	Authors stated that "there was forest buffer zone to protect the stream from solar loading" associated with the 20m buffer stream. However, there was no information to support this claim.	Harvest reaches were downstream of lakes and therefore stream temperatures entering the reach are elevated. Because this study was focusing on affects to brook trout, the evaluation period was fall, winter, and spring. Summer period results were not presented. Stream temperatures trends in the control (no harvest) basin paralleled air-temperature trends. Compared to control reach, spring stream temperatures in 20m buffer increased by an average of 2.7 *C in the three years following treatment activities. Authors speculate the warming of stream water in the 20 m buffer stream suggests "the mechanism of temperature change was related to groundwater flow to the stream and not direct solar inputs, i.e., there was forest buffer zone to protect the stream from solar radiation." That is, temperature increases are a result of elevated surface temperature associated with the clearcut zones warming up the groundwater which enters the stream. The authors observed a temperature recover in the last year of the study, however it appeared that the spring period during this last year was an extremely cool period (i.e., the clearcut harvest treatment reach was cooler than pre-harvest temperature conditions.)

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3.1 - Stream Shade Modeling Effects of Riparian Buffer Width, Density and Height Modeled shade conditions 40^{o}N Latitude *DeWalle., 2010*	Not specifically outlined in the analysis. The riparian buffer was modified to illustrate the effects of various buffer attributes and resulting shade conditions.	Input parameter in model	Vegetation on the north bank buffer of an east-west aspect stream can produce up to 30% of the daily shade occurring on the stream surface. The **density** of the buffer is one of the most important controls on buffer shading. Relatively high shading was only achieved with the high buffer densities. Shading by vegetation along a stream increased as **buffer width** was increased. Shading is primarily associated with the top of the vegetation (i.e., shadow length) at narrower buffer widths. Outside of this “inner” zone, sunlight traveling through the side of the buffer increases in importance towards shade production. Stream shading increased rapidly with increased **buffer height**. Shading is primarily associated with the side of the vegetation at shorter vegetation heights. Outside of this “inner” zone, sunlight traveling through the top of the vegetation (i.e., shadow length) increases in importance towards shade production.	Not Presented

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
3.2 - Stream Shade Modeling Potential Shadow Length Associated with Riparian Vegetation Modeled shade conditions 45.7^{o}N Latitude *Leinenbach, 2011*	Not specifically outlined in the analysis. Vegetation height was modified to illustrate the potential shadow length associated with various tree height conditions at various hillslope angles and at various months of the year along a stream situated at a latitude of 45.7^{o}N.	Input parameter in model	Results indicate that a tree located on a flat hillslope along the stream **within a distance of its height** can be influential on shade production (i.e., the shadow length associated with the tree is long enough to reach the stream), and ultimately on stream temperature during the summer period (July/August). However, there are commonly occurring situations which trees outside of this distance can contribute to shade production (For example, a 100 foot tall tree located on a hillslope of 20 degrees can cast a 169 foot long shadow at 4 PM during the late summer.).	Not Presented

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
3.3 and 3.4 - Stream Shade and Temperature Modeling Variable Buffer Widths/Thinnings and Water Quality Western Washington (**46.65° Latitude**) *Science Team Review, 2008* *and* *ODEQ Memorandum, 2008*	Four buffer conditions were evaluated for BLM administered lands along Canton Creek, Oregon (North Umpqua Basin): (1) A 46 m (150 ft) no-touch buffer width; (2) A 31 m (100 ft) no-touch buffer width; (3) A 31 m variable retention buffer (i.e., 18 m (60 ft) no-touch buffer, with a 13 m (40 ft) 50% canopy cover outside of the "no-touch" zone); and (4) A 46 m variable retention buffer (i.e., 18 m (60 ft) no-touch buffer, with a 28 m (90 ft) 50% canopy cover outside of the "no-touch" zone). Clearcut occurred outside of this zone. Pre-thinning canopy cover associated with large conifers was 80%. Calculated shade conditions associated with the various buffer combinations were modeled for shade and temperature response using Heat Source 7.0.	Input parameter in model	Very little shade reduction was observed associated with the 46 m "no-touch" buffer (maximum reduction was 1 unit of percent shade). The 31 m no-touch buffer had shade reductions of over 10 units at several locations, while other areas had only minimum reductions (i.e. 1 unit of percent shade). There were many more areas with 1 unit of shade reduction than was observed for the 46 m no-touch buffer. The 31 m variable retention buffer had shade reduction of over 12 units of shade at several locations along the river, with two regions of the river approaching a reduction of 20 units of shade. There were many more areas with 1 unit of shade reduction than was observed for the 46 m and 31 m no-touch buffers. The 46 m variable retention buffer had shade reductions of around 4 units at several locations along the river. There were many more areas with 1 unit of shade reduction than was observed for the 46 m no-touch buffer.	Temperature response was expressed as the maximum change in the seven day average of the maximum daily temperature during the modeling period (July 12th through July 31st). Very little (less than 0.1 C) increase in water temperature was observed for the 46 m "no-touch" buffer. The 31 m no-touch buffer produced changes in stream temperature in excess of 0.5° C at one location along Canton Creek, and temperature increases of over 0.2 C at several other locations. The 31 m variable retention buffer produced changes in stream temperature in excess of 0.6° C at one location along Canton Creek, and temperature increases of over 0.2 C at several other locations. The 46 m variable retention buffer produced changes in stream temperature approaching 0.2° C.

