Plate 7.7 Temperature Fluctuations in Rivers and Streams, 1976–2005

Introduction

Water temperature plays a decisive role in relation to the composition and development of aquatic life. The viability and activity of aquatic organisms depend on both an optimum range of temperature and extreme temperatures. The occurrence of many species is therefore limited to certain river sections owing to their preference and tolerance of specific temperature ranges.

The principal factors that affect water temperature patterns are the temperature of the source water and tributaries, the radiation balance (cf. plate 4.2), precipitation, evaporation (cf. plate 4.1), condensation, the exchange of heat with the substrate and the air, as well as the morphology of the watercourses and channel flow. A further factor that influences the temperature of Alpine rivers and streams in particular is snow and glacier melt. Furthermore, climatic change and the inflow of warmed water, for example cooling water from power stations or industrial plants and treated waste water, also contribute to changes in the water temperature [5]. The initial temperature of a river or stream is determined by the temperature of the groundwater in the source area, which in turn depends on the altitude.

Typical daily or seasonal fluctuations, which partly overlap, have already been explained in plate 7.3. The present plate deals with various long-term aspects of fluctuation in water temperature. Among other things, it addresses question of the temporal trend in phases of high temperatures and the resulting duration of potential stress for flora and fauna; the 1:500 000 map shows the mean number of hours per year when a given water temperature is reached or exceeded. These figures were obtained for a total of six 5-year periods between 1976 and 2005. The trend in temperature change since the 1970s is demonstrated using statistical analysis of daily values for the two consecutive periods of 1976 to 1987 and 1988 to 2005. Moreover, the same statistical data are presented for the year 2005, so that measurements from newer stations have also been included.

The consequences of higher temperatures

As the temperature of the water rises, gases become less soluble, which means that the water absorbs less oxygen. At the same time, organisms become more active and in doing so require more oxygen. An increased need for and decreased supply of oxygen cause stress symptoms in cold-water fish. If threshold temperatures are exceeded such fish will only survive if they have the possibility of escaping to cooler parts of the river, i.e. if there is no artificial or natural barrier to their migration. The main decisive factor is the duration of stress situations caused by high temperatures: the longer they persist, the greater the danger for cold-water fish. The optimum ranges of temperature vary in extent depending on the species. Trout, whitefish or grayling, for example, display symptoms of stress if the water temperature rises above approximately 18 °C, and temperatures of over 25 °C can prove fatal. Carp, perch and pike can tolerate higher temperatures more easily. Preferred temperatures and limits for the various species of fish found in Swiss rivers and streams have been described by [7].

The outbreak of disease among fish, for example proliferative kidney disease (PKD), is also highly dependent on water temperature. It has been shown in brown trout that although a pathological reaction can develop in the kidney tissue at temperatures below approximately 15 °C this condition is not normally fatal. An outbreak of the disease occurs, in most cases with a high rate of mortality, if the pathogen is present and at the same time the mean daily water temperature remains over 15 °C for a period of two weeks or more [3].

The measuring network, data and evaluation

The information presented here is based on data provided by 72 federal hydrometric stations. Between 2002 and 2004 the federal network of temperature-measuring stations was considerably expanded in order to cover smaller catchments and Alpine regions. The stations cover only rivers and streams; the water temperature in lakes is not recorded by the federal measuring network but the main inflowing and outflowing rivers and streams are observed. The measuring network and procedures are described in plates 7.1[2] and 7.3, as well as in [5].

The existing, current measurement series for four stations (Rhein–Diepoldsau, Rhein–Weil, Rhône–Chancy and Limmat–Baden) were combined with observations from nearby stations that have closed down. As a rule this did not require any corrections. The figures from the Rhein–Schmitter station that were used were reduced slightly for conversion to the Rhein–Diepoldsau data series [5]. The daily means for the Aare–Untersiggenthal station were calculated from the data obtained from the Aare–Brugg, Reuss–Mellingen and Limmat–Baden stations. For this reason there are no hourly figures available for Untersiggenthal. Moreover, many stations were recording daily values (one standard value per day) before continuous records of temperature were established, which meant that measurement series could be partly extended [5].

The statistical measurement figures were calculated using daily means. In order to demonstrate the range of temperature fluctuation the 5 % and 95 % quantiles were also calculated in addition to the median.

