INDEPENDENT MULTIDISCIPLINARY SCIENCE TEAM (IMST)

State of Oregon

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Dear Sirs:

Your letter of August 12, 2002, requested that the IMST respond to three questions concerning stream temperature and its consequences for fish populations. We met with staff from DEQ and ODA, Mike Unsworth (OSU), and George Taylor (OCS) on September 4, 2002 to discuss the questions you raised. The IMST also discussed these questions in detail at our September 26, 2002 meeting. In our meeting with your staffs, your agencies requested short, direct responses to the questions. This letter provides brief answers to your questions, but we encourage you to refer to the IMST Temperature Report for further information, which will be completed early in 2003. Our immediate responses to your questions are provided below:

1. The recent IMST temperature workshop identified several factors related to stream temperature including elevation. Is elevation a primary factor in determining stream temperature or is elevation an autocorrelate with other more significant factors such as exposure to solar radiation?

The IMST Stream Temperature Workshop in 2000 clearly indicated that air temperature (as influenced by elevation) is one of many factors influencing stream temperature. Air temperature influences the exchange of heat between water and air. But the report did not indicate that elevation or air temperature were more important than other factors. The report repeatedly stated that "solar radiation is the principal energy source that causes stream heating". All models of stream temperature in the scientific literature include incoming solar radiation at the water's surface as a primary factor that determines stream temperature.

The process used by the State of Oregon to assess stream temperature and to address the human activities that affect stream temperature does not overlook this factor. The State of Oregon has developed a scientifically sound stream temperature model, Heat Source, for developing watershed management plans for stream temperature in the TMDL process. This model clearly incorporates the influence of elevation because it accounts for differences in air temperature along the stream reaches being evaluated.

Patterns of stream warming with changes in elevation incorporates the cumulative effect of shade (or lack of it) along streams in the network. When stream temperatures are less than the surrounding air temperatures, incoming solar radiation at the water's surface will cause the water to warm. After stream temperatures equal air temperatures, cooler water may continue to enter the stream from subsurface exchange (hyporheic), groundwater, and cooler tributaries. As a result, factors that affect the amount of incoming solar radiation at the water's surface (e.g., vegetative shade, channel morphology) may continue to influence patterns of stream temperature even after stream temperature reaches an equilibrium with air temperature.

Some have suggested that adiabatic lapse rates explain changes in temperature with elevation and adequately explain temperatures that would be expected in streams at different elevations. Adiabatic lapse rates apply to air temperatures in the open atmosphere. Changes in air temperature that would be expected from adiabatic lapse rates in the open atmosphere are not observed at the land surface because of the thermal properties of land and water (based on consultation with Dr. Mike Unsworth, Atmospheric Sciences, Oregon State University).

The IMST Temperature Workshop noted that stream temperature was determined by a large number of factors, including the influence of air temperature as influenced by elevation. The Temperature Workshop Report repeatedly noted that human activities directly influence four major factors:

"Stream temperature is a product of complex interactions between geomorphology, soil, hydrology, vegetation, and climate within a watershed. Changes in these factors will result in changes in stream temperature. Human activities influence stream temperature by affecting one or more of four major components: riparian vegetation, channel morphology, hydrology, and surface/subsurface interactions. Stream systems vary substantially across the landscape, and site-specific information is critical to understanding stream temperature responses to human activities."

Some of the concerns raised by the public about the influence of elevation on stream temperature are linked to suggestions that streamside vegetation has little influence on stream temperature. Participants in the IMST Temperature Workshop clearly noted that riparian vegetation is a critical factor related to human land uses:

"Riparian vegetation can directly affect stream temperature by intercepting solar radiation and reducing stream heating. The influence of riparian shade in controlling temperature declines as streams widen in downstream reaches, but the role of riparian vegetation in providing water quality and fish habitat benefits continues to be important. Besides providing shade, riparian vegetation can also indirectly affect stream temperature by influencing microclimate, affecting channel morphology, affecting stream flow, influencing wind speed, affecting humidity, affecting soil temperature, using water, influencing air temperature, enhancing infiltration, and influencing thermal radiation."

