Comparative measurements of water and air parameters in stream corridors of Suceava County, Romania

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 Vol. 29 / 2019, 124-130

Published:

28 September 2019

ABSTRACT: Monitoring of water temperature and air temperature and relative humidity was carried out for four streamwaters (Suceava, Viţău, Brodina, Dorna) and the surrounding air in stream corridors of the Eastern Carpathian Mountains during summer months of 2011 and 2018. Measurements with high temporal resolution reveal average water and air temperatures (in the selected time intervals) that ranged between 12°C and 16.8°C and, respectively, between 13.8°C and 17.2°C. The monitoring sites offer cool to warm bioclimatic conditions, with the mention that the bioclimatic comfort is reached during daytime in the forests that borders the studied streamwaters. Streamwaters in valleys below 700 m above sea level have warm waters (temperatures greater than 21-22°C) during the afternoons and ideal for bathing or swimming, especially in reaches with deeper water (such as Suceava River). Also, neither cold, nor warm waters can often be found in all sites during summer months.

KEY WORDS: streamwater, mountain, temperature, bioclimate, bathing.

1. Introduction

The long-term monitoring of environmental parameters is of high interest today. This monitoring is often carried out with high temporal resolution measurements, meant to identify variations caused by weaker factors, but which cause the small changes in time series which are attributed, up to date, to local events. Another benefit of the high resolution measurements is the better identification of the shape of diurnal profiles of various parameters, such as air and water temperature.

Streamwater temperature is an important environmental parameter, studied and reviewed by numerous (Caissie, 2006; Webb et al. 2008). It is not only an indicator of natural processes, such as evapo(transpi)ration, rainfall, tide, thawing/freezing (Callède, 1977), but also of human society

activities, directly or indirectly (Kinouchi et al., 2007). The main control factors of water temperature are air temperature and precipitation (Poole and Berman, 2001; Nimick et al., 2011).

The aim of this study is to show the evolution of water and air temperature during consecutive summer days in order to assess the relationship between these parameters and the usefulness of some sites for bathing.

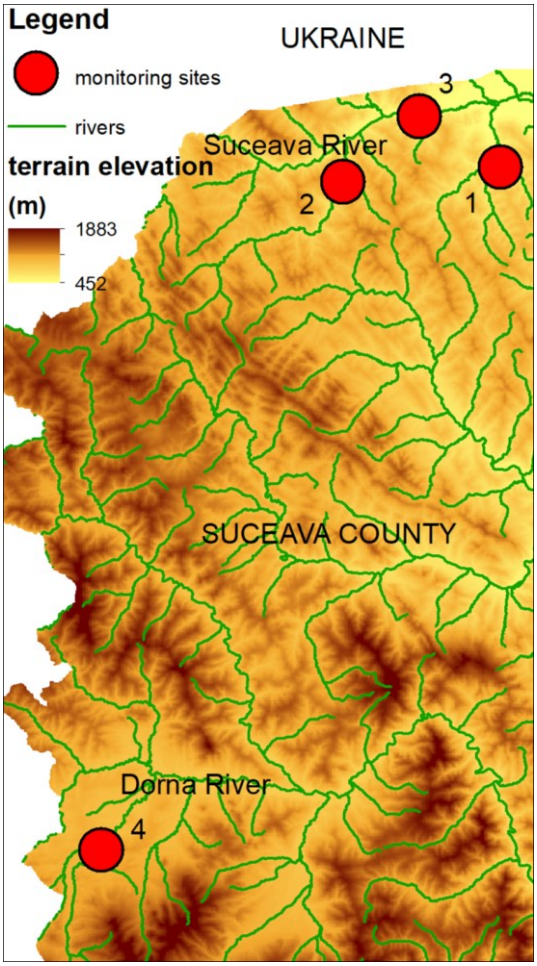

Figure 1 Location of the monitoring sites within Suceava County: 1. Vițău stream corridor, 2. Brodina stream corridor, 3. Suceava stream corridor, 4. Dorna stream corridor. This figure is available in colour online at www.georeview.ro.

