Journal of Ecology and the Natural Environment Vol. 3(3), pp. 72-77, March 2011
Available online at http://www.academicjournals.org/jene
ISSN 2006- 9847©2011 Academic Journals

Full Length Research Paper

Preliminary study of the changes in water temperature at pond Cibuntu

Luki Subehi* and M. Fakhrudin

Research Centre for Limnology, Indonesian Institute of Sciences, Cibinong 16911, Indonesia.

Accepted 8 December, 2010

Water temperature is one of the important parameters in the aquatic systems, and it remains an interesting subject of world-wide environmental research. The objective of this study is to identify the parameters of hydrological, meteorological and topological that influence water temperature and its change at pond Cibuntu based on data from April 2008 to April 2009. In addition, the analysis of changes in water temperature during rainfall events could lead to the identification of the mechanisms that generates the initial response as direct inputs of rainwater. In order to gain an insight on water temperature fluctuations, the results of water temperature measurement for one year were statistically analyzed using root mean square (Rms) and harmonic methods. From our analysis, the highest temperatures of air (Ta) and water (Tw) were of 30.6 and 30.9°C, respectively. On the contrary, the lowest of those were 21.1 and 23.0°C, respectively. In addition, the highest values of Rms 7-days for Ta and Tw in September were 1.51 and 1.57, respectively. Based on hourly Tw changes during rainfall events, it seemed that subsurface flow influenced water temperature changes. In addition, the management of pond influenced the flow paths differently through the changes of infiltration rate, surface runoff, interflow/subsurface flow and groundwater percentage.

Key words: Water temperature, air temperature, root mean square, harmonic method, rainfall event.

INTRODUCTION

Most physical properties of water and the rates of many chemical and biological processes in water are expressed as functions of water temperature (Bogan et al., 2004; Caissie, 2006). In addition, most aquatic species have specific ranges of water temperature that they can tolerate (Jensen et al., 1989; Eaton and Scheller, 1996; Dunham et al., 2003). Some studies showed that the meteorological parameters (air, solar radiation, humidity, rainfall) as well as hydrological ones (water discharge, groundwater percentage) are among the main factors that influence water temperature changes (Sinokrot and Gulliver, 2000; Gu and Li, 2002; Sophocleous, 2002; Becker et al., 2004; Lambs, 2004; O'Driscoll and DeWalle, 2006).

Generally, between air and water temperatures, strong relationship could be established. It was supported by some scientific researches in which water temperature often had been related to air temperature and meteorological conditions as yearly or longer time-scale fluctuations (Mohseni et al., 1999; Fukushima et al., 2000; Ozaki et al., 2003; Webb et al., 2003; Hannah et al., 2004; Tung, 2006; Subehi et al., 2009; Subehi et al., 2010b).

In addition, it was found that during rainfall event, water temperature changes were influenced by different characteristic of flow paths (Subehi et al., 2010a). Rainfall events related to water flow paths at watersheds continue to be interesting for water temperature analysis. Changes in water temperature during rainfall events help to identify the mechanism that generates the initial response as direct inputs of rainwater, surface/subsurface flow or discharge of groundwater. An understanding of the processes underlying water temperature dynamics is fundamental for the assessment and prediction of thermal response to climatic variability and change.

The objectives of this study are: (1) To examine water

*Corresponding author. E-mail: luki@limnologi.lipi.go.id. Tel/Fax: 62-21 - 875 - 7071/62-21 - 875 – 7076.