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3.5 - Stream Shade and Temperature Modeling Variable Buffer Widths and Water Quality Western Washington (**46.65° Latitude**) *Cristea and Janish, 2007*	Variable "no-touch" buffer widths were tested (i.e., **9m**, **15m**, and **23m**) with a vegetation height of 15 m. Harvest unit on only one side of the stream. Angular canopy density for each buffer width condition was estimated using two models (Brazier and Brown, 1973; Steinblums et al., 1984), which was used as an estimate of canopy cover condition in the "Shade.xls" model. Calculated shade conditions associated with the various channel width and buffer combinations were modeled for temperature response using QUAL2Kw.	Input parameter in model	As the riparian buffer width was reduced from 23 m to 15 m, stream shade was reduced by 4 to 8 units of shade for a 3m wide stream channel. As the riparian buffer width was reduced from 23 m to 9 m on a 3 m wide stream, stream shade was reduced by 12 to 16 units of shade.	For a 3 m wide stream channel after 472m stream channel distance, stream temperatures in creased between 0.11 and 0.17 C as the riparian buffer width was reduced from 23 m to 15 m. For a 3 m wide stream channel after 472m stream channel distance, stream temperatures in creased between 0.27 and 0.33 C as the riparian buffer width was reduced from 23 m to 9 m. Temperature results associated with the 6m channel indicate that the "shadow length" from the 15 m tall vegetation was not sufficient to cast a proper shadow across the stream leading to very low shade conditions. Accordingly, despite greater shade conditions associated with the wider riparian buffers, the temperature response was muted in the 6m stream channel. In other words, shade levels for the 6m stream are low for all buffer width conditions and therefore stream temperature increases are high for all scenarios.

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4.1 - Effects of Riparian Thinning Riparian Buffer Component of the Density Management Studies Project - 1 Oregon Coast Range and west side of the Cascade Mountains in western Oregon. *Chan et al., 2004a*	Thinning treatments include: 1) Unthinned control – 500 to 750 trees per ha (tph) greater than 12.7 cm dbh. 2) High density retention – 70 to 75% of area thinned to 300 tph, 25 to 30% unthinned Riparian Reserves or leave islands. 3) Moderate density retention – 60 to 65% thinned to 200 tph, 25 to 30% unthinned Riparian Reserves or leave islands, 10% circular patch openings. 4) Variable density retention.	Thinning to 200 tph decreased stand density by up to 70% (i.e., unthinned controls had 500 to 700 tph).	Thinning to 200 tph increased available light from 10 to 16 units of shade in the buffer (i.e., 13–19% in the unthinned buffer to about 29% within the thinned buffer). Light values indicate that upland thinning to 200 tph increases available light within the first **20 m** of the adjacent riparian buffer. Thus, the authors conclude that thinning may result in some significant (but potentially transitory) changes in stand light and microclimate conditions.	Not Presented
4.2 - Effects of Riparian Thinning Riparian Buffer Component of the Density Management Studies Project - 2 Oregon Coast Range and west side of the Cascade Mountains in western Oregon. *Chan et al., 2004b*	See above for Chan et al., 2004a	Not Presented	Commercial thinning substantially increased understory light when stand density was decreased to a basal area (BA) less than 120 ft^2/ac, or in other terms, below a relative density (RD) of 30. At BA ≥ 160 ft^2/ac, and RD ≥40, light levels average about 10% of open conditions, similar to those of unthinned stands.	Not Presented

