EC 1489
May 1997
$1.50

Stream Temperatures

Some Basic Considerations

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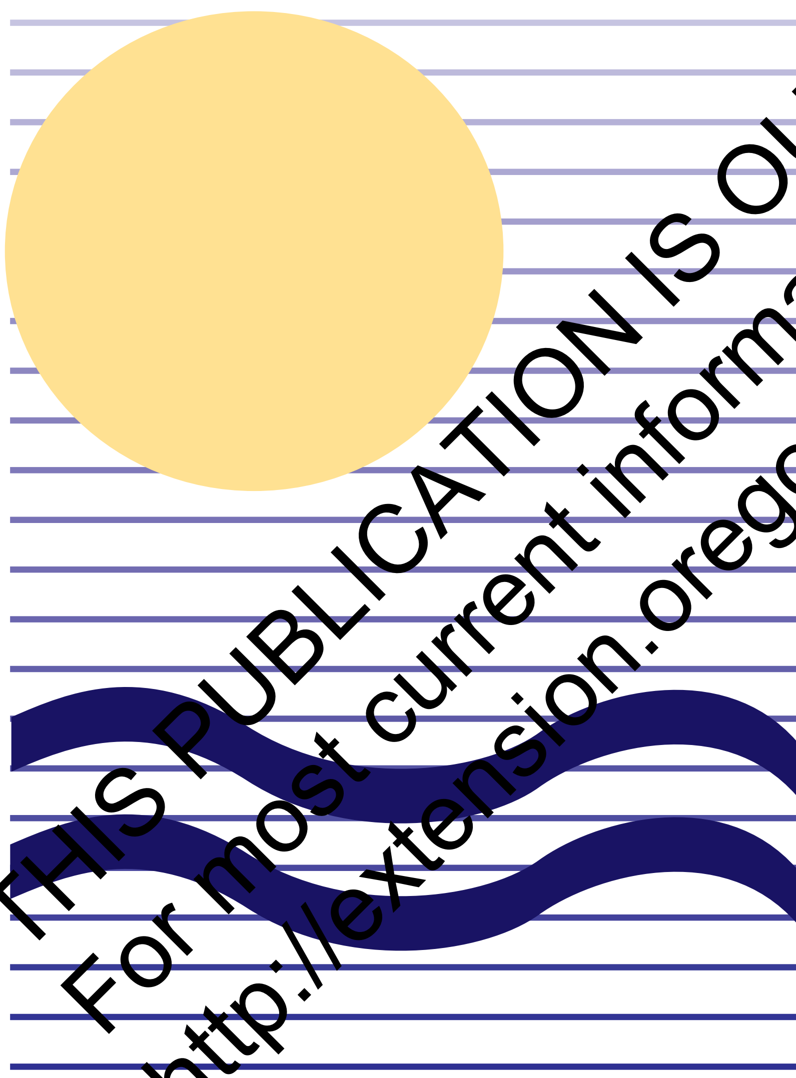

The temperature of the water in our streams and rivers is very important to the well-being of fish and other aquatic organisms. Most species need cool water to survive. As a result, Oregon's water-quality standards include maximum stream temperature criteria. Streams that are monitored and found to exceed these temperatures are listed as water-quality limited.

When humans use water, they can degrade its quality. Thus, it isn't surprising that some community and land-use practices can contribute to elevated stream temperature.

This issue is complex and involves many aspects of science. Although new research is underway, the basic science related to stream heating and cooling is not new and is widely accepted. This publication will present some basic concepts that are important in understanding the stream temperature issue.

The basics—sun and water

The energy that heats the surface of the land and water comes from the sun. Energy is stored and exchanged by the atmosphere, water, and land according to the rules of physics. Taken together, these processes are known as the net energy balance.

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The net energy balance includes several parts. To analyze a complete energy balance, all of these factors must be considered. In this publication, however, we'll review only the major energy balance pathways.