2. Study area

The stream corridors that were chosen for water and air measurements are located in the Carpathian Mountains (Fig. 1). The first three monitoring sites belong to Suceava River catchment (on the stream corridors of Vițău (upstream of Vițău discharge into Putna), of Brodina, upstream of Brodinioara tributary, and of Suceava, upstream of Straja settlement. The fourth monitoring site is located in the stream corridor of Dorna River near and inside Tinovul Poiana Stampei Nature Reserve (TPSNR) and upstream of Dornișoara tributary.

On average, the selected rivers have flows during summer months of up to 1 m^3/s in in site 1, 2 and 4 and up to 10 m^3/s in site 3. The climate of the study area is temperate continental, with mean daily temperatures of summer months in the catchments of the selected rivers, upstream of the monitoring sites, ranging from 8°C to 16°C. Mean annual rainfall amount in the same areas is about 1000 mm. The dominant topoclimate is that of mountain forests and pastures. According to the national classification of bioclimates in Romania (H.G. 1154/2004), the first three monitoring sites have a sedative-indifferent bioclimate (as they have elevations below 700 m above sea level (a.s.l.)), while the forth monitoring site has a tonic-stimulant bioclimate (elevations above 800 m a.s.l.).

The diurnal profile of streamwater temperature in sites 1-3 were studied by Briciu and Oprea (2015), who showed the time lag between air and water minima and maxima, temporal position of the diurnal minimum and maximum in streamwater (7:00-8:00 EEST, respectively 16:00-17:00 EEST) and the very good Pearson correlation between the water and air temperature time series (0.88 and over). According to the reports of the Romanian Environmental Protection Agency, the selected rivers in this study have a good ecological condition. These streamwaters have a very good quality in terms of surface water chemistry and a low turbidity, making them suitable for swimming and bathing.

3. Methods and data

Water and air parameters were measured with iButton instruments. In sites 1-3 we used model DS1922L-F5 for monitoring water and model DS1921G-F5 for monitoring air. In site no. 4, water was monitored with a DS1922L-F5 instrument, while air was monitored by using a DS1923-F5 model.

Temperature measurements were done automatically every 10 minutes for water and every 20 minutes for air in sites 1-3 as follows: site 1 - June 29th – July 27th, 2011; sites 2 and 3 - June 26th – July 23th, 2011. Air data were upsampled to 10 minutes through linear interpolation. Monitoring in site 4 was carried out during the entire three summer months of 2018 (June-August), with measurements done every hour; measurement types: water temperature, air temperature and relative humidity.

The thermo-hygrometric index (THI) used in this study is useful for assessing the bioclimate of a space and time and was calculated according to the method of Kyle (1994):

$$THI = T - (0.55 - 0.0055 * RH) * (T - 14.5),$$

where T is the air temperature and RH is the air relative humidity.

4. Results and discussion

The monitored parameters had an evolution with clear diurnal cycles (Figs. 2 and 3) over which long-term trends were imposed by the changing synoptic conditions. The mean water and air temperatures in sites 1-3 ranged between 15.6°C and 16.8°C and, respectively, between 14.6°C and 17.2°C (rounded values). The three months of measurements in site 4 show a moderate variability of the studied parameters mean monthly values: water temperature ranged between 12°C and 14.6°C, air temperature near streamwater ranged between 14.6°C and 16.2°C, air temperature inside TPSNR ranged between 13.8°C and 15.2°C, while Air relative humidity ranged between 88.4% and 90.8%. Site no. 4 had lower water and air temperature than in other sites mainly due to its higher terrain elevation and secondarily due to the cooler June (minimum air temperature was 1.04°C).

