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# BODY THERMAL RESPONSE TO ENVIRONMENT TEMPERATURE IN RAINBOW TROUT (*Oncorhynchus mykiss*) DURING THE SUMMER SEASON

**Paul UIUIU, Daniel COCAN, Radu CONSTANTINESCU, Călin LAŢIU, Florentina POPESCU, Cristina EL MAHDY, Andrada IHUȚ, Alexandru SAVA, Camelia RĂDUCU, Vioara MIREŞAN**

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Animal Science and Biotechnologies, 3-5 Mănăştur Street, 400372, Cluj-Napoca, Romania

Corresponding author email: vmiresan@yahoo.com

***Abstract***

*The body temperatures of rainbow trout, Oncorhynchus mykiss were monitored from June through August 2018 in three trout farms from Bistrița-Năsăud County (Romania). The body temperature was measured from 3 different regions of the body: head, trunk (epaxial and hypaxial muscle region) and caudal peduncle. Body temperatures were compared to the basins water temperature. The lowest water temperature in the basins was recorded in May and June, in Șoimul de Jos farm, and the highest temperature in Fiad farm. In July, Strâmba farm, recorded the highest water temperature, and in August, Fiad farm. In all farms studied, the body temperature of the trout was higher than that of the basins water temperature regardless of the studied region. The highest differences between the basins water and body temperature in farms were found in the caudal peduncle and epaxial muscle regions, due to their role in locomotor mechanism. This is due to the high growth density, the feeding and the intensification of metabolism, with energy release, as well as a much higher level of stress than that encountered in the natural environment.*

***Key words***: *body temperature, infrared thermometer, metabolism, rainbow trout, Salmonidae.*

## INTRODUCTION

The Rainbow trout (*Oncorhynchus mykiss)* is one of the most studied fish species from the Salmonidae family, due to their high economic value (Ihuț et al., 2018b;Topuz et al., 2017), growth rate (Hokanson et al., 1977), interesting biologically life cycle and the history of translocation across many continents, alongside other species of high economic value (Nicolae et al., 2018).

Changing environmental conditions (Pörtner and Farrell, 2008) are affecting reproduction (Pankhurst and Munday, 2011; Donelson et al., 2010; Uiuiu et al., 2017), feeding (Fu et al., 2009), swimming (Blake, 2004; Day and Butler, 2005; Green and Fisher, 2004; Imre et al., 2002), physiological traits of fishes by affecting energy sources through the changes in temperature (Brune and Tomasso, 2005) and concentration of dissolved oxygen (Lee et al., 2003, Ihuț et al., 2018a). Digestion, food consumption (Kausar and Salim, 2006), behavior (Wagner et al., 1997), immunity (Cocan et al., 2018), are also influenced by the temperature. Inadequate temperatures can lead to a state of stress, being the precursor of pathological conditions. The immune system of most fish species has optimal performance at about 15°C of water temperature (Schmidt-Nielsen, 1991).

Temperature has great importance and plays a very important role in the life of aquatic poikilotherms organisms (Barton, 1996), which means that their body temperature is the same as the water in which they live or has 0.5 to 1.5°C tolerance below or above the temperature of water (Bidgood, 1980).

In natural habitats, fish can easily tolerate seasonal temperature changes such as 0°C during winter and up to 20-30°C (depending on species) during summer in the temperate continental climate. However, these changes should not be sudden.

Thermal shocks in trout occur when placed in a new environment, where the difference of temperature is higher or lower by 8°C, compared to the initial temperature of the water (Svobodová et al., 1993).

Rainbow trout tolerates diurnal temperature differences above 5°C but generally prefers a constant temperature. Each species has a temperature range in which the metabolic processes run with maximum intensity. Also, the species has lower and upper temperature threshold (lethal temperature). Rainbow trout, along with other species of the Salmonidae family, is a stenotherm species, but however, it exhibits higher plasticity, tolerating higher temperature variations. Optimal temperatures are between9 and 18°C, but feeding and growing at water temperatures of 4 to 20°C takes place in good conditions. At water temperatures below 4°C and above 20°C the intensity of feeding and growing is reduced. Rainbow trout have a specific type of metabolism, their metabolic rate continues at low temperatures, but at high temperatures, usually above 20°C they consume less food and become less active. Temperature above 20°C is not comfortable for trout, the lethal temperature is from 24.9 to 26.3°C (Matschak et al., 1998).