The sun—where it all begins

The energy transferred from the sun to the earth is known as solar radiation. The amount of solar energy transferred to a given location depends on the position of the sun relative to that location.

We get more solar radiation in the summer, when the sun is more nearly overhead and the days are longer, than in the winter, when the sun is at a lower angle in the sky (Figure 1). Thus, the season of major concern with regard to high stream temperatures is summer, when we receive more direct solar radiation.

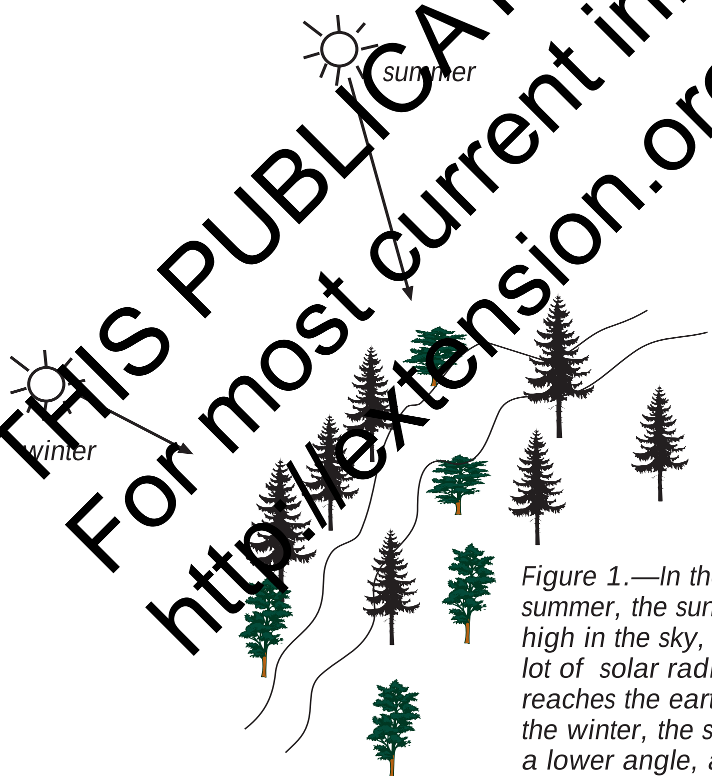


Figure 1.—In the summer, the sun is high in the sky, and a lot of solar radiation reaches the earth. In the winter, the sun is at a lower angle, and the earth receives less solar radiation.

For any given location, day, and time, scientists can calculate the incoming direct solar energy because they know the angle of the sun.

Stream volume

In general, streams with smaller volumes of water change temperature faster than streams or rivers with larger volumes of water.

Perhaps an example will help show this (Figure 2). We'll use two equal-sized buckets. Let's put 2 inches of water in bucket A and 4 inches of water in bucket B. Now let's place the two buckets in the sun.

The same amount of energy falls on each bucket since they are at the same location and have the same surface area. However, there is twice as much water to receive the energy in bucket B. Thus, in the time it takes for the water temperature in bucket B (4" deep) to increase 1°F, the temperature of the water in bucket A (2" deep) will increase nearly 2°F.

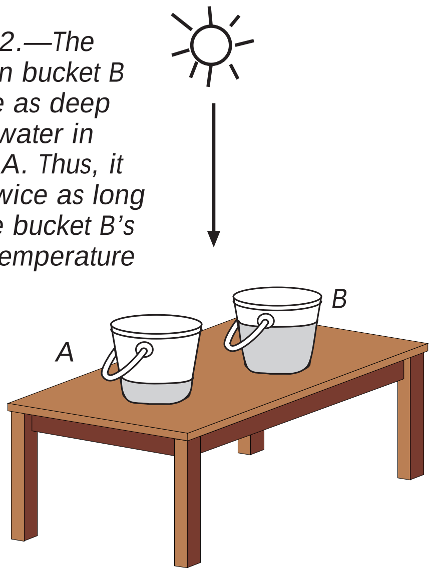
This factor has significant implications for stream temperature. First, small streams are at greatest risk of experiencing day-night temperature change. Second, late summer is when stream flows typically are lowest. At this time, there is less water in a stream to heat, so it heats faster.

