Temperature

Water temperature expresses how warm or cold the water is. It is defined as the amount of average kinetic energy in water molecules and is measured in degrees Fahrenheit (F) or Celsius (C).

Why do we measure temperature?

Water temperature influences the majority of physical, biological, chemical, and ecosystem processes in aquatic environments. Altered stream temperature is a significant cause of water quality impairment in the U.S. and influences other water quality parameters. Measuring temperature helps to understand the magnitude and variability of temperature fluctuations and anticipate the consequences for water quality and ecosystem health (Figure 1).

Figure 1. Measuring temperature in the field. Credit: Photo courtesy of USGS

In general, increased water temperature can result in:

- Decreased dissolved oxygen (DO) available to aquatic life.
- Increased solubility of metals and other toxins in water.
- Possible increased toxicity of some substances to aquatic organisms.
- Algal blooms, which typically occur during the summer season or periods of unusually warm temperatures.

Short- and long-term increases in temperature can negatively impact aquatic health in different ways (Table 1).

Table 1. Potential effects of short- and long-term increases in temperature on aquatic life.

Short-term summer heat stress	Long-term temperature increases
• Reduced or blocked sexual maturation • Inhibited or blocked critical stages of larval development • Reduced feeding and reduced growth of juveniles and adults • Increased susceptibility to predation • Reduced productivity of macroalgae and seagrasses • Increased death, organisms forced to leave, and increased incidence of disease or parasitism	• Loss of aquatic species whose survival and breeding are temperature dependent • Change in the abundance and spatial distribution of aquatic species and reduced populations of some species • Increase in rates of evaporation from surface water, causing increased salinity and waterbody shrinkage, resulting in a loss of habitat

For factsheets on other water quality parameters, visit: epa.gov/awma/factsheets-water-quality-parameters.

For more information about the CWA Section 106 Grants Program, visit: epa.gov/water-pollution-control-section-106-grants.

Decreased water temperature can also harm aquatic life. Specifically, decreased water temperature can alter the timing of migration, decrease spawning for some fish species (pallid sturgeon, salmonids), and change the timing of egg hatching. Other potential effects of decreased water temperature include reduced rate of photosynthesis (resulting in a decrease in aquatic plants) and a decreased metabolic rate of aquatic organisms.

What affects water temperature?

The transfer of heat between a waterbody and the atmosphere, sunlight, or other water source (groundwater, wastewater discharges, etc.) affects the temperature of water. Water temperature depends on many factors, including:

- Weather (air temperature, wind speed and direction, cloud coverage, and precipitation)
- Stormwater runoff from impervious surfaces (highways, roads, large roofs, parking lots)
- Loss of shading when streambank vegetation is lost
- Cooling water discharges (from power plants and other facilities)
- Impoundments (dams)
- Groundwater inflow
- Evaporation rate
- Streamflow
- Turbidity

Both rivers and lakes undergo daily temperature changes. Lake waters also exhibit seasonal temperature changes, typically stratifying (forming temperature layers) in the summer and winter. During the fall and spring, temperature changes lead to turnover and mixing of the water column (Figure 2).