The workshop also reviewed studies in northern California, which examined influences of both elevation and riparian vegetation. The author of these studies noted:

"We plotted our 1998 canopy data from about 330 sites versus the natural log of distance from the watershed divide and found that at about 70 km from the watershed divide, canopy values drop below 20 to 30%. Stream temperature is more a function of air temperature in a system that is too wide for riparian shading. However, we must remember that both air and water temperature are both greatly influenced by solar radiation."

Participants in the Temperature Workshop jointly developed several major conclusions:

- Solar radiation influences both air and water temperature.
- Solar radiation is the principal energy source that causes stream heating.
- Direct absorption of solar radiation by the stream and the streambed warms water; interception of solar radiation by vegetation reduces potential for warming.
- Shading (vegetative and/or topographic cover) reduces direct solar radiation loading.
- Shading (vegetative and/or topographic) of the water surface reduces potential stream heating.
- The factors that human activities can affect to influence stream temperatures are vegetation, stream flow (hydrology), channel morphology, and subsurface/surface interactions (factors are not listed in order of importance).
- The influence of vegetation on stream temperature decreases with increasing channel width.

The IMST Temperature Workshop also identified areas for future research. One of these areas of research directly addresses the concern over the effect of elevation on stream temperature:

"To improve temperature prediction confidence at the reach scale, we need additional studies to understand processes in the stream energy balance (radiative transfer, evaporation, convection, and advection of heat in the atmosphere, conduction of heat in the streambed), particularly in eastside semi-arid environments."

The IMST recommends that a productive area of investigation would be sensitivity analysis to resolve the relative influence of various factors in the Heat Source model. This would allow the State to explicitly identify the relative influences of major factors that determine stream temperature and where they have the greatest influence across the landscape. In addition to the question about elevation and air temperature, the sensitivity analysis could explore the relative influences of the four major factors that are affected by human land use activities; shading by vegetation, stream discharge, channel morphology, and surface/subsurface exchange.

2. Are there significant benefits to sensitive uses, e.g. cold water fishes, from apparently small decreases in stream temperature, e.g. 2 degrees F in summer maximum temperatures? Is the reduction in extremes of diurnal variation in stream temperature a significant benefit? Are

restoration efforts that produce desirable but somewhat disconnected refugia a significant benefit?

This question consists of three parts. The answer to all three of these parts hinges on the word "significant". The answer is also contingent upon how close the temperature under consideration is to the thermal tolerance limits of that species. The following is a discussion relevant to the individual parts of the overall question. While the answers are rooted in scientific fact, some of the examples originate from prevailing theory founded on scientific fact.

Are there significant benefits to sensitive uses, e.g. cold water fishes, from apparently small decreases in stream temperature, e.g. 2 degrees F in summer maximum temperatures? Yes, a small decrease in temperature could benefit fish living in water near or slightly above their thermal tolerance limits. Because effects of different stressors produce cumulative effects, fishes living near their thermal tolerance limits would be especially vulnerable to other stressors (e.g., pathogenic organisms, social interaction, and other less than optimal habitat factor) and less capable of performing other necessary functions of life (e.g., migrating, normal reproductive development, and avoiding predators). A decrease in temperature sufficient to bring the ambient water to a temperature below a species' critical thermal limit would help fish from suffering direct thermal stress. If temperatures were elevated to an extent that a decrease would not bring the temperature down below a critical thermal threshold, then the fish would still be at risk.

Small decreases in temperature for reaches also provide significant benefits when the longitudinal patterns of stream temperature are considered. The cumulative effects of local reductions in stream temperature lead to more gradual warming along the stream network. The magnitude of this benefit will depend on the number of areas that provide such small reductions in temperature along the stream network. If restoration efforts lead to numerous areas of more gradual warming, distances of stream that have temperatures that protect designated beneficial uses will be greater.

Is the reduction in extremes of diurnal variation in stream temperature a significant benefit? Yes, especially if the variation in stream temperature is exceptionally large or if the upper extent of the elevation exceeds the thermal tolerance threshold of a species. In the former case, it is energetically more costly for a fish to cope with great variations in environmental extremes such as temperature over the course of a day than to cope with smaller diurnal variations. This results in less energy available to perform other necessary life functions. In cases where the diurnal variation in temperature places fish in a thermal regime where they spend part of a day at temperatures elevated above a thermal threshold, the consequences depend on the magnitude of the thermal elevation and the length of time the fish spend at temperatures above their tolerance limits. It appears that fish can accumulate exposure "doses" above a critical temperature; that is, repeated daily exposures to elevated temperature for periods of time may have cumulative effects. Therefore, any reduction in the maximum daily temperature could benefit a fish by reducing the "dose" of temperature to which the fish has been exposed.