## MATERIALS AND METHODS

The biological material used in this study was sampled from Strâmba, Şoimul de Jos and Fiad trout farms, Bistriţa-Năsăud County (Figure 1). The study took place in the summer of 2018, between May-August. The number of fish specimens from which temperature measurements were taken was 25. Clinically healthy specimens were used in order not to negatively affect the obtained results

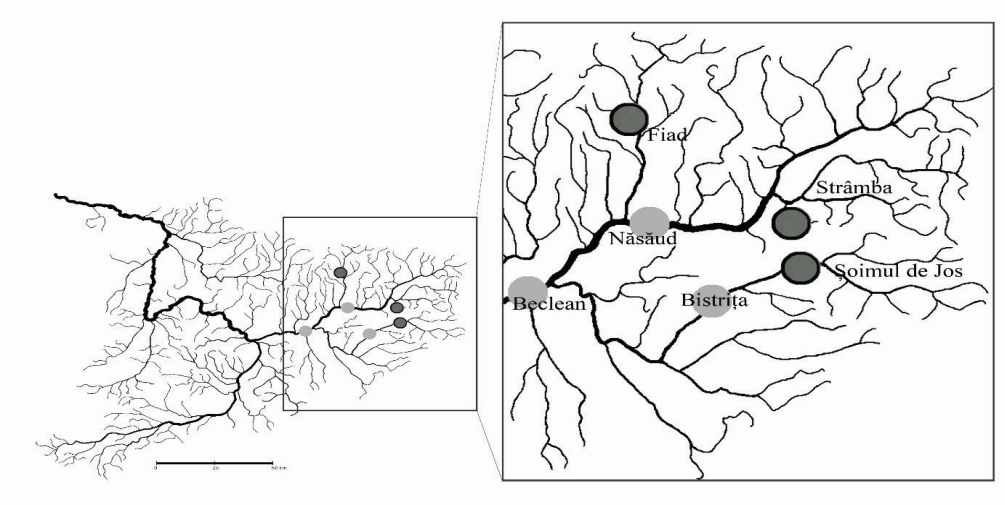


Figure 1. Someş River catchment – Fiad trout farm (Sălăuţa River), Strâmba trout farm (Strâmba River) and Şoimul de Jos trout farm (Şoimu River)

For the determination of body temperature, we used Hannah HI-99551-00 Infrared Thermometer with IR Sensor. The accuracy of the thermometer is± 2%, the range -10 to 300°C and the IR sensor optic coefficient 3:1 (ratio of distance to target diameter). The IR thermometer was compared to a mercury thermometer and it was within his stated accuracy. The body temperature was measured from 4 different regions of the body: head, trunk (epaxial and hypaxial muscle region) and caudal peduncle. For a better manipulation, the trout specimens were anesthetized with clove oil (*Eugenia caryophyllata*), 0.047 ml/L concentration in water, a solution used as a local antiseptic and anaesthetic until the fish lost equilibrium and did not respond to physical stimuli. Clove oil is a natural anaesthetic that under immersion conditions, acts on the somatic nervous system, leaving the functions of the vegetative nervous system active (opercular movement). After anesthetization, the measurements were made in the shortest time possible to reduce the level of stress that they are subjected. Immediately after the measurements were made, the fishes were transferred in tanks with fresh water for easier recovery from anaesthesia.

For the determination of water temperature, we used the Hanna HI 9828/4-01 Multi-Parameter, with a range of -5.00 to 55.00°C, resolution 0.01°C and an accuracy ±0.15°C. The measurements of water temperature were made at the same time as those for the body temperature.