Withdrawals for irrigation from small streams may significantly affect the total volume of the stream and the resulting rate of temperature change of the remaining water.

Surface area

The surface area of a stream is very important in the transfer of energy. The width of a stream determines the surface

Figure 2.—The water in bucket B is twice as deep as the water in bucket A. Thus, it takes twice as long to raise bucket B's water temperature by 1°F.



area exposed to the atmosphere. A wide, shallow stream receives more energy (and therefore increases in temperature faster) than a stream of the same volume that is narrow and deep. As in the example of the buckets, a stream with twice as much surface area, but the same volume as another stream, warms nearly twice as fast as the narrow, deeper stream (Figure 3).

Any land use activity or natural event that knocks down stream banks, making the stream shallower, also makes the stream wider for the same volume of water. This increase in surface area increases the water temperature when the stream is exposed to heating by solar radiation.

Other factors that affect stream temperature

For any water surface, at any time, some processes are adding heat while others are removing heat. The rate at which water temperature changes basically depends on how much energy is striking the surface and how much is being lost from the surface at a given time.

For example, at night, the land or water may lose heat faster than it is being added, with a resulting decrease in temperature. Out in the open on a midsummer day, energy is added faster than it is lost, resulting in warming.

Some of the factors that affect how much heat is added and lost are discussed below.

Shade

Direct sunlight transfers the greatest amount of energy to the earth's surface. On cool mornings, we are warmed by standing in the sunlight. On hot, midsummer afternoons, we seek shade to reduce the energy that warms us. On cloudy days, or when a cloud passes between us and the sun, less direct sunlight reaches us.

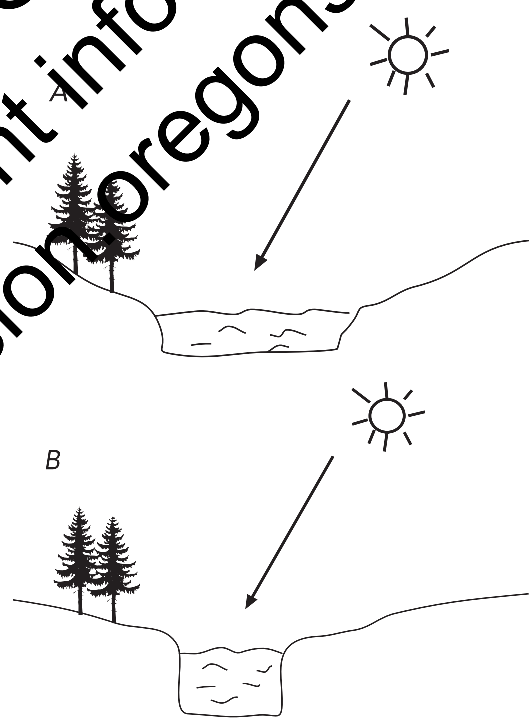


Figure 3.—Stream A and B both carry the same volume of water. Stream A has twice as much surface area to receive solar radiation as does stream B. Thus, the water temperature in stream A will rise nearly twice as fast as that in stream B.

Shade is very important as a means of intercepting sunlight and reducing the energy that is transferred to the surface of a stream. This shade can come in the form of tall grass, which is very effective in shading a small, narrow stream. Shrubs or brush along the stream also provide shade protection to the water. Taller trees farther from the edge of the stream also provide shade, except during midday, when the sun is almost overhead (Figure 4).

Regardless of the type of shade, canopy density and height are important factors in determining how much sunlight is intercepted. The thicker and taller the canopy, the less direct solar energy reaches the water surface over the course of a day.

