# Bull Trout Temperature Thresholds
# Peer Review Summary

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***Peer Review Panel***

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**Introduction**

In 1996, Oregon Department of Environmental Quality revised their water temperature standard and submitted it to EPA for approval. EPA approved Oregon's standard in 1999, but during the review process concerns were raised by EPA, the National Marine Fisheries Service and others that the standard would not fully protect all life stages of threatened and endangered salmonids.

To address these concerns, EPA Region 10 started a project to develop regional temperature criteria guidance that would be protective of salmonids. States and tribes in the Pacific Northwest could then use this guidance when developing their temperature standards, as required by the Clean Water Act. This project is unique because it is a collaborative process between states, tribes and federal agencies. The guidance will supplement the national water quality criteria for temperature to meet the specific needs of salmonids in Northwest streams and rivers.

Washington Department of Ecology, Idaho Department of Environmental Quality, Oregon Department of Environmental Quality, National Marine Fisheries Service, U.S. Fish and Wildlife Service, and representatives of Pacific Northwest Tribes are all joining EPA in this effort. There are two workgroups supporting this project. The Technical Workgroup is made up of scientists from various federal, state and tribal organizations who will be responsible for developing and recommending a regional temperature criteria guidance for adoption. As part of their work, they wrote peer-reviewed papers on the following:

- the most recent science on how temperature affects salmonid physiology and behavior,
- the combined effects of temperature and other stressors on threatened fish stocks,
- the pattern of temperature fluctuations in the natural environment, and other relevant issues

The Policy Workgroup is made up of state, federal and tribal members who will assist EPA Region 10 in reviewing and finalizing the regional temperature criteria guidance. Some of the issues that the policy group will address are:

- how to make the guidance practical and;
- its compliance with the Clean Water Act and the Endangered Species Act.

A cornerstone of the proposed EPA Regional Guidance is the recommendations by the Technical Workgroup for specific upper optimal temperature thresholds for different salmonid species by life stage. The Technical Workgroup provided the Policy Workgroup with a recommendation for a juvenile bull trout upper optimal temperature threshold, as well as recommendations for temperature thresholds for other salmonids.

During the Guidance Project's recent public comment period, dissenting opinions were presented by the states of Washington and Idaho, and it became evident that there was disagreement within the Technical Workgroup on the recommended temperature thresholds for bull trout.

The goal of the bull trout temperature peer review was to have a panel of experts review the three papers written by the Technical workgroup members supporting their recommendations for bull trout temperature thresholds. The panel was composed primarily of researchers investigating different aspects of bull trout temperature requirements, plus a thermal ecologist and biometrician. Through this review, the panel members attempted to answer specific questions related to the range of optimal temperatures for bull trout and the risks associated within and beyond that range.

The peer review panel met in Boise on Aug. 1, 2002. Dr. Chris Myrick, fish physiologist, thermal ecologist and a panel member, was responsible for writing the following summary of the review. All panel members were given the opportunity to comment on a draft of the summary, and their comments have been incorporated in this final version.

## General Comments

The peer review panel (Table 1) covered a number of items during our August 1 meeting. One area that was extensively discussed was the definition of optimal temperature. We felt that the EPA definition was somewhat vague. However, we were unable to come up with a single definition of "optimal temperature" that satisfied all members of the peer review panel. The major definitions that were mentioned are shown below.

*Definitions of optimal temperature*

- EPA definition: We have defined "upper optimal" as the estimate of the higher end of thermal conditions known to support the life stages and biological functions of bull trout. We are assuming that adverse effects are more likely to occur as temperatures rise above this thermal upper optimal. The EPA looks at biomass, abundance, population trends, connectivity, and life stages when determining optimal temperatures.
- Physiological definition: The optimal temperature is the one that maximizes the performance of a particular physiological parameter, such as growth or reproductive output. Optimal temperatures for growth are strongly influenced by ration level, with lower optimal temperatures at ration levels lower than the satiation level.
- Ecological definition(s): Optimal temperature is one in which individuals realize maximum lifetime reproductive success, which summed across all individuals leads

to higher population growth rates.  This optimum will vary spatially and temporally in relation to other influential factors, including resource availability and species interactions such as disease, predation, parasites, and competition.

