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27 August 2009

Mr. Steven Herrera
Manager, Permitting Section
SWRCB

By email

Regarding: GSB:D1631

Thank you for the opportunity to comment on studies regarding environmental (instream) flow needs on Rush and Lee Vining Creeks. These studies are:

> Taylor et al. (2009a) Rush and Lee Vining Instream Flow Study;
> Taylor et al. (2009b) Radio Telemetry-Movement Study of Brown Trout in Rush Creek;
> Shepard et al. (2009) Effects of Flow, Reservoir Storage, and Water Temperatures on Trout in Lower Rush and Lee Vining Creeks, Mono County, California

The approach in the instream flow study is essentially similar to the familiar Physical Habitat Simulation System (PHABSIM) method, except that the area of patches of habitat defined as suitable, based on binary criteria, was determined by field mapping at different levels of flow instead of by hydraulic simulations. The telemetry study, in part, provided information for the suitability criteria for winter habitat. The Shepard et al. study consists primarily of a statistical evaluation, using linear regression, of the relations among trout biomass, size and condition and various environmental factors, using data from long-term monitoring on the creeks. The authorship of the three studies overlaps, as does some of the text, so they are best evaluated as a group. I have not reviewed and so do not comment on the details of the studies, but have instead considered the general approaches taken, and the studies' treatment of the scientific literature. I begin with a question:

*What is the relevant question?*

It is not reasonable to expect studies to come up with the right answers if they do not ask the right question, so let us consider first what the right question is. Taylor et al. (2009a) give the following language in their introduction, at p. 6:

> The brown trout populations are healthy and self-sustaining, although they are not meeting the fisheries termination criteria (as defined in Order 98-05) because of the relatively low number of fish larger than 14" (350 mm). For Rush Creek, the fisheries termination criteria of "size and structure of fish populations" was defined as "fairly consistently produced brown trout weighing

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> 0.75 to two pounds (0.34 to 0.91 kg). Trout averaging 13 to 14 inches (330 to 355 mm) were also allegedly observed on a regular basis prior to the 1941 diversion of this stream". For Lee Vining Creek, the fisheries termination criteria of "size and structure of fish populations" was defined as "to sustain a fishery for naturally-produced brown trout that average eight to 10 inches (200 to 250 mm) in length with some trout reaching 13 to 15 inches (330 to 380 mm)".

From this, I infer that the overarching question is, what kind of flow regimes will support brown trout populations that meet the size criteria set by Order 98-05. One obvious answer, based on the evidence behind Order 98-05, is the pre-regulation flow regimes. In the current context, however, we also want to know *whether other flow regimes exist that will meet the criteria set by Order 98-05, and also allow for the diversion of useful amounts of water?* One way to address this second question would be empirical; for example, we now know that the current flow regime is very unlikely to meet the criteria. A better approach would be based on a biological understanding of the conditions that are likely to produce larger trout, that is, the conditions that steer trout toward a life history trajectory leading to large size. Unfortunately, the studies do not address this question. Instead, for example, the Shepard et al. study considers statistical relations among environmental factors and the condition of the existing populations, which do not meet the criteria. Essentially, we learn more about what does not work.

Put somewhat differently, the assumption implicit in especially the Shepard et al. study is that the way to have more large brown trout is to have a lot of small, rapidly growing ones. However, biology is more complicated than this. On theoretical grounds, we can expect that a trout's aim in life should be to maximize its expected number of progeny, not simply to get big. If conditions are such that a trout can maximize the expected number of its progeny by maturing early and thereafter allocating resources to reproduction rather than to growth, then likely that is what it will do. This is not just theoretical. The flexibility and variability of brown trout life-histories, like those of other salmonids, is well known (Elliott 1994; Thorpe et al. 1998), and has been successfully modeled for Atlantic salmon (Mangel 1994) and for steelhead (Satterthwaite et al. 2009). Successfully determining whether there are flow regimes that will support populations producing large brown trout as well as allow diversions from Rush and Lee Vining creeks almost certainly requires considering what controls brown trout life-history trajectories. The studies fail to do this. More specifically, the objectives of the Shepard et al. study are given as (p. 6):

> Our objectives are to evaluate how flow and water temperatures influence:
> - Densities of age-1 and older brown trout in Rush Creek,
> - Densities of age-0 brown trout in Rush Creek,
> - Average length of age-0 brown trout in Rush Creek,
> - Total (all ages) standing crops of brown trout in Rush Creek,
> - Condition of 150 to 250 mm brown trout in Rush Creek,
> - Densities of age-0 brown trout and rainbow trout in Lee Vining Creek,
> - Average length of age-0 brown trout and rainbow trout in Lee Vining Creek.

As explained above, these objectives are not sufficient for addressing the problem at hand, particularly because the evaluation is essentially descriptive, and describes only statistical associations. As a simple example of a relevant question that was not addressed, consider the matter of diet. Smaller brown trout are insectivorous. Larger brown trout (>~25 cm) are increasingly piscivorous with size (Moyle 2002). Thus, a relevant question would be the extent to which, and under what conditions, trout in Rush Creek are