The obtained data was interpreted and processed statistically with the GraphPad Prism v6 software and Pearson Correlation and Scatter Plot Matrix was made with IBM Statistics SPSS 20 software. Drafting, images, graphics, and spreadsheets were edited in Microsoft Word v. 2016. All the methods used are up-to-date and the existing data has been processed in the laboratories of UASMV Cluj-Napoca, Faculty of Animal Science, Physiology of Aquatic Organisms Discipline.

## RESULTS AND DISCUSSIONS

We used the Bivariate Pearson Correlation to produce a sample correlation coefficient that measures the force and direction of linear relationships between pairs of variables. We also analysed the correlations between water temperatures over four consecutive months (May, June, July and August)in the three trout farms (Figure 2). All relations are positive, but not all are statistically significant.

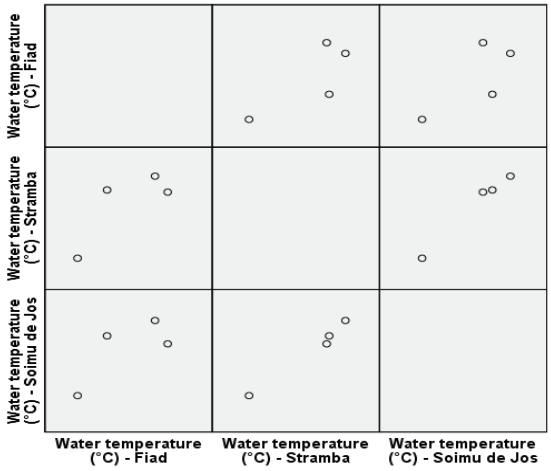


Figure 2. Water temperatures correlations from Fiad (Sălăuța River), Strâmba (Strâmba River) and Șoimul de Jos (Șoimu River) trout farms from Bistrița-Năsăud County, May-August 2018

The strongest correlation and statistically significant water temperature is encountered in the case of Strâmba and Şoimul de Jos trout farms (0.993), resulting in a significance threshold of 1%. This can also be seen from the collected data, the temperature values being very close to each other. Strong correlations are the result of the close proximity of the two farms due to their geomorphological conditions in volcanic mountains. Geographical location and landscape are the main elements that directly influence the climatic and meteorological properties of the area. By its geographical position, the Bârgăului and Călimani Mountains belong to the area with continental moderate climate, often subject to the advection of maritime polar air, with frequent frontal activity. Also, the length of the river (from spring to farm unit emplacement) plays a very important role in water temperature. In Strâmba and Şoimul de Jos trout farms, the distance between the springs and the water emplacement of the farm is relatively short, 5 km (Strâmba) and 4 km (Şoimul de Jos). Fiad farm is supplied by the Sălăuța River, which has a length of 20 km from the spring to the emplacement of the farm.

In Table 1 are presented the Rainbow trout body and water temperatures obtained from Fiad trout farm located on Sălăuța River, Bistrița-Năsăudand the differences between them, during the summer months. To determine the thermal response tothe environment, the

temperatures recorded from the fish body were compared to those of the water. Body temperature was measured from 4 different regions of the fish's body: head region, trunk region (epaxial and hypaxial muscle region) and caudal peduncle region.

Table 1. Rainbow trout body and river temperatures simultaneously recorded, fromFiad trout farm, Sălăuța River, Bistrița-Năsăud, May- August, 2018