**Question 1**

a) *Given that we want to fully protect juvenile rearing, is there an important difference in the level of protection offered by the three temperature proposals (11, 12, 13°C 7DADM)?*

   There is a *biological* difference in the level of protection offered by the three temperature proposals.  Because of the confidence bounds associated with the various data sets, it is possible that you would not be able to detect a *statistically* significant difference between these three temperature proposals. However, even with the uncertainty that results from large confidence intervals, there will be a difference whose importance depends largely on the amount of risk the EPA is willing to assume.

b) *If so, what is the difference?  If not, why not.*

   The primary difference between the three temperature proposals is the amount of risk that accompanies each proposal.  The lower the proposed temperature, the lower the risk to bull trout populations and individuals, especially when they occur sympatrically with other salmonid species.

c) *Which of these three proposals can be reasonably defended as being the upper end of optimal as defined in our process?  Should the temperature criterion be set lower or higher than those identified here?*

   The peer review panel was unable to agree on a definition of optimal.  As mentioned in the General Comments section, a number of different definitions of optimal are possible.  We were not able to identify a sole proposal that could be reasonably defended as the upper end of optimal because of (1) the overlap generated by the uncertainty in the data and (2) the varying definitions of what is considered “optimal”.  We would not recommend setting the temperature criterion higher than those identified here.  Setting the temperature criterion lower than those identified here may be beneficial to bull trout faced with competition from other salmonids, but would not be considered optimal from a physiological standpoint.  It should be noted, however, that bull trout have access to a spectrum of water temperatures in most systems, including temperatures that are warmer than the proposed thresholds.  Therefore, even if a colder threshold is selected, the potential negative effects (e.g., slower growth) could be offset because of the availability of warmer temperatures. The peer review panel did not reach a consensus on whether setting a threshold is going to *make* any stream colder than it would naturally. It was pointed out that some restoration options (e.g., decreasing stream width, increasing overhead riparian cover) might reduce stream temperatures in streams that had been impacted by other activities (e.g., grazing, logging), but in streams that were in a relatively natural state, few, if any techniques for cooling beyond the natural thermal regime exist. For any given threshold, it is likely that fish will have access to water colder and warmer than the threshold, provided they can move upstream or downstream from the point where the threshold occurs.

**Question 2**

a) *What is the significance of the risk (effects on key life processes, such as growth, reproduction, competitive ability, disease, survival, fecundity, ability to feed and hold territories, ability to respond to environmental stress, etc.) presented under typical field conditions from lack of available food, and disease if we set the threshold at: 11°C 7DADM, 12°C 7DADM, or 13°C 7DADM*

b) *Does research or information exist to support the assumptions on limited food availability in streams at these temperatures?*

We do not know what level of feeding occurs under natural conditions. One possible line of evidence involves the size difference between wild and laboratory-reared bull trout. Wild bull trout are generally smaller than bull trout of the same age raised under laboratory conditions that receive satiation rations. However, one should keep in mind that laboratory fish receive feed formulations that have different energy contents and levels of palatability than natural feeds; they also do not experience a true winter.

Evidence from a variety of studies on other salmonids under natural conditions suggests that both individual growth and population productivity increase in response to increases in the food supply. Food availability has long been recognized as a potential limiting factor for population productivity. It is probably true that food limitation acts on some bull trout populations, as indicated in a recent study in Lake Billy Chinook, OR. Differences in growth among bull trout populations occupying thermally-similar environments would be evidence of differences in food availability. Additionally, because life history theory predicts that migrations may be a response to limited resources, including food, the extensive nature of migratory life histories across the species' range suggests that some resources are limiting.

c) *How important is the role of temperature in allowing bull trout to maintain strong, healthy populations in the face of potential competition from brook trout and rainbow trout?*

Water temperature could play a central role in determining the outcome of interspecific competition between bull trout, rainbow trout, and brook trout. In cases where you have a mix of salmonids, the proportion of bull trout is higher at lower temperatures than at higher temperatures. This field data is supported by the results of laboratory competition experiments. Elevated water temperatures may not completely exclude bull trout, but they may well shift the competitive advantage towards rainbow and brook trout. There are projects currently underway that are further examining the role that water temperature plays in brook trout *vs*. bull trout interactions. These projects are also trying to understand the mechanisms behind these interactions.

d) *Are there temperatures associated with dominance by bull trout, codominance, or loss of dominance in competition with other salmonid species?*

There are temperatures associated with dominance by bull trout and loss of dominance with other salmonid species. The mechanisms underlying this "dominance" (e.g., increased relative abundance, behavioral dominance), such as competition or other interspecific interactions, are not clear. Temperatures at the lower end of the range may provide bull trout with favorable conditions for competing with other salmonid species. It is important to note that these lower temperatures are not necessarily optimal from a strict physiological basis. In other words, physiologically optimal temperatures may differ from ecologically optimal temperatures. The EPA will have to decide whether it is more important to provide bull trout with optimal conditions from physiological or ecological standpoints.