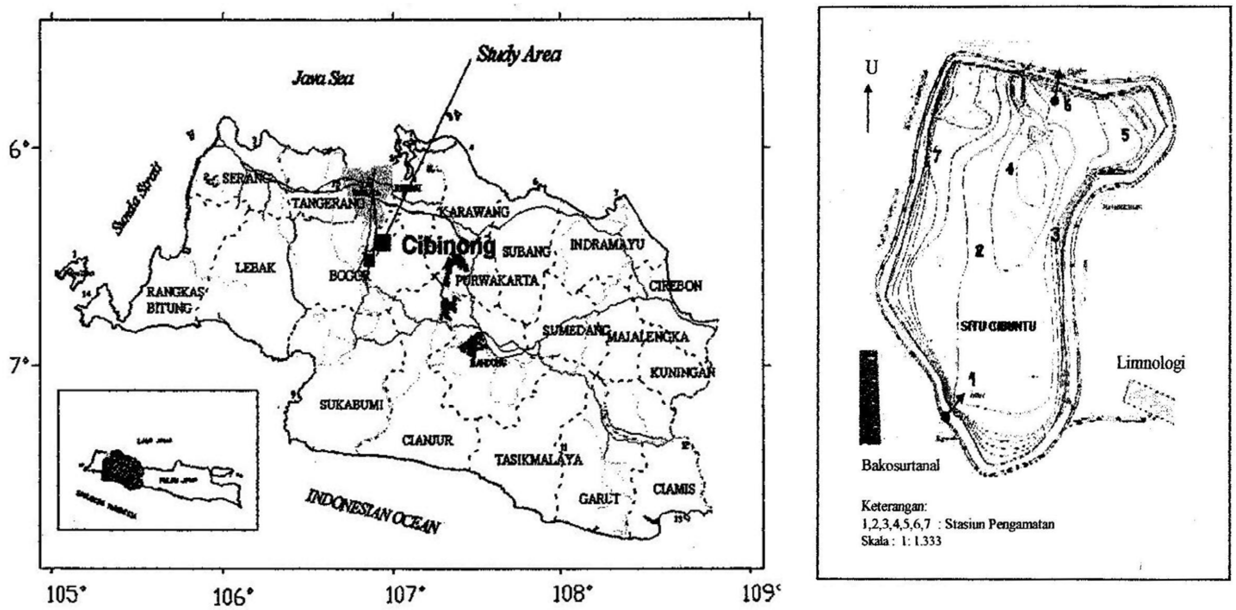

Figure 1. Location of study area.

temperature characteristics at pond Cibuntu, and (2) To elucidate the hydrological dynamics from water temperature changes. We analyzed water temperature at pond Cibuntu from April 2008 to April 2009.

MATERIALS AND METHODS

Pond Cibuntu as a small and shallow lake has surface area of about 15.83 m^2 with average depth of 0.88 m and volume of about 13.55 m^3 (Tarigan, 2001; Sulawesty et al., 2000). The studied area is located in Bogor district of West Java, Indonesia which lies 06°29'S, 103°51'E and 103 m above sea level (Figure 1).

The data on air and water temperatures were taken at intervals of 5 min from April 2008 to April 2009 by sensor, Global Water GL 500. In addition, rainfall was also measured by a tipping bucket rain gauge at intervals of 5 min during those periods.

For fluctuation temperature analysis, we used not only the standard deviation (σ) but also the root mean square variation over 7 days (Rms 7-days) using the formula:

$$\text{Rms 7-days} = \sqrt{(1/n)\sum_{i=1}^{n}(x_i - \overline{x}_i^m)^2} \quad (1)$$

where n represents the number of days analyzed (monthly: 28 to 31, yearly: 365), x_i is the daily average temperature (°C), and x_i^m is the m-day moving average of daily temperature.

We used 7 days for m. The weekly average temperature is commonly used to quantify water temperature changes (Bogan et al., 2004) because the weekly (7 days) timescale gives a good correlation between air and water temperatures (Pilgrim et al., 1998; Mohseni and Stefan, 1999) and also eliminates most transient variations, including diurnal effects of solar radiation and air temperature.

We also employed harmonic method, the representation of functions or signals as the approximation by means of basic harmonic waves:

$$y_T = A \sin (ct+\varphi) \quad (2)$$

where y_T represents the sine curve of temperature T; t is the time (day); A is the amplitude of temperature fluctuations; c defines the frequency: c equals $2\pi/L$ (L = time period = 365 days) and φ represents the phase shift.

Next, for the analysis during rainfall events, we selected the rainfall events of which the intensity rainfall is more than 5.0 mm/h. The changes of water temperature (ΔTw) and air temperature (ΔTa) during those events were observed.

RESULTS AND DISCUSSION

Daily air and water temperatures were observed (Figure 2) from April 2008 until April 2009. According to graph, air and water temperature changes were not so different. The largest of air and water temperatures were 30.6 and 30.9°C, respectively. On the contrary, the smallest of those were 21.1 and 23.0°C, respectively. Figure 3 shows the mathematical approximation of air and water temperatures more clearly by harmonic method. The maximal values of air temperatures were observed from May to August. On the other hand, the minimal values of water temperature were observed from September to December. It was suggested that the seasonal variations are reflected in the air and water temperature changes.