| Month | Water temperature (°C) | | Body temperature (°C) (N=25) | | | |
|---|---|---|---|---|---|---|
| | | | Trunk region (muscle) | | Caudal peduncle | Head region |
| | | | Epaxial | Hypaxial | | |
| May | 13.32 | Mean ± SD | 14.69±0.40 | 14.57±0.40 | 14.80±0.34 | 14.60±0.43 |
| | | SEM | 0.08 | 0.08 | 0.07 | 0.09 |
| | | Min-Max | 14.00-15.50 | 13.80-15.60 | 14.20-15.40 | 13.90-15.90 |
| | | V% | 2.76% | 2.81% | 2.27% | 2.92% |
| | | Dif (Bt-W) | 1.37 | 1.25 | 1.48 | 1.28 |
| June | 17.17 | Mean ± SD | 19.90±0.50 | 19.95±0.40 | 20.32±0.50 | 19.93±0.51 |
| | | SEM | 0.10 | 0.08 | 0.10 | 0.10 |
| | | Min-Max | 19.10-20.80 | 19.40-20.90 | 19.60-21.30 | 19.30-21.30 |
| | | V% | 2.52% | 1.99% | 2.48% | 2.56% |
| | | Dif (Bt-W) | 2.73 | 2.78 | 3.15 | 2.76 |
| July | 14.58 | Mean ± SD | 16.48±0.40 | 16.35±0.55 | 16.93±0.46 | 16.56±0.47 |
| | | SEM | 0.08 | 0.11 | 0.09 | 0.09 |
| | | Min-Max | 15.70-17.30 | 15.40-17.40 | 15.90-17.70 | 15.60-17.30 |
| | | V% | 2.40% | 3.36% | 2.72% | 2.82% |
| | | Dif (Bt-W) | 1.90 | 1.77 | 2.35 | 1.98 |
| August | 16.63 | Mean ± SD | 17.82±0.42 | 17.99±0.36 | 18.45±0.29 | 18.09±0.29 |
| | | SEM | 0.08 | 0.07 | 0.06 | 0.06 |
| | | Min-Max | 17.10-18.60 | 17.30-18.50 | 17.80-18.90 | 17.40-18.50 |
| | | V% | 2.35% | 1.98% | 1.58% | 1.60% |
| | | Dif (Bt-W) | 1.19 | 1.35 | 1.82 | 1.46 |

*Note: N – Number of specimens; SD – Standard deviation; SEM – Standard error of mean; Min/Max – Minimum/Maximum; V% -Coefficient of variation; Dif (Bt-W) – The difference between body and water temperature

The body temperature of fishes was higher in all cases than the water temperatures. As we can notice in all months, the difference between the caudal peduncle and the water temperature is higher than in the hypaxial and epaxial muscle and in the head region. This is due to the fact that the caudal peduncle has a very important role in the mechanism of locomotion, resulting in an increase of the temperature in accordance to Joule's law. Rainbow trout is a fast swimming and powerful fish, due to its natural habitat conditions (high water speed). When we analysed the differences between water temperature and hypaxial/epaxial muscle regions, we noticed when environmental water temperature is lower (May, July) the activity of epaxial muscle region is more intense than that of hypaxial muscle region resulting in an increase in temperature of epaxial muscle region (due to the higher movement and swimming of fishes). When the water temperature is higher (June, August) the activity of epaxial muscle region decreases. Hypaxial muscle region temperature is higher than epaxial muscle region due to the reduction of movement and swimming. This is a consequence of the increasing temperature of water, which has as result a slow metabolic rate.

In Table 2 are presented the Rainbow trout body and water temperatures obtained from Strâmba trout farm located on Strâmba River, Bistrița-Năsăud and the differences between them, during the summer months.

Table 2. Rainbow trout body and river temperatures simultaneously recorded, from Strâmba trout farm, Strâmba River, Bistrița-Năsăud, May-August, 2018