**Question 3**

a) *What is the risk (to individuals and populations) involved in setting a temperature criterion at 1 or 2°C below the upper end of optimum vs. 1 or 2°C above the upper end of optimum?*

Bull trout (both individuals and populations) will be placed at greater risk if the temperature criterion is set 1 or 2°C above the upper end of optimum than if it is set at 1 or 2°C below. A criterion that is set 1 or 2°C above the upper end of optimum reduces the size of the buffer zone separating tolerable temperatures and those that will start to have negative sublethal or even lethal effects. While bull trout can tolerate temperatures of 16°C or more, they appear to do better in cooler temperatures in the face of interspecific competition with other salmonids (and potentially for other reasons, e.g. food limitation). Additionally, a criterion that is 1 or 2°C above optimum will result in significantly less thermally-suitable habitat than a criterion that is set 1 or 2°C below the upper end of optimum. The hypothetical changes in suitable habitat that would result from a 2°C increase or decrease in air temperature which is correlated with water temperature for the Boise River are illustrated in Figure 1.

Under most *natural* situations, it is difficult to envision the implementation of a temperature standard that would result in a significant cooling of streams. Under these situations, the imposition of a standard might consist of selecting an elevation where the threshold temperature naturally occurs. While this appears outwardly favorable, it is important to realize that selecting a threshold temperature that does not maintain or increase the connectivity between patches or populations of bull trout does nothing to reduce the risk of their extinction through stochastic and demographic processes. If the EPA is concerned with the loss of connectivity between patches/populations of bull trout, then the risk is obviously higher when there is less suitable habitat. These risks will be even greater in cases where populations are already fragmented or isolated as a result of distributions on the southern margins of the range, habitat loss, barriers to migration or the expansion of exotic species. The technical guidance for EPA temperature criteria points to the importance of maintaining thermally suitable habitats that are large and interconnected, and which allow for expression of life history diversity. This is an important consideration for the effects of temperature on bull trout populations, as opposed to individuals.

Assuming that we can actually achieve the temperature standards, the colder temperatures would likely provide less risk to bull trout populations. The risk reduction would result from their lower susceptibility to replacement by competing salmonids such as cutthroat or brook trout. However, this does not mean that the lower temperatures would generate the highest bull trout densities or biomass. Furthermore, low water temperatures are likely to be detrimental to other native salmonids, including redband trout, steelhead, and cutthroat trout.