It was possible to analyse daily means for 33 stations for both periods, namely 1976 to 1987 and 1988 to 2005; in the case of 6 further stations this was possible only for the second period, namely 1988–2005. One station had no measurements for 1976 (Rhein–Weil) and three had none for that year or 1977 (Glatt–Rheinsfelden, Kleine Emme–Litau and Ticino–Riazzino); this had only a marginal effect on the evaluation of the periods in question, however. Thirty-one stations have come into operation relatively recently and show the temperature range for only the year of comparison, namely 2005.

The number of hours when the temperature was within a certain range was calculated over a long period for a total of 39 stations, all values being under the 15 °C-limit for around one quarter of the stations. In order to record the frequency of higher water temperatures the number of hours in which the water temperature exceeded 15 °C was counted within each 5-year period. Water temperatures of 18 °C, 21 °C and 24 °C were used as further divisions. Only continuously recorded measurement series could be used for these analyses.

The criteria for selecting the stations included in figures 1 and 2 were the length of the measurement series, the breadth of spatial coverage and the seasonal pattern.

Figure 3 and table 2 show all stations that were operational in 2003 with their maximum temperatures. In the case of stations where longer measurement series (≥ 10 years) were available it is indicated whether new maxima were measured in summer 2003. Shorter measurement series were not included in the map.

Long-term trends, 1954–2005

Series of water temperature measurements at selected stations (fig. 2) show that mean annual temperatures have clearly risen since 1954, a greater rise being observed in the Central Lowlands (up to 2 °C) than in the Alpine areas. In particular, there has been no marked rise in temperature in the catchments that are influenced by glaciers, such as the Lütschine (catchment 17.4 % glaciated). It is interesting to note that a particularly marked rise in water temperatures occurred between 1987 and 1988 [4,5]. In view of this fact the two periods 1976–1987 and 1988–2005 are compared in many of the diagrams and on the main map.

Long-term variation in temperature indicates that the flora and fauna of the watercourses will be forced to adapt to warmer conditions. Species that live in the middle or lower reaches of the rivers and streams will migrate upstream to stretches that would have been too cold for them before [1]. The habitat of trout has already shifted 100 to 200 m upstream, for example [4].

Variation in seasonal patterns

Water temperatures rose more quickly in spring in the more recent period (1988–2005) than in earlier years; longer summers were also observed (fig. 1) [4,6]. In the case of rivers and streams in the Alpine foothills the influence of melt water resulted in a lower rate of temperature fluctuation.

The rise in the temperature of the larger watercourses in the winter and spring has extended the growth period of local flora and fauna. In the summer, those organisms that prefer warmer water have the advantage [1].

The heat wave of 2003

The summer of 2003 saw massive rises in water temperatures in some areas (fig. 3). Levels were reached and maintained over a relatively long period that were life-threatening for cold-water fish [2]. The rivers and streams containing fish populations in the Jura Mountains and the Central Lowlands were the worst hit. In summer 2003 new peak temperatures were also recorded in the rivers and streams of the Alpine foothills where the catchment is less than 10 % glaciated, while the situation in the Alpine watercourses that are affected by melting snow and ice was not a problem.

In the summer of 2006 the temperature of rivers and streams was again extremely high. New maxima were recorded in particular in stations near the Alps. In comparison with summer 2003, in 2006 temperatures were already very high in July and fell rapidly in August, reflecting the weather pattern with an extremely hot July and an unusually cool August. With climatic change bringing regular high temperatures the summer heat waves are expected to occur more frequently [1].

Temperatures of over 15 °C

Between 1976 and 2005 there was an increase in the number of hours with higher temperatures recorded at measuring stations at all altitudes; this naturally led to a rise in the annual means. In the rivers and streams of the Alpine foothills, an increase was observed mainly in the hours when the temperature rose to between 15 °C and 18 °C, which must be considered high for watercourses in this area. In the larger rivers of the Central Lowlands, the number of hours when the water was within this range tended to fall, while the number of hours when the water temperature was over 18 °C rose in most cases. At these measuring sites the temperature of the water passes more quickly through the intermediate 15 °C to 18 °C range in spring and autumn, whereas in summer water temperatures remain in the higher range for longer (fig. 1 and [6]). Water temperatures of over 24 °C were observed principally in the rivers of the Central Lowlands, in particular those downstream from lakes. The temperature of the surface water in a lake rises considerably during a long period of hot weather, and it is this surface layer that subsequently flows out of the lake.

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