Based on fluctuations in air and water temperatures, expressed by Rms 7-days, one could assess that both

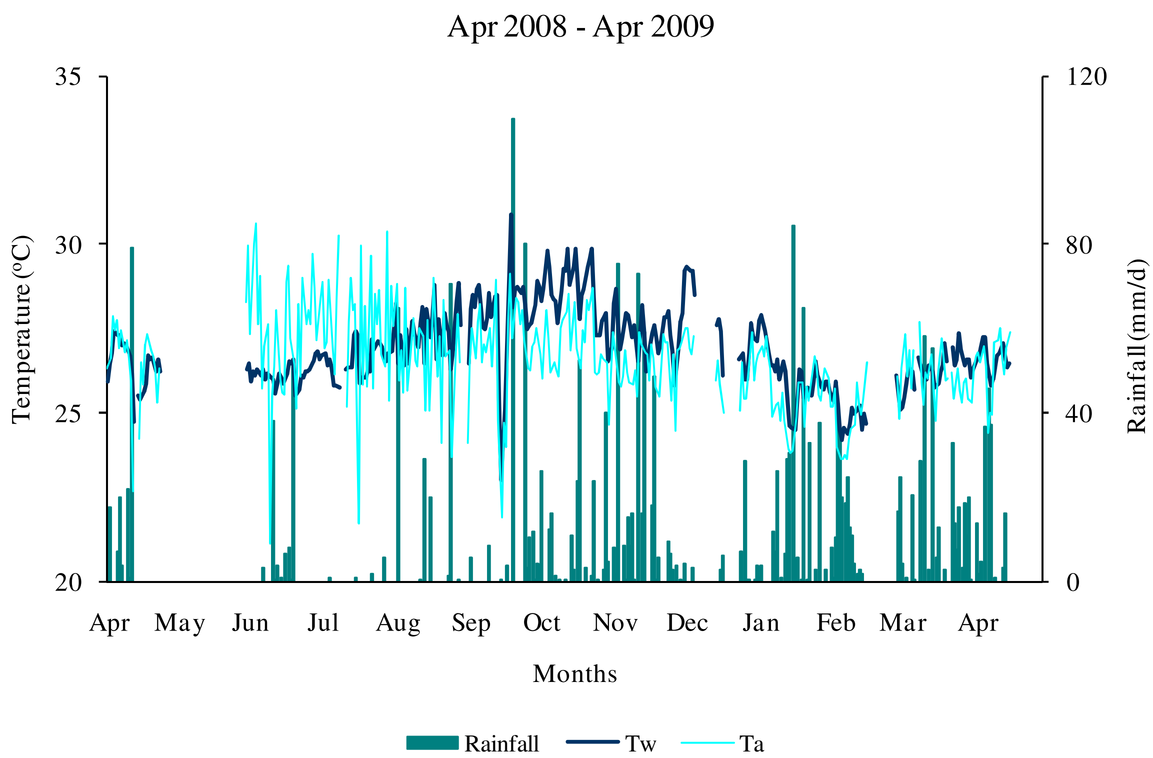

Figure 2. Daily air and water temperatures at pond Cibuntu.