| Month | Water temperature (°C) | Body temperature (°C) (N=25) | | | | |
|---|---|---|---|---|---|---|
| | | | Trunk region (muscle) | | Caudal peduncle | Head region |
| | | | Epaxial | Hypaxial | | |
| May | 11.6 | Mean ± SD | 14.12±0.33 | 14.28±0.47 | 14.37±0.34 | 14.18±0.49 |
| | | SEM | 0.07 | 0.09 | 0.07 | 0.10 |
| | | Min-Max | 13.30-14.70 | 13.50-15.60 | 13.70-15.10 | 13.10-15.20 |
| | | V% | 2.37% | 3.31% | 2.37% | 3.44% |
| | | Dif (Bt-W) | 2.52 | 2.68 | 2.77 | 2.58 |
| June | 15.58 | Mean ± SD | 17.15±0.44 | 17.18±0.47 | 17.56±0.54 | 17.48±0.78 |
| | | SEM | 0.09 | 0.09 | 0.11 | 0.16 |
| | | Min-Max | 16.40-17.90 | 16.20-17.90 | 16.90-18.70 | 16.50-19.00 |
| | | V% | 2.59% | 2.75% | 3.05% | 4.46% |
| | | Dif (Bt-W) | 1.57 | 1.60 | 1.98 | 1.90 |
| July | 15.71 | Mean ± SD | 17.24±0.45 | 17.47±0.41 | 17.72±0.37 | 17.49±0.54 |
| | | SEM | 0.09 | 0.08 | 0.07 | 0.11 |
| | | Min-Max | 16.40-17.90 | 16.80-18.40 | 16.90-18.60 | 16.60-18.60 |
| | | V% | 2.60% | 2.33% | 2.10% | 3.08% |
| | | Dif (Bt-W) | 1.53 | 1.76 | 2.01 | 1.79 |
| August | 16.54 | Mean ± SD | 17.69±0.30 | 17.56±0.32 | 18.04±0.41 | 17.87±0.37 |
| | | SEM | 0.06 | 0.06 | 0.08 | 0.07 |
| | | Min-Max | 17.20-18.30 | 16.90-18.10 | 17.40-19.20 | 17.40-18.80 |
| | | V% | 1.72% | 1.80% | 2.26% | 2.07% |
| | | Dif (Bt-W) | 1.15 | 1.02 | 1.50 | 1.33 |

*Note: N – Number of specimens; SD – Standard deviation; SEM – Standard error of mean; Min/Max – Minimum/Maximum; V% -Coefficient of variation; Dif (Bt-W) – The difference between body and water temperature

Water temperature varies daily and seasonally due to the temperate climate of our country. Both in natural habitats and trout farms, salmonids are exposed to fluctuating water temperatures. The same situation as in Fiad trout farm also occurred in Strâmba farm, where the body temperature of fishes was higher in all cases than the water temperatures.

In May, water temperature was 11.6°C in Strâmba trout farm (Strâmba River) and the mean trunk epaxial muscle region temperature was 14.12°C with 2.52°C higher than water temperature. As for hypaxial muscle region, the temperature was higher (2.68°C). Regarding the caudal peduncle region temperature, the difference was 2.77°C. The same situation was encountered in the head region, where the difference was 2.58°C.

Baird and Krueger (2003) found in a study that took place in the Adirondack River, New York, in the summer of 1997, from June to September, that in the case of Brook trout, *Salvelinus fontinalis*, body temperature was lower with 2.3°C and in Rainbow trout (*Onchorhyncus mykiss*) with 1.5°C than the main river water temperature. Both brook trout and rainbow trout used localized cooler water areas to lower their body temperatures below that of the main river. Stream temperatures may differ at various locations and may include localized cooler water areas that could serve as thermal refuges, allowing the survival of fish that are sensitive to high temperatures. Water which is cooler than mainstream flows can also occur where tributaries or groundwater sources discharge cooler water. In trout farms, these thermal refuges do not exist, so the body temperature is usually higher than that of water. In captivity and under intensive feeding conditions, temperature differences are reversed compared to those from the mentioned study, due to the lack of shade, benthic structures, depth and cooler water areas that could serve as thermal refuges. Also farming

stock density, feeding intensity, stress level compared to natural habitat may be a source of increasing the body temperature. In Table 3 are presented the Rainbow trout body and water temperatures obtained from Șoimul de Jos trout farm located on Șoimu River, Bistrița-Năsăud and the differences between them, during the summer months.