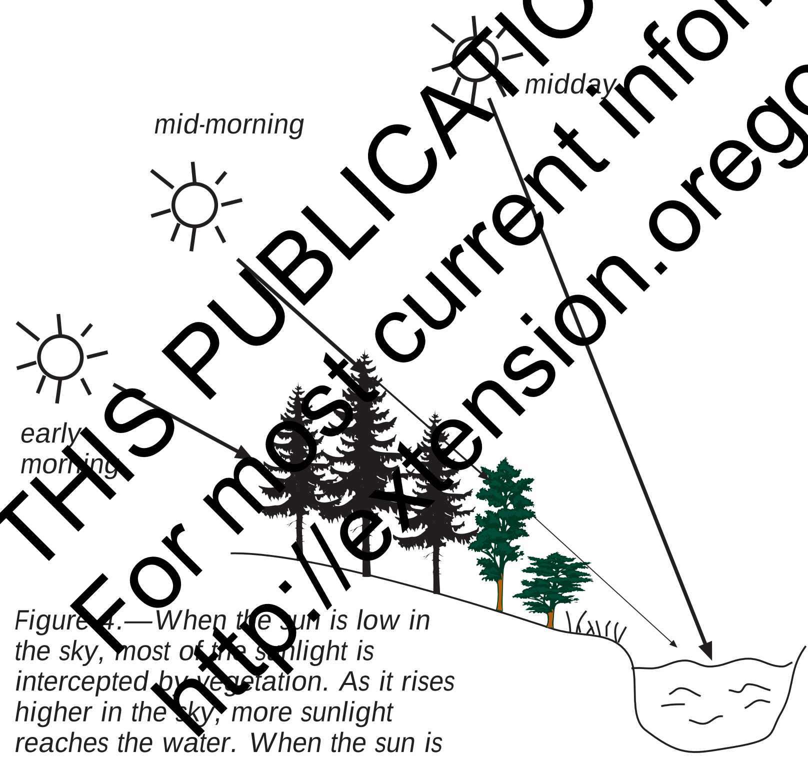


Figure 4.—When the sun is low in the sky, most of the sunlight is intercepted by vegetation. As it rises higher in the sky, more sunlight reaches the water. When the sun is nearly directly overhead, vegetation no longer intercepts the sunlight.

Radiation

At night, no solar radiation adds energy to the stream, but radiation from the stream surface continues to transfer energy to the atmosphere. Generally, there is a net loss of energy at night, thus cooling the stream. In open, unshaded areas, losses to cold, open sky can be significant. Where there is significant streamside vegetation, some of the heat is trapped, and the heat loss or cooling is reduced.

Air temperature

Another factor that influences the warming of streams is air temperature. When air temperatures are high, some heat is added to the stream directly from the air (known as convection). Simultaneously, this warmer air causes more evaporation.

Because energy (heat) is used to evaporate water, heat energy is lost from the stream when evaporation occurs, thus cooling the stream. This process is similar to the way we are cooled as sweat evaporates from our bodies.

In general, air temperature has a relatively minor effect on stream temperatures as compared to solar energy additions. Since we have no control over air temperature, and it generally is high on the days of concern, it offers a limited management opportunity to achieve desired stream temperatures.

Water inflow and outflow

In some sections of a stream or river, water moves from the stream into the surrounding soil, causing significant losses of flow volume. In other sections of the same stream, water may flow from the soil into the stream, adding to the flow volume.

During much of the summer, the water flowing into the stream from the soil is cooler than the water already in the stream. As the cooler water is added, the temperature of that part of the stream can decrease.

Inflow and outflow occur in most streams, but are very difficult to measure. Flow into the stream usually is higher in the spring, when the surrounding landscape may be saturated. The same stream may lose water in the fall as the surrounding water tables decline (Figure 5).

What happens as a river travels toward the sea?

Generally, stream temperatures are coolest at the headwaters and become warmer as the water flows toward the sea. For example, the Columbia is warmer when it reaches the ocean than it was when it started its journey in Canada.