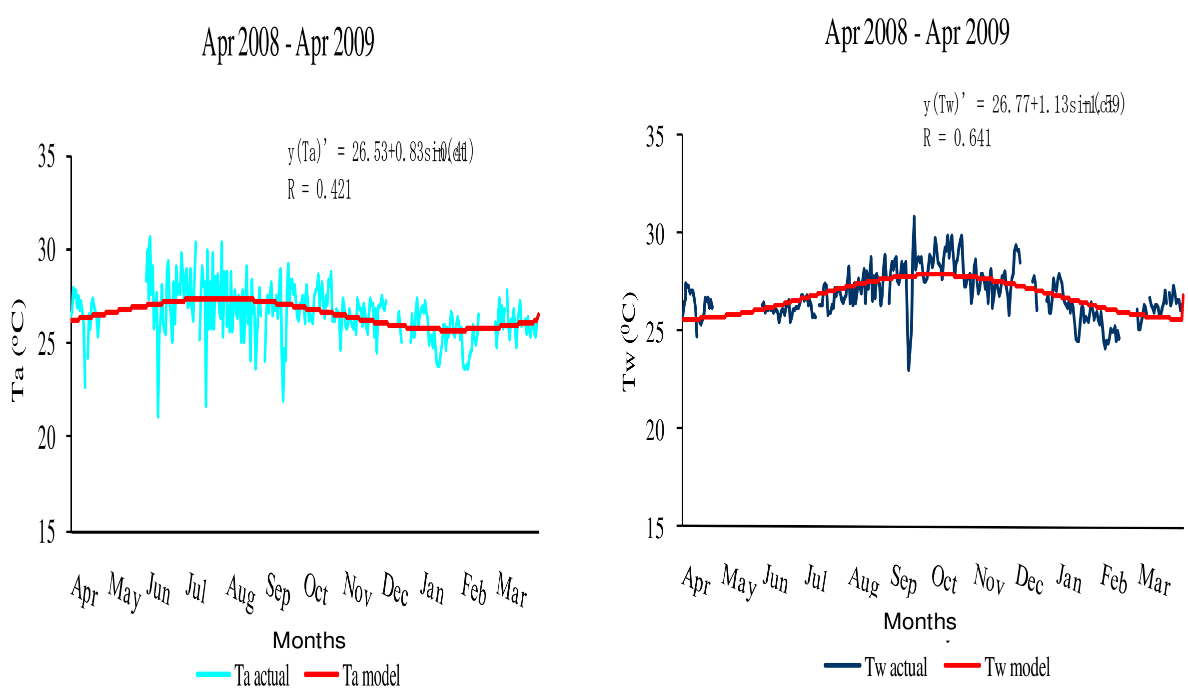

Figure 3. The changes in air and water temperatures by harmonic method analysis and correlation coefficient values.

fluctuations change rather proportional from March 2008 to March 2009 (Figure 4) with almost identical maximal values of Rms 7-days for Ta and Tw in September (1.51 and 1.57, respectively). As expected, the water

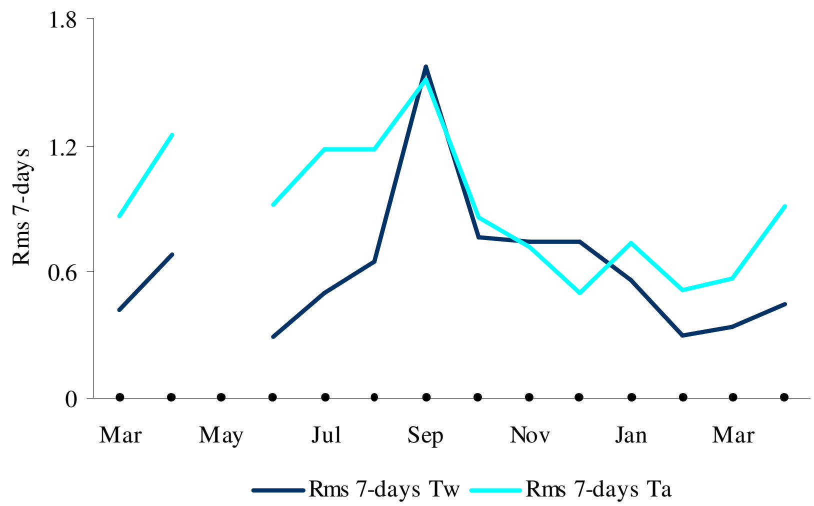

Figure 4. Monthly changes in Rms 7-days of daily air and water temperatures.