Table 3. Rainbow trout body and river temperatures simultaneously recorded, from Șoimul de Jos trout farm, Șoimu River, Bistrița-Năsăud, May-August, 2018

| Month | Water temperature (°C) | | Body temperature (°C) (N=25) | | | |
|---|---|---|---|---|---|---|
| | | | Trunk region (muscle) | | Caudal peduncle | Head region |
| | | | Epaxial | Hypaxial | | |
| May | 10.57 | Mean ± SD | 13.09±0.33 | 12.92±0.32 | 13.56±0.27 | 13.34±0.39 |
| | | SEM | 0.07 | 0.06 | 0.05 | 0.08 |
| | | Min-Max | 12.60-13.90 | 12.30-13.40 | 12.90-14.10 | 12.70-14.00 |
| | | V% | 2.50% | 2.51% | 1.99% | 2.90% |
| | | Dif (Bt-W) | 2.34 | 2.17 | 2.81 | 2.59 |
| June | 13.35 | Mean ± SD | 15.80±0.39 | 15.87±0.38 | 16.20±0.29 | 15.91±0.36 |
| | | SEM | 0.08 | 0.08 | 0.06 | 0.07 |
| | | Min-Max | 15.00-16.80 | 15.10-16.50 | 15.70-16.80 | 15.10-16.40 |
| | | V% | 2.46% | 2.40% | 1.78% | 2.28% |
| | | Dif (Bt-W) | 2.45 | 2.52 | 2.85 | 2.56 |
| July | 13.75 | Mean ± SD | 15.88±0.34 | 15.88±0.32 | 16.22±0.32 | 15.98±0.29 |
| | | SEM | 0.07 | 0.06 | 0.06 | 0.06 |
| | | Min-Max | 15.10-16.40 | 15.20-16.40 | 15.70-16.70 | 15.40-16.50 |
| | | V% | 2.11% | 2.02% | 1.94% | 1.80% |
| | | Dif (Bt-W) | 2.13 | 2.13 | 2.47 | 2.23 |
| August | 14.52 | Mean ± SD | 16.57±0.32 | 16.70±0.41 | 17.03±0.48 | 16.78±0.46 |
| | | SEM | 0.06 | 0.08 | 0.10 | 0.09 |
| | | Min-Max | 16.10-17.20 | 16.00-17.50 | 16.20-17.90 | 16.00-17.50 |
| | | V% | 1.94% | 2.49% | 2.82% | 2.77% |
| | | Dif (Bt-W) | 2.05 | 2.19 | 2.51 | 2.26 |

*Note: N – Number of specimens; SD – Standard deviation; SEM – Standard error of mean; Min/Max – Minimum/Maximum; V% -Coefficient of variation; Dif (Bt-W) – The difference between body and water temperature

In Șoimul de Jos trout farm, we noticed that in most regions the differences between body and water temperature are higher in caudal peduncle and in the head region. At the level of the head region, we recorded the temperature from operculum, which is a series of bones found in bony fish that serves as a facial support structure and a protective covering for the gills; it is also used for respiration and feeding. The higher is the feeding intensity and the opercular rate, the higher is the temperature in the region.

In the conditions of a salmonid trout farm, over several generations, there is an artificial and phylogenetic adaptation of the fish, where they tolerate larger variables of minimum and maximum temperatures. However, in the natural environment, growth, survival and successful reproduction are more sensitive to thermal tolerances. Fish are able to physiologically adapt to farming thermal conditions due to artificial selection, but in natural habitats, when ecological factors such as food availability, vulnerability to predators, hydrological factors (rainfall, flood and drought) represent the action of natural selection. It is important to remember that fish from the Salmonidae family are physiologically adapted to live in cold water environments and that their capacity to adapt to higher water temperatures is limited due to the degree of

amelioration and genetic evolution of the species.

## CONCLUSIONS

Fish, like other aquatic organisms, are poikilotherms. There are specific adaptations and responses to temperature changes. The results indicate a higher temperature in the caudal peduncle compared to the head region and higher temperatures in the epaxial muscles region compared to the hypaxial muscles region. Improving thermal tolerance can be done through selective reproductive programs. Although the ability to develop a tolerance for some of the variables is still debatable (pH), the selective growth to produce a tolerant high-temperature line appears as feasible within a few generations. However, further research should be undertaken on the tolerances of young stages (embryos, juveniles) to confirm the development of tolerances.

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