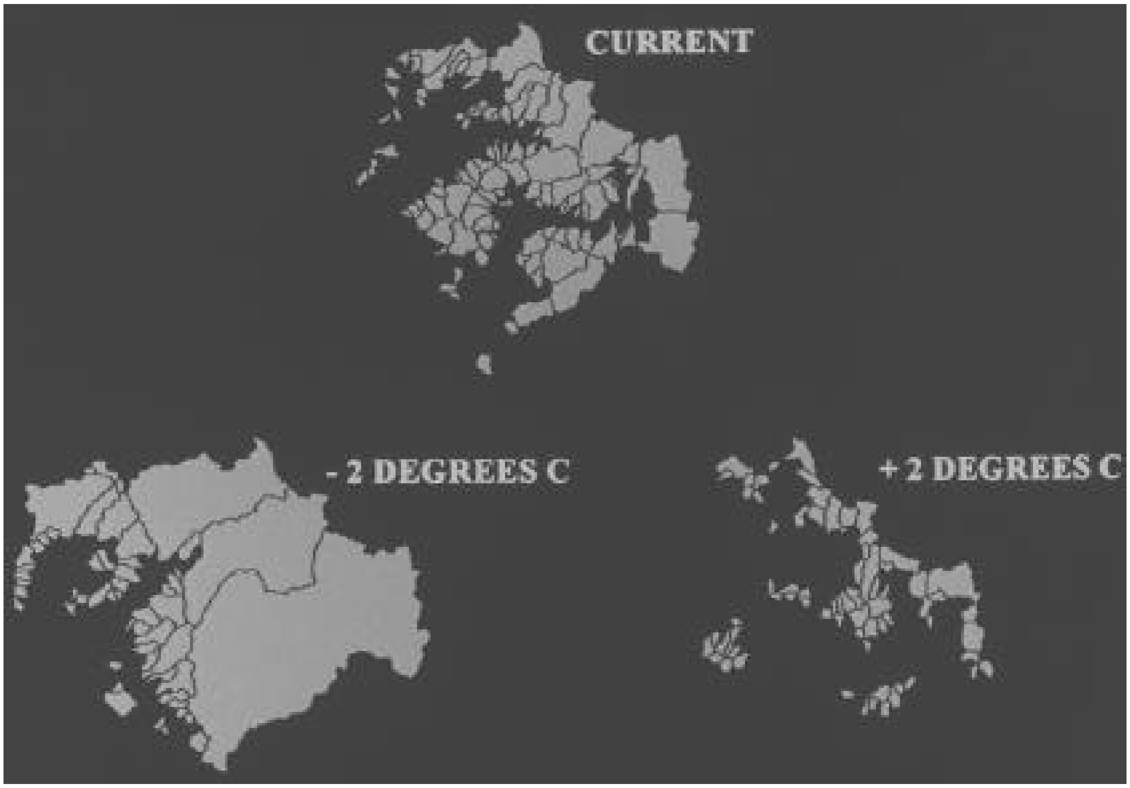


Figure 1. Predictions of changes in available bull trout habitat in part of the Boise River Basin if the air temperature was increased or decreased by 2°C from current levels. The model used assumes that water temperature is directly related to air temperature and that the relationship between elevation, air, and water temperatures remain the same as they are at present.

The risks that are associated with any temperature threshold that might be chosen will more likely be a function of where the threshold is imposed and how well it can be implemented. The threshold that potentially leads to the most warming or loss of suitable habitat will also represent the greatest risk. In some cases the additional risk would likely generate higher rates of local extinction, but in others it may be irrelevant.

**Question 4**

a) *If the upper optimal are only achieved every 9 out of 10 years, what is the risk to the population?*

The risk to the population will be a function of the duration of the period of super-optimal temperatures and the magnitude of the super-optimal temperatures. If the duration is short or the super-optimal temperatures are only slightly higher than the optimal temperature, then the risk is relatively low. Increasing either the magnitude of the super-optimal temperatures or the duration of the interval during which they occur will increase the risk. If the EPA is concerned with minimizing risk, then lower optimal temperatures will give the largest buffer or cushion before negative effects are observed. The EPA should entertain the possibility of giving special consideration to bull trout populations inhabiting small, isolated habitats, such as the upper Snake River (including the Bruneau/Jarbidge system), and Klamath basins. Further changes in the amount or distribution of suitable habitats (e.g., cold water) in these areas could have particularly important consequences for bull population persistence.

**Question 5**

a) *What level of risk is there to the population if there is not optimal growth for 2 – 4 weeks of the year?*

The level of risk to the population should be relatively low if there is not optimal growth for 2 – 4 weeks of the year, provided temperatures remain below the optimum. Sub-optimal temperatures are unlikely to have serious physiological consequences, though they will result in lower growth rates. Super-optimal temperatures are more of a concern because as temperatures increase, data indicate: i) an increased rate of physiological damage; ii) changes in the relative abundance of bull trout in relation to other salmonids; and iii) reductions in overall bull trout abundance.