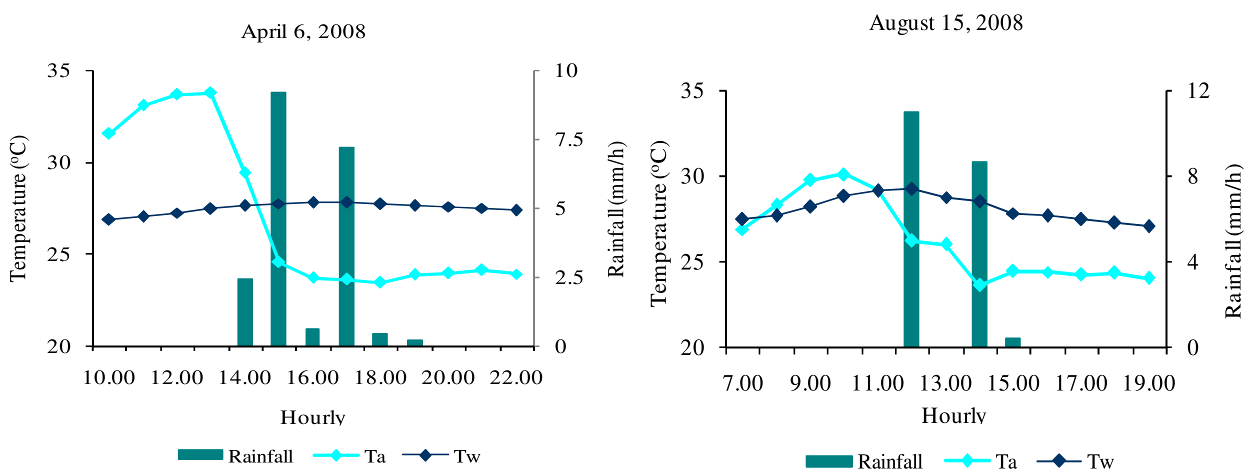

Figure 5. Hourly air and water temperatures on April and August.

temperature changes seasonally.

Next, in order to understand the hydrological dynamics, air and water temperatures changes were analyzed during rainfall events with the intensity rainfall of more than 5.0 mm/h (Figures 5 and 6, respectively). As shown in Figures 5 and 6, the air temperature decreased with increasing water temperature during rainfall events in hourly. It was suggested that subsurface flow or groundwater flow probably influenced water temperature conditions. Similarly, the data from September, December and February (Figure 6), suggest that probably large flow paths contributed from deeper pathways (subsurface and groundwater flows).

Rainfall is a specific event that influences water temperature changes through alteration of flow paths. Precipitation may cause changes in water temperature due to direct inputs and by inducing runoff from various hydrological stores and pathways (Kobayashi et al., 1999; Brown and Hannah, 2007). Changes in water temperature during rainfall events help to identify the mechanism that generates the initial response as direct inputs of rainwater, surface/subsurface flow or discharge of groundwater.

Besides the meteorological background, also the geological and topological parameters (like steep slope) should be considered as key parameters that could influence the proportion of flow paths. Water temperatures are predominantly related to weather and lake morphometry (Hondzo and Stefan, 1993a; Hondzo and Stefan, 1993b). In addition, solar radiation forces stabilize the density stratification and reduce vertical mixing resulting in shallow mixed layer depths (Herb and Stefan, 2004). It could be assumed that air temperature