The evolution of water temperature is imposed mainly by air temperature; high diurnal thermal amplitudes in air imply similar amplitudes in water temperature, excepting the days with rainfalls (detected indirectly, in the days with increased air relative humidity), when surface runoff reduces thermal amplitude in streamwater. Due to the exposure of riverbeds to direct sunlight, water temperature appears to be sometimes greater than air temperature, this being also caused by the low discharge of Vițău and Brodina, especially in reaches with low water velocity. At the same time, the air temperature measurements were done in the dark forests nearby the selected streams, where air temperature is lower than in the exposed river channels.

A river with a high discharge, such as Suceava River in the selected monitoring point, has a higher thermal inertia than its local tributaries and its water show temperatures greater than those of the air during periods of rapid atmospheric cooling (comparison valid for sites 1-3 as they share similar time intervals and catchments – the difference between the minimum and maximum for the entire monitoring time: Vițău = 16.096°C, Brodina = 17.204°C, Suceava = 15.337°C).

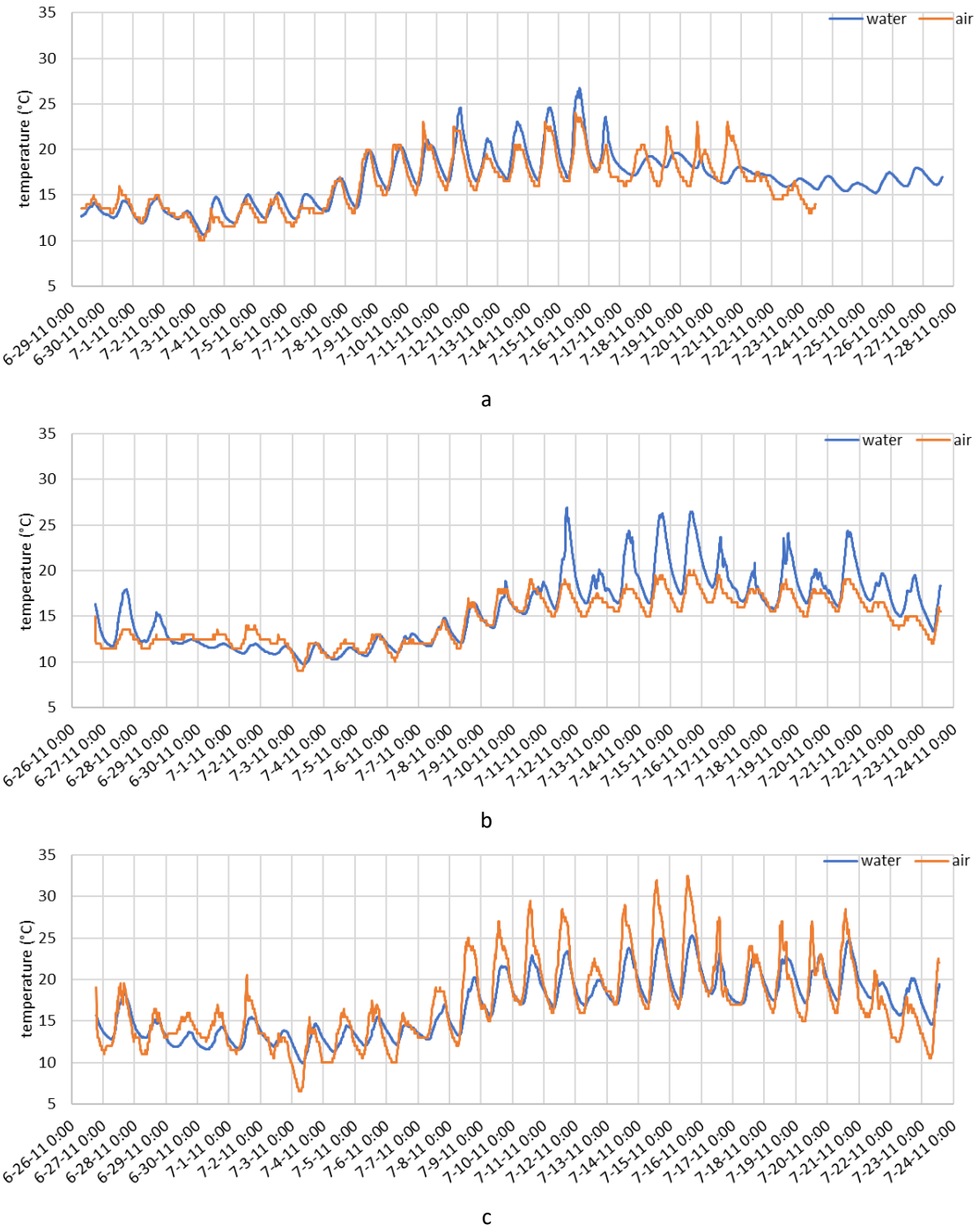

Figure 2 Water and air temperature evolution in the selected monitoring sites of Suceava catchment: 1. Viţău River and the surrounding air, 2. Brodina River and the surrounding air, 3. Suceava River and the surrounding air. This figure is available in colour online at www.georeview.ro.

