Effect of Strip-thinning on Stream Temperature Responses in Headwater Catchments

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INTRODUCTION

Timber harvesting by removal of forest stands along streams increased stream temperature ranging from 2° to 12 °C because of increases in solar radiation inputs (Moore et al., 2005). Most of the previous studies focused on evaluating the effects of clear-cutting on increases in stream temperature. More recently, forest thinning has been applied widely for the economic and ecological objectives of plantation forest around the word (Ishii et al., 2008). Previous studies found that thinning elevated stream temperature with 4.4° to 5.5°C in the first year after 50% randomly thinning in headwater streams, British Columbia (Kreutzweiser et al., 2009; Guenther et al., 2014). Hence, the effects of strip-thinning on stream temperature responses were not been examined. Furthermore, increased in stream temperature can be related to various factors such as solar radiation inputs, air temperature and stream discharge (Caissie, 2006). Such multiple factors may alter the variability of treatment effects after forest harvesting. Therefore, the objectives of this study were to (1) evaluate the rate of increases in stream temperature one year after 50% strip-thinning, and (2) identify factors for controlling the rate of increases in stream temperature.

STUDY SITE AND METHODOLOGY

The study was conducted in two headwater catchments named as treated K2 (17.1 ha) and control K3 (8.9 ha) in Mt. Karasawa (36°22'N, 139°36'E). The catchment elevations of two catchments range from 90 to 290 m above sea level, with the slope ranging from 20° to 45°. The orientation of two catchments is northwest. Both catchments are covered by 20-50 years Japanese cypress (*Chamaecyparis obtusa*) and cedar (*Cryptomeria japonica*) plantation. Catchment K2 was subjected to 50% of strip-thinning from July to December 2011, while forest in K3 remained as a control catchment. We focused on one year after thinning because most of the previous studies showed that stream temperature significantly increased in the first year after forest harvesting (Moore et al., 2005).

Stream temperature was obtained by TruTrack water level logger (precision ± 0.3°C) and HOBO TidbiT (precision ± 0.2 °C) at 5 mins interval. Automated HOBO U30-NRC Weather Station was installed in the open area for measuring meteorological variables. Paired catchment analysis for estimating treatment effects (T_e) was applied for daily maximum, mean, and minimum stream temperature (Gomi et al., 2006). The significance of T_e between the pre- and post-thinning was tested by a t-test with a 95% confidence level. For evaluating factors for controlling the variability of T_e from April to August 2012 in K2-1, multiple regression analysis was applied by using solar radiation, air temperature, relative humidity, wind speed, and stream discharge as explanatory variables. Prior to analysis, variables were standardized using the method proposed by Bring (1994). Stepwise selection was used to evaluate the statistical significance of these variables based on AICs. Statistical analysis was conducted using R software.

RESULTS AND DISCUSSION

[1] The rate of increases in stream temperature after one year forest thinning.

Annual mean air temperature and precipitation in pre- and post-thinning periods were 14.2°C and 1226 mm, 15.1°C and 1295.2 mm, respectively. T_e for daily maximum, mean, and minimum stream temperature in the post-thinning period was significantly higher than that of the pre-thinning ($p < 0.001$). The observed maximum stream temperature in K2 became 26.2°C, whereas in K3 was 21.5°C on 31 August 2012 of the post-thinning period.

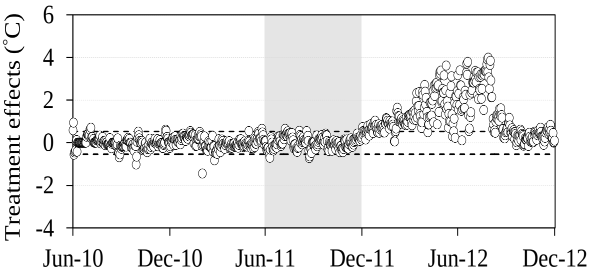

Fig 1. Time series of T_e for daily max stream temperature at catchment K2. The black dashed lines indicate bands of ±1.96 s_e (s_e is the standard residuals from regression). Shaded area shows period of thinning operation.

Mean T_e of daily maximum stream temperature was 1.3°C (SD ± 1.0°C) and maximum of T_e increased up to 4°C after one year forest thinning in treated catchment K2 (**Fig.1**). The magnitude of increases in T_e was similar to others thinning studies such as Kreutzweiser et al. (2009) and Guenther et al. (2014). By comparing clear-cutting studies with 8.8° to 12°C of T_e (Gomi et al., 2006; Harris, 1977), thinning by remaining trees and the recovery of understory vegetation at our sites possibly mitigated the rate of increases in T_e.

[2] Factors for controlling the variability of T_e.

The final model of multiple regression was selected based on the smallest of AICs score (Burnham and Anderson, 2004) with four out of five explanatory variables explained 77.8% the variability of T_e of daily maximum stream temperature from April to August 2012. Solar radiation accounted for the highest standardized regression coefficient (0.82) followed by stream discharge (-0.45) ($p < 0.001$), while the standardized regression coefficient of relative humidity and air temperature were 0.41 and 0.23 ($p < 0.001$), respectively. This result suggested that solar radiation inputs was primary factor for controlling rate of increases in stream temperature which is agree to the findings by Brown (1969). In addition, stream discharge was also an important factor for controlling T_e for daily maximum, mean, and minimum stream temperature. Because high flow volume required more thermal energy (Caissie, 2006), T_e became small values for the days with high discharge.

CONCLUSIONS

The findings of our study indicated that stream temperature in the first year after 50% strip-thinning increased up to 4°C depending on solar radiation inputs and stream discharge. The increases in stream temperature of this study tended to be small compared to clear-cut practices because of understory vegetation providing effective shading for the stream after forest harvesting. Thus, such detail information of the results of our study could be important for developing management application for mitigating and evaluation the impact of forest harvesting on stream temperatures.

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