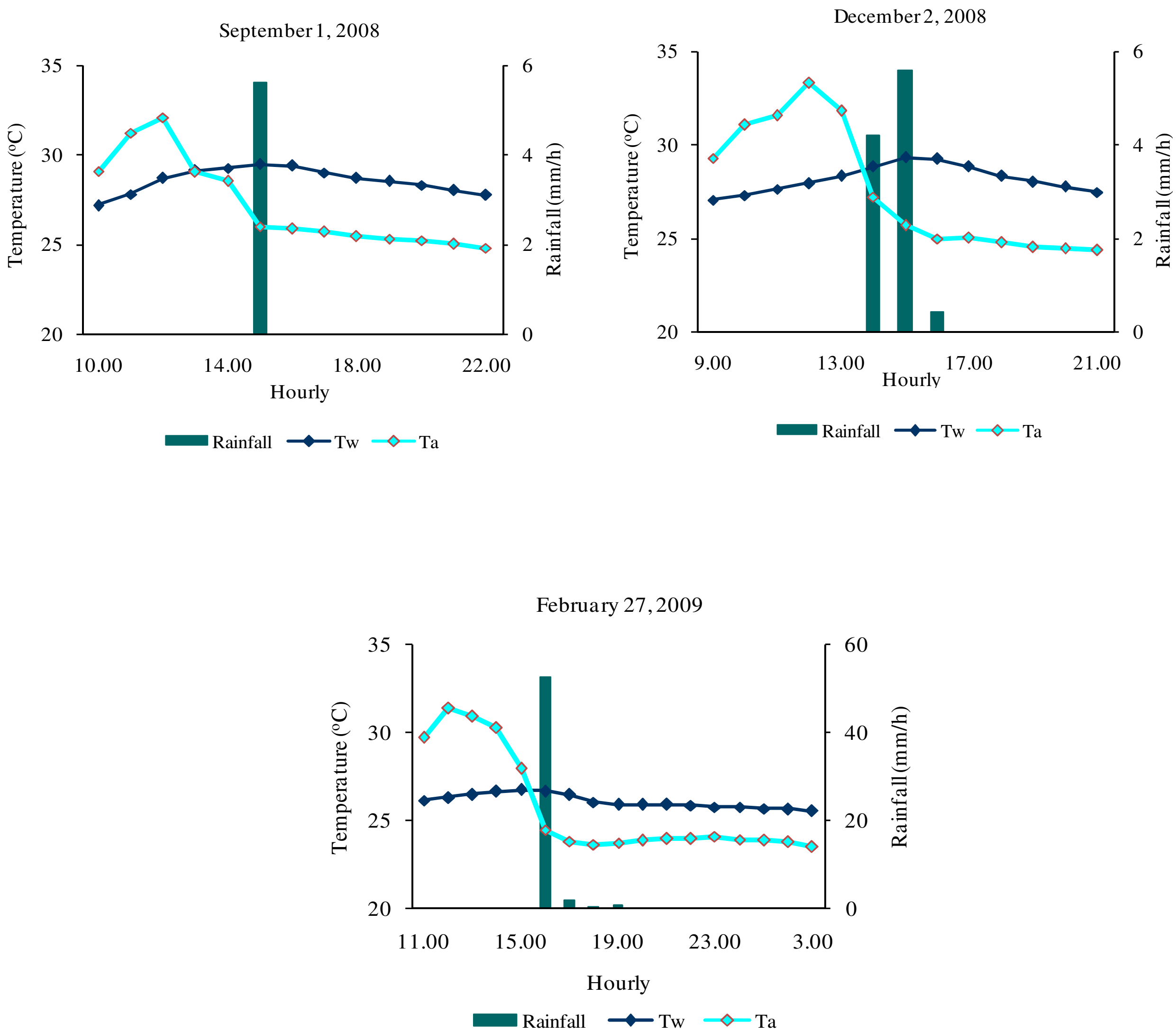

Figure 6. Hourly air and water temperatures on September, December and February.

fluctuations related to solar radiation affected water temperature.

Conclusion

Water temperature fluctuations are very important because every aquatic organism has a preferred temperature range for its life. A hypothesis on how water temperature changes in yearly intervals and during rainfall events at pond Cibuntu was developed and tested.

Based on the analyses, not only meteorological parameter but also geological and topological conditions affected water temperature. Interactions among surface, subsurface and groundwater flows during rainfall events were suggested as possible factors affecting the temperature dynamics from this study. Next, soil temperature and groundwater analysis, combined with geological and topological at pond Cibuntu are planned to be investigated to understand the water temperature dynamics in the future research.

ACKNOWLEDGEMENTS

This study was supported by Research Centre for Limnology Project, Indonesian Institute of Sciences (LIPI). We express our thanks to all members who were involved in this project.

REFERENCES

Becker MW, Georgian T, Ambrose H, Siniscalchi J, Fredrick K (2004). Estimating flow and flux of groundwater discharge using water