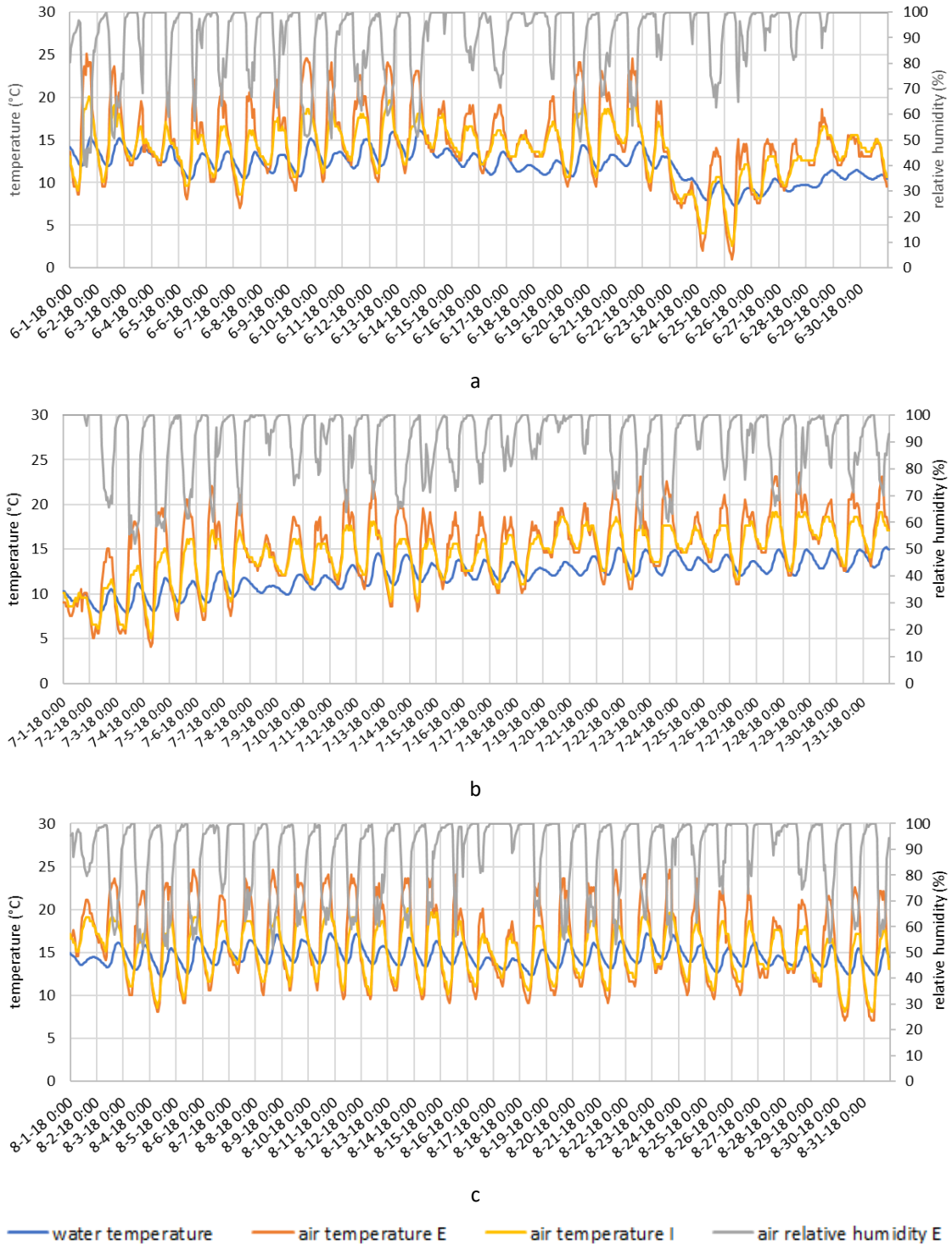

Figure 3 Water temperature and air temperature and relative humidity of Dorna River and the surrounding air during: a. June 2018, b. July 2018, c. August 2018 (I – inside TPSNR, E – near TPSNR). This figure is available in colour online at www.georeview.ro.

The bioclimatic conditions of site 4 were calculated due to the monitoring of both air temperature and relative humidity. The average monthly values of THI outside versus inside TPSNR were as follows: 14.3°C vs 13.7°C – June, 14.9°C vs 14.3°C – July, 15.8°C vs 14.9°C - August. Excepting August outside TPSNR, all mean values indicate, according to standard classifications (Mihăilă et al., 2016), a cool bioclimatic condition and a slight bioclimatic discomfort due to overcooling. THI values between 15°C and 20°C represent bioclimatic comfort, which appears in the afternoon of the warmest days, as indicated by the monthly maxima of THI inside TPSNR: 18.7°C – June and July, 19.4°C – August. Outside the TPSNR peat bog forest, the monthly maxima of THI was 22.1°C in June and July and 22.3°C in August, indicating a warm bioclimatic condition and a slight bioclimatic discomfort due to overheating.

We suppose that, due to the lower terrain elevation and higher air temperature, sites 1-3 offer a bioclimatic comfort during summer days, in general, and a warm bioclimatic condition in the afternoons. In such conditions, supplementary cooling can be obtained by bathing or swimming. According to Morgan et al. (2000), the