Variation alone is may not be either beneficial or detrimental. There is some suggestion that variation in temperature may be beneficial to individuals if that variation is small and within tolerance limits. Variation in temperature provides a range of thermal conditions for either

individual species or the communities of multiple species. The benefits or adverse effects of variation within the thermal tolerances of organisms will differ for different species.

Maximum temperature attained at a site during a day is related to the rate of increase in stream temperature through the course of the day. More gradual warming rates in the early part of the day will limit the maximum temperature that is attained within a local reach. Reduced daily variation may indicate that rates of warming have been reduced, which could provide significant ecological benefits.

Are restoration efforts that produce desirable but somewhat disconnected refugia a significant benefit? Yes. The presence of refugia can help sustain, though not optimally, a population. In addition, certain species may be able to undertake migrations in systems that are "too hot" if refugia are present; they basically will move form one refugium to the next. In this regard of course, the smaller the distance between refugia the better.

In a system overly warm for salmonids, any small reduction in temperature, while perhaps not having a dramatic effect in its own right, would be present to build upon in the future. Similarly, the restoration of any thermal refugia in a system would be available for the combined effect of any subsequent refugia. Studies of rivers in eastern Washington demonstrated that longitudinal patterns of cold water areas made it possible for adult salmon to migrate through stream reaches that exceed their thermal tolerances by providing areas to lower the core temperatures of their bodies. Likewise, salmon occurred in cooler habitats along the John Day River system.

3. Are management practices available for riparian areas that allow livestock grazing and result in improved landscape conditions that prevent or control stream heating? What are these practices? Are the implementation costs of these practices offset, by benefits in livestock production?

Are management practices available for riparian areas that allow livestock grazing and result in improved landscape conditions that prevent or control stream heating?
Yes, on a site-specific basis. Most of our knowledge in riparian zones is based upon vegetation and streambank erosion response to vegetation. It is reasonable and logical to allow vegetation response and improvement in riparian zone status to serve as a surrogate to other riparian values in addition to stream temperature. Improved riparian vegetation increases sediment filtering and bank building processes. This relates, over time, directly to stream width and depth. Wide streams experience great heat energy loads from radiant energy when compared to streams that have a smaller width. The response of vegetation growing in riparian zones to grazing depends upon a combination of site (geology, soils, slope, climate, vegetation, depth to ground water, etc) and management (season of grazing, length of grazing, number of animals, grazing rotation, types of animals) factors. These can be meshed together in such a way that many managerial and environmental objectives can be met.

What are these practices? The practices vary according to site and circumstances. The human factor is important as well. Ehrhart and Hansen (1997) indicated that the one constant in successful livestock management practices in improving riparian areas was "commitment by the operator". In addition, practices also must be monitored carefully and appropriate adjustments

(adaptive management) must be made as climatic and growing conditions shift during the course of the grazing period.

Are the implementation costs of these practices offset, by benefits in livestock production? One can rationally expect that well-managed riparian zones will be more productive than riparian zones that are grazed at inappropriate seasons, for excessive lengths of times, in sensitive habitats or locations, and/or inappropriate types, age classes, or breeds of livestock. Bear Creek in central Oregon was supporting 75 animal unit months (AUMs) prior to a shift in time of year in which it was grazed. This allowed recovery and it is currently being sustainably grazed at the rate of 400 AUMs (Elmore, personal communication). Dick Nelsen who is the permittee on this allotment has also reported a $15,000 reduction in his hay feeding expenses due to grazing during this late winter period. Studies on Meadow and Catherine Creeks indicated that managed grazing promoted weight gains in an experimental livestock herd in addition to fostering improved riparian conditions. Such increases are often, but not always, reported across ecosystems and ecoregions when the site and management factors are brought into balance.

The IMST has attempted to briefly answer your questions. We hope these responses and the upcoming Temperature Report will be useful in working with the public in improving the management of the natural resources of the State of Oregon and accomplishing the goals of the Oregon Plan for Salmon and Watersheds. We would be happy to provide further clarification to information in the letter or to supply you with references related to our letter.

Sincerely,

Stan Gregory

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