Project	Buffer/Harvest	Vegetation Response	"Shade" Response	Water Temperature Response
4.3 - Effects of Riparian Thinning Riparian Buffer Component of the Density Management Studies Project - 3 Oregon Coast Range and west side of the Cascade Mountains in western Oregon. *Anderson et al., 2007*	Three types of unharvested buffers were bounded by riparian harvest: (1) Streamside retention buffers (SR) – average **9 m** wide, which consisted of retaining all trees having a portion of their crown extending directly over the stream; (2) Variable width buffers (VB) – averaged **22m** wide, with an minimum buffer of 12m from the stream center and maximum width up to 32m; and (3) One site potential tree height buffer (B1) – **69m**, and ranging from 53 to 73 meters. There were two harvest activities occurring outside of the buffer zone: (1) patch opening (i.e., small (0.4-ha) clearcut harvest); and (2) thinning to a density of 198 trees per hectare (tph). (Unharvested controls reaches had around 500 to 750 tph (Chan et al., 2004)).	Basal areas of the thinned treatments were relatively constant over distance in the upslope, treated portions of the transects. Basal area reductions associated with the 0.4 ha patch treatments were observed.	Clearcut harvest outside of the 69m no-touch buffer ("B1-P") did not result in a significantly different light condition over the stream than the unharvested condition ("UT") and appears to be decreasing less than 1 unit of percent visible sky. Clearcut harvest outside of the 22m no-touch buffer ("VB-P") resulted in significantly higher light conditions over the stream ($p = 0.002$), increasing 5.1 units of percent visible sky.	None reported *Maximum **air** temperature above the stream for the SRT was similar to that of the thinned upslope and were 4 C warmer than observed for streams with unharvested stands. This indicates that the stream center and buffer microclimates were essentially the same as the upslope in the thinned stand. Although statistically insignificant, temperature maximum of the SRT treatment exceeded that for untreated stands by 4.5°C. Temperature increases above the stream associated with thinning retaining buffers of 22 m width (VBT) were approximately 1°C and statistically insignificant. Maximum soil and air temperatures were associated with the 0.4 ha circular patch openings for the patch sites and were the highest for all monitoring sites.*

Project	Buffer/Harvest	Vegetation Response	“Shade” Response	Water Temperature Response
4.4 - Effects of Riparian Thinning Over Time Oregon Coast Range Project Oregon Coast Range. *Chan et al., 2006*	Four Treatment Groups: (1) Unthinned (≈550 trees/ha (i.e., tph)); (2) light thinning (≈250 tph); (3) moderate thinning (≈150 tph); and (4) heavy thinning (≈75 tph). Stands were monitored over an eight year period.	Thinning reduced basal area (BA) by 51%, 67%, and 84% in lightly, moderately, and heavily thinned stands, respectively. Tree densities in thinned stands were reduced in the moderate and heavily thinned stands by windthrow and stem breakage during severe winter storms in the first 4 years of the study.	Immediately after thinning, % skylight through the canopy ranged from 2% in unthinned stands to 48% in heavily thinned stands. After 8 years, % skylight in lightly thinned stands was similar to levels in unthinned stands, and % skylight in moderately thinned stands had diminished to levels similar to those in lightly thinned stands just after thinning. Percent skylight for the moderate and heavy thinned stands was elevated above unthinned stand conditions for the eight year period associated with this study.	Not Presented

Project	Buffer/Harvest	Vegetation Response	“Shade” Response	Water Temperature Response
4.5 – Effects of Riparian Harvest on Microclimate Gradients Microclimate Gradients in Western Washington Study Western Washington State *Brosofske et al., 1997*	Variable no cut riparian buffer width: 23m (and 17m on other bank), 17m(23m), 25m (60m), 60m (25m), and 60m (25m). One year of pre-harvest and one year of post-harvest data collection.	Not Presented	Solar radiation and relative humidity did appear to have some association with buffer width. Edge influences appeared to allow solar load to penetrate the forest buffer and affect stream microclimate. Accordingly, the authors surmise that as the buffer widens the amount of solar radiation able to penetrate the vegetation and reach the stream station would decrease.	They did not find any relationship between water temperature and buffer width. It is important to point out that the temperature response associated with each treatment was not presented so it is not possible to determine the exact impact of various riparian buffer widths on stream temperature. Observe a strong influence of soil temperature in the surrounding land area on water temperature, even for sites well away from the stream. The authors concluded that this suggests that activity in the watershed up to or more than 180 m away may affect the stream even when a buffer strip is left intact. Authors conclude that a buffer at least 45 m on each side of the stream is necessary to maintain a natural riparian microclimatic environment along the stream.

Project	Buffer/Harvest	Vegetation Response	“Shade” Response	Water Temperature Response
4.6 – Effects of Riparian Harvest on Blowdown Coast Range of Washington Study Coast Range of Washington State *Jackson et al., 2007*	Four stand conditions: (1) No adjacent harvest (reference stream), (2) standard clearcut, (3) full riparian buffer, and (4) a non-merchantable harvest (There was very little non-merchantable vegetation so these effectively became clearcut harvest.). Widths of buffers applied to the buffered streams were dictated by operational considerations and the widths of the linear buffers ranges from 8 to 10 meters on each side of the channel. The stream length harvested was not presented.	Buffer blowdown was extensive in 2001 (two years following harvest activities associated with buffered streams). Blowdown ranged from 33 to 64% of buffered trees with attendant effects on canopy cover. After blowdown, the newly fallen trees either spanned the channels or lay beside the channels, so blow down trees were not adding woody debris to the channels or altering channel structure at the time of the study.	Not Presented	See *Jackson et al, 2001*