most preferred bathing water temperatures in natural water bodies ranged from 22°C to 26°C (warm water). Similarly, Leatherman (1997) classifies waters with temperatures of 21 - 27°C as optimal bathing waters. Morgan et al. (2000) also considers water with 16 - 21°C as being neither cold, nor warm. Streamwater temperatures in the studied sites no. 1-3 has sometimes exceeded 22°C, being excellent for bathing, especially in places with deeper water (Fig. 2); excepting the water genesis and mineralisation and taking into account only the temperature parameter, the streamwater temperature in the afternoon in sites 1-3 is similar to hypothermal waters. Neither cold, nor warm waters can often be found in all sites during summer months (Figs. 2 and 3), for tourists who prefer cooler water. The late afternoon moment of diurnal thermal maxima in streamwater is perfect for enjoying the bathing water during hours of reduced insolation. The forests nearby streamwaters also offer a comfortable bioclimate for the entire afternoon.

5. Conclusions

Measurements carried out in stream corridors of Carpathian Mountains show good conditions for tourist activities during summer months: bioclimatic comfort and warm bioclimatic conditions in the same time with neither cold, nor warm streamwaters or even warm streamwaters for bathing or swimming. The diurnal cycles of the studied parameters indicate the late afternoon as the best time for enjoying the natural waters

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