**Question 6**

a) *Of the three temperatures, does any one of them more adequately account for the uncertainties of translating laboratory thresholds to the field?*

The uncertainties of translating laboratory thresholds to field conditions require the selection of a conservative (i.e., colder) temperature criterion. Laboratory data typically include large confidence bounds that can result from a number of sources, including: 1) the natural variability between individual fish, or between groups of fish; 2) the physical design of the experimental apparatus, and; 3) the experimental procedures. Laboratory studies are valuable for understanding the underlying mechanisms, but they do represent an artificial system that has been necessarily simplified to isolate the variable of interest. If the EPA chooses to translate laboratory data to the field, then we recommend that they use a conservative temperature estimate that provides some allowance for the interactions of variables not present in laboratory studies. The EPA must also recognize that temperatures are dynamic and that bull trout populations use spatially and temporally variable networks of cold water habitat. Therefore, the successful application of *any* threshold would require a detailed knowledge of actual stream temperatures. If such information is unavailable, then we recommend that lower temperatures, *possibly even lower than those considered by the peer review panel*, would account for the most uncertainty.

b) *Would the uncertainty rise to a level that would cause a likely risk to bull trout populations?*

The answer to this question depends largely on the chosen threshold. The lower the temperature (within the bounds of the proposed criterion), the larger the buffer zone and the lower the risk to bull trout populations. The risks will also depend on the disparity between actual stream temperatures, the threshold selected, and the location where the threshold is actually imposed. Risks are associated with the level of warming and habitat loss that are allowed. In areas where bull trout populations are already small, the risks will be greater.

**Question 7**

a) *Which of these thresholds applied as the upper limit on summer maximum water temperatures will also typically protect spawning and incubation in the fall and winter?*

The peer review panel did not develop a firm answer for this question. We noted that streams that are warmer in the summer can be colder in the winter because they often have hydraulic and watershed characteristics that allow greater temperature fluctuations. We also noted that it was unclear whether bull trout spawning activity is triggered by temperatures falling past a certain point or if their spawn timing is driven by when the fry need to emerge from the gravel. The association between summer and winter temperatures will also be affected by a variety of hydrological factors (e.g., rain or snow-dominated runoff) across the expansive range of bull trout.

**Question 8**

a) *Is it warranted to establish separate spawning season criteria, and if so what would be most appropriate as expressed as a highest permissible 7DADM applied to the starting date of the natural spawning period?*

We did not feel that it would be appropriate to establish separate spawning season criteria, with the possible exception of regulated rivers (i.e., those with dams). On part, determination of spawning season criteria depends on what is defined to be the spawning season. If a basin has undergone thermal alterations, the bull trout spawning season may have also been altered. Thus, estimates of spawning seasons from past and contemporary observations of spawning activity are likely to underestimate the full seasonal range of potential spawning activity under unaltered conditions.

b) *Is 10°C 7DADM an appropriate criterion for protection of summer spawners (prior to September 21$^{st}$) applied to the starting date of the natural spawning period on a site-specific basis?*

The peer review panel felt that we could not answer this question using the species life-stage approach. Other factors such as thermal potential would have to be considered, as discussed in the EPA technical guidance documents.

c) *Standards are normally applied to the well-mixed flow in the stream reaches providing critical habitat. If summer spawning by bull trout takes place under unique local conditions (e.g., associated with cold groundwater influences), should the standard apply only to the local areas (e.g., refugia) and not the well-mixed flow? This question basically asks whether summer-spawning bull trout utilize unique streams that are colder than the majority of bull trout streams and would provide the very cold spawning and egg incubation temperatures needed.*

There are currently insufficient data to determine whether all summer-spawning bull trout population use unique streams that are colder than the typical bull trout stream. Until such data can be collected, we do not recommend the application of a standard (if any) to local areas of such streams. Existing standards in some states do recognize the value of unique coldwater conditions (thermal “refugia”), but further work is needed to provide clearer guidance.

d) *Would specific criteria need to be developed to be protective of these early spawners to ensure that water temperatures are not raised?*

Potentially, but only if satisfactory site-specific information exists to justify such measures.

**Question 9**

a) *Do migratory fish (adults and subadults) face the same risks with these numbers as fish of other life stages do?*

This question refers to lifestages that have dispersed to rivers that serve as foraging corridors and to juvenile rearing areas. In general, adult fish are *less* tolerant of temperatures than smaller fish of the same species. The greater temperature tolerance of smaller fish is partially related to predation risks—by inhabiting marginal habitats where adults do not typically occur, smaller fish can reduce their exposure to predators. Also, even though larger fish are less tolerant of extreme temperatures, they do possess a great ability to behaviorally thermoregulate by moving to more suitable thermal environments. We feel that there currently aren't enough bull trout – specific data to provide a strong yes or no answer—efforts to collect data on the temperatures subadult and adult bull trout encounter are currently underway.

b) *Can you describe the risks to migratory populations using the range 12 – 16°C 7DADM? Provide special focus on whether establishing summer maximum temperatures of 16°C 7DADM (currently proposed to protect most salmon and trout waters) would likely harm the individuals and the populations.*

Although bull trout experience few, if any, negative effects when reared at 16°C under laboratory conditions, data on bull trout competition with other salmonids suggest that bull trout are at a disadvantage at temperatures of 16°C. It is probably true that bull trout historically migrated through areas that experienced elevated temperatures, but data to support this assumption do not exist. In terms of risk to individuals and populations, the risk is lower at 12°C than at 16°C, although we have no means of quantifying the level of risk.