temperature and velocity. J. Hydrol., 296: 221-233.
Bogan T, Stefan HG, Mohseni O (2004). Imprints of secondary heat sources on the stream temperature/equilibrium temperature relationship. Water Resour. Res., 40: 1-16.
Brown LE, Hannah DM (2007). Alpine stream temperature response to storm events. J. Hydrometeorol., 8: 952-967.
Caissie D (2006). The thermal regime of rivers: A review. Freshwater Biol., 51: 1389-1406.
Dunham J, Schroeter R, Rieman B (2003). Influence of maximum water temperature on occurrence of Lahontan cutthroat trout within streams. North Am. J. Fisheries Manage., 23: 1042-1049.
Eaton GJ, Scheller RM (1996). Effects of climate warming on fish thermal habitat in stream of the United States. Limnol. Oceanogr., 41: 1109-1115.
Fukushima T, Ozaki N, Kaminishi H, Harasawa H, Matsushige K (2000). Forecasting the changes in lake water quality in response to climate changes, using past relationships between meteorological conditions and water quality. Hydrol. Process., 14: 593-604.
Gu RR, Li Y (2002). River temperature sensitivity to hydraulic and meteorological parameters. J. Environ. Manage., 66: 43-56.
Hannah DM, Malcolm IA, Soulsby C, Youngson AF (2004). Heat exchanges and temperatures within a salmon spawning stream in the Cairngorms, Scotland: Seasonal and sub-seasonal dynamics. River Res. Appl., 20: 635-652.
Herb W, Stefan HG (2004). Temperature stratification and mixing dynamics in a shallow lake with submersed macrophytes. Lake Reservoir Manage., 20: 296-308.
Hondzo M, Stefan HG (1993a) Regional water temperature characteristics of lakes subjected to climate change. Climat. Change, 24: 187-211.
Hondzo M, Stefan HG (1993b). Lake water temperature simulation model. J. Hydraulic Eng., 119: 1251-1273.
Jensen AJ, Johnsen BO, Saksgard L (1989). Temperature requirements in Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), and Arctic char (*Salvelinus alpinus*) from hatching to initial feeding compared with geographic-distribution. Can. J. Fisheries Aquat. Sci., 46: 786-789.
Kobayashi D, Ishii Y, Kodama Y (1999). Stream temperature, specific conductance and runoff process in mountain watersheds. Hydrol. Process., 13: 865-876.
Lambs L (2004). Interactions between groundwater and surface water at river banks and the confluence of rivers. J. Hydrol., 288: 312-326.
Mohseni O, Stefan HG (1999). Stream temperature/air temperature relationship: A physical interpretation. J. Hydrol., 218: 128-141.
O'Driscoll MA, DeWalle DR (2006). Stream-air temperature relations to classify stream-ground water interactions in a karst setting, Central Pennsylvania, USA. J. Hydrol., 329: 140-153.
Ozaki N, Fukushima T, Harasawa H, Kojiri T, Kawashima K, Ono M (2003). Statistical analyses on the effects of air temperature fluctuations on river water qualities. Hydrol. Process., 17: 2837-2853.
Pilgrim JM, Fang X, Stefan HG (1998). Stream temperature correlation with air temperature in Minnesota: implications for climate warming. J. Am. Water Resour. Assoc., 34: 1109–1121.
Sinokrot BA, Gulliver JS (2000). In-stream flow impact on river water temperatures. J. Hydraulic Res., 38: 339–349.
Sophocleous M (2002). Interactions between groundwater and surface water: the state of the science. Hydrogeol. J., 10: 52–67.
Subehi L (2010a). A Study on stream water temperature change in Japanese forested watersheds. Doctor Dissertation, University of Tsukuba, January 2010.
Subehi L, Fukushima T, Onda Y, Mizugaki S, Gomi T, Kosugi K, Hiramatsu S, Kitahara H, Kuraji K, Terajima T (2010b). Analysis of stream water temperature changes during rainfall events in forested watersheds. Limnology, 11: 115–124.
Subehi L, Fukushima T, Onda Y, Mizugaki S, Gomi T, Terajima T, Kosugi K, Hiramatsu S, Kitahara H, Kuraji K, Ozaki N (2009). Influences of forested watershed conditions on fluctuations in stream water temperature with special reference to watershed area and forest type. Limnology. 10: 33–45.
Sulawesty F, Badjoery, Sudarso Y, Mulyana E (2000). Struktur komunitas makrozoobentos di perairan Situ Cibuntu (Indonesian version). Technical Report, Research Centre for Limnology – LIPI: 503–510.
Tarigan T (2001). Perencanaan pengelolaan daerah tangkapan untuk pelestarian Situ Cibuntu Cibinong menggunakan model AGNPS (Indonesian version). Master thesis Bogor Agriculture University, Bogor.
Tung CP, Lee TY, Yang YC (2006). Modelling climate-change impacts on stream temperature of Formosan landlocked salmon habitat. Hydrol. Process., 20: 1629–1649.
Webb BW, Clack PD, Walling DE (2003). Water-air temperature relationships in a Devon river system and the role of flow. Hydrol. Process., 17: 3069–3083.