For some of the reasons discussed above, the rate of increase of the water temperature slows as the water moves downstream. Although the river may continue to warm, it does so at a much slower rate.

This change occurs largely because the river has a much greater flow volume, and the sunlight has more water to heat. Thus, if we are to implement practices aimed at reducing the rate of heating in streams, we should focus our efforts on the small streams high in the watershed. Also recognize that several management practices exist to reduce the rate of stream heating, and each site needs to be evaluated for its unique conditions.

Measuring stream temperature

Many streams or sections of streams in Oregon do not have measured stream temperature data. Many agencies, institutions, companies, and private citizens now collect such data. Very good temperature-recording instruments are available. These units are relatively low cost ($70–$400), have excellent temperature resolution, and are capable of taking and storing hundreds of measurements.

However, there are some concerns for those interested in collecting stream temperature data. Although monitoring the temperature of a stream is relatively easy, it is much more difficult to interpret the data. This publication discussed just a few of the basic considerations of stream temperature. Many additional factors must be considered when collecting and using stream temperature data.

Placement of the instrument(s) in the stream cross section, location along the reach of the stream, and distance between instruments all influence the value of the data collected. Other information besides

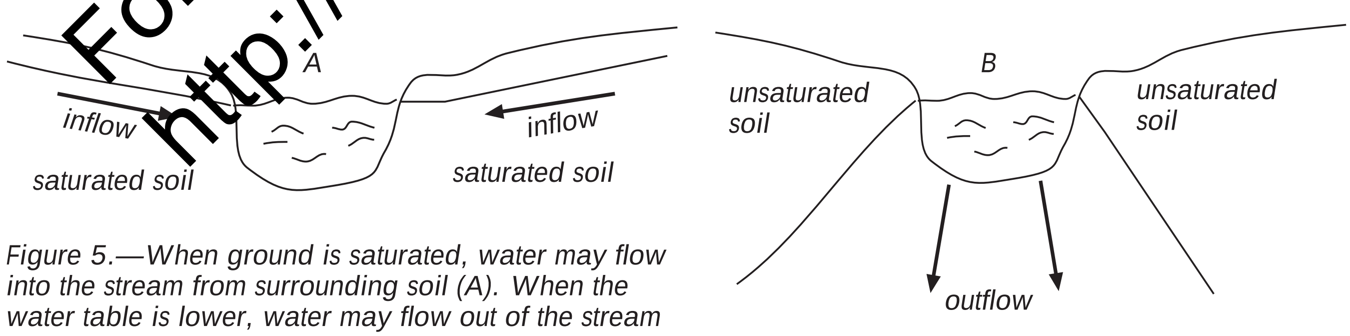


Figure 5.—When ground is saturated, water may flow into the stream from surrounding soil (A). When the water table is lower, water may flow out of the stream into the surrounding soil (B).

water temperature may be needed to get a complete picture. For example, in almost all cases, knowing the stream flow volume is critical when using and interpreting stream temperature data.

Before you begin a monitoring program, it's imperative that you carefully define the purpose of the monitoring. Only then can a monitoring plan be developed. It is suggested that you talk with someone experienced in monitoring and interpreting stream temperature data before beginning your program.

So, what do I do?

Recognizing that stream temperatures are important in determining a stream's ability to support sensitive fish and other aquatic species, a land manager has three basic approaches to protect the stream.

They are:

- Keep it shaded.
- Keep it narrow.
- Keep it flowing.

For more information

The Water Quality Limited Stream Segments List—What does it mean? EM 8636, by J. Ron Miner (Oregon State University, Corvallis, 1996). No charge.

Available from county offices of the OSU Extension Service, or from the Extension and Experiment Station Communications Web site. (Go to *http://wwwagcomm.ads.orst.edu/* and then choose "Educational Materials Catalog," followed by "Soils and Water.")

THREE WAYS TO KEEP A STREAM COOL. . .

- **KEEP IT SHADED**
- **KEEP IT NARROW**
- **KEEP IT FLOWING**

This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.