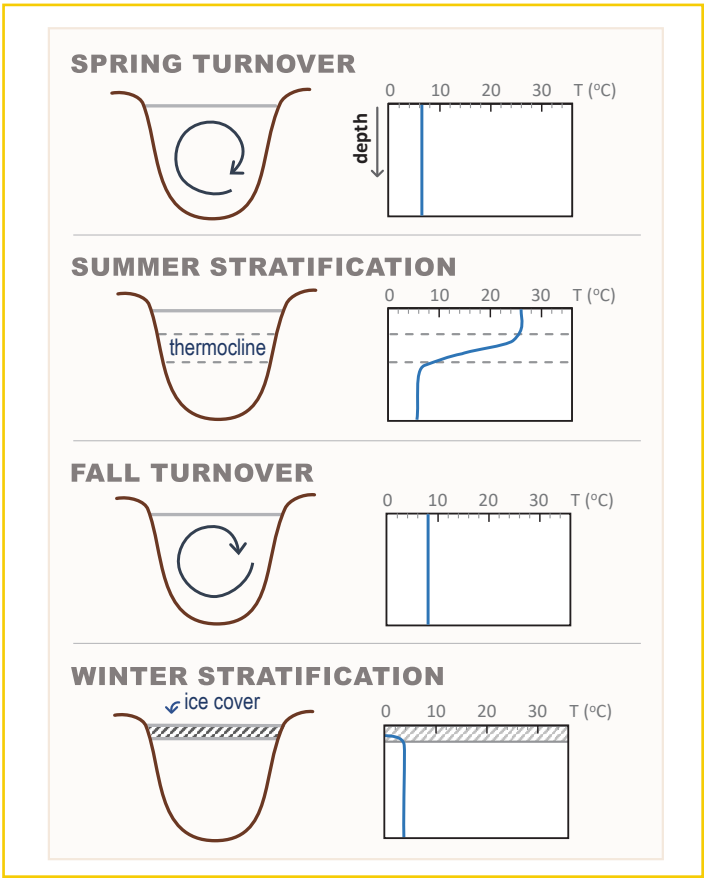

Figure 2. Temperature layers and turnover in lakes by season. Adapted from Wetzel (1975)

What are EPA's recommended criteria for temperature?

EPA's *Quality Criteria for Water* (1986) recommends the temperature criteria below for aquatic organisms. Two types of limiting temperature exist for each **freshwater location** based on important sensitive species:

- The **maximum temperature for short-term exposure** is time-dependent and calculated using a species-specific mathematical equation.

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- The **maximum weekly average temperature** must do one of the following: protect against mortality in cooler months; protect for physiologically optimum temperature in warmer months; protect for successful migration, spawning, egg incubation, fry rearing, and other reproductive functions in reproductive seasons; or preserve normal species diversity.

Table 2 lists examples of the two types of limiting temperature metrics (the maximum weekly average temperatures and the maximum short-term temperature) for four example fish species. These are examples only and do not necessarily indicate protective values in every location.

Table 2. Maximum average temperatures for growth and short-term maximum temperatures for selected fish (°C and °F).

Species	Max. weekly avg. T for growth (juveniles)	Max. T for survival of short exposure (juveniles)	Max. weekly avg. T for spawning	Max. T for embryo spawning
Common carp	---	---	21 °C (70 °F)	33 °C (91 °F)
Channel catfish	32 °C (90 °F)	35 °C (95 °F)	27 °C (81 °F)	29 °C (84 °F)
Largemouth bass	32 °C (90 °F)	34 °C (93 °F)	21 °C (70 °F)	27 °C (81 °F)
Rainbow trout	19 °C (66 °F)	24 °C (75 °F)	9 °C (48 °F)	13 °C (55 °F)

Source: USEPA (2012)

How do we measure temperature?

Temperature can be measured at discrete points in time or continuously. Monitoring sensors (continuous monitoring) allow assessment of temperature changes throughout the day and are a cost-effective option for collecting temperature data as compared to individual readings using thermometers.

Temperature is generally measured in the field along with other water quality parameters including pH, DO, specific conductance (SC), turbidity, and is generally measured along with any water samples being collected.

Temperature can vary both horizontally and vertically in a waterbody. Measurement locations should be well mixed (not substantially warmer or cooler than the rest of the segment of the waterbody). If a goal is to look for trends, measurements should be taken at the same time of day. Measurements at different depths at each location (depth integrated) will provide information on vertical variability. Measurements should capture spatial variability, stratification, and seasonal trends to the degree feasible.

What are the challenges of using temperature as a water quality parameter?

Temperature varies naturally throughout the day, throughout seasons, and throughout the depth of a single waterbody. Additionally, aquatic species in a single waterbody can have different optimal water temperature ranges. It is, therefore, challenging to set water quality criteria for water temperature.

It can be logistically challenging to collect the data needed to fully characterize seasonal and spatial variability. Furthermore, because many factors can affect temperature, it can be difficult to determine the source(s) of alterations to temperature patterns.

EPA 841F21007A | July 2021