**Question 10**

a) *Have we (authors of the 3 review papers and EPA's proposed criteria recommendation) used the research appropriately in our assessments?*

b) *Was the work interpreted correctly in the 4 review papers?*

c) *Did we omit any important research or concepts in thermal ecology?*

d) *Did EPA's recommendation omit any important research or concepts in thermal ecology?*

The peer review panel decided to only comment upon the EPA's draft proposed criteria during the meeting. Panel members were encouraged to send comments on the other 3 papers to Dr. C. Myrick for inclusion in this summary. No comments had been received as of 8/15/02. The comments on the EPA's paper are below.

- Comments on 1
  - The frequency of observations doesn't reflect the distribution of the sample. The proportions and probabilities of detection should be used instead.
- Comments on 2
  - The conversions the EPA used are not understood, so we cannot comment on their validity.
  - The EPA needs to better justify/explain how they equated constant temperatures with daily, weekly, and seasonal means.
  - The interpretation of the optimal growth data could be improved by looking at the *amount of energy* consumed, not the ration level. The data analyses shown by Dr. Barrows at the meeting demonstrated that the optimal temperature (where growth rates were highest) did indeed decline as the amount of energy consumed declined.
  - We did not understand how the EPA came up with their conclusions in 2d.
- Comments on 3
  - The presence of heat shock proteins[1] (HSPs) indicates that the fish is experiencing stress at a cellular level, but the cause of that stress isn't necessarily known.
  - The EPA cannot conclude that 13°C does not produce the same level of stress as 14°C. A better conclusion would be that HSP induction occurs between 12 and 14°C.
- Comments on 4
  - The data set that is being used is unknown.

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[1] Heat shock proteins are formed when fish are exposed to stressors such as high temperature and some pollutants. Heat shock proteins aid in the repair of damage caused by the stressors. During the time that these repairs are underway, most of the cells' energy above some basal metabolic level is diverted to the repairs, forcing a shut-down of non-essential functions.

- Gammett's thesis data do not agree with the EPA's conclusions. The site with the highest number of bull trout had a moving maximum of 13.5°C and a mean of 7.7°C.
- It was unclear why the EPA selected just these two studies when there are data available for lots of other sites.

♦ Comments on 5

- The method of applying the criteria is inappropriate because the presence of fish in a location doesn't mean that the location is capable of supporting temperatures that are optimal.
- Defining use as a location where bull trout currently occur may be a problem. It is possible that bull trout currently occur in locations that are suboptimal.
- It is important to understand that juvenile bull trout will naturally occupy the entire range of suitable temperatures, not just those that are optimal. Many stream reaches occupied by juvenile bull trout that have temperatures above optimal likely never experienced optimal temperatures. Furthermore, just as stream temperatures show seasonal fluctuations, so would bull trout habitat use. Juvenile fish may overwinter in habitats that experience lethal summer temperatures. On the other hand, in some stream reaches anthropogenic influences have likely resulted in elevated water temperatures that have caused a contraction in the downstream distribution limits of juvenile bull trout. In at least some of these cases, we would want to restore downstream water temperatures to increase the range of suitable habitat. Therefore, it may be inappropriate to apply the temperature standard to the "lowest downstream extent of use" as indicated in the draft EPA proposal.

**Question 11**

a) *Should any lines of the lines of evidence used in determining upper optimal be weighed more heavily than others based upon strengths and weaknesses of the research, and applicability to field conditions?*

In addition to the major lines of evidence listed in the proposed EPA criteria, the peer review panel felt that the EPA should also evaluate the literature on patch size and persistence of bull trout populations. We also felt that the use of data from site-specific case studies should be down-weighted because the criterion will be applied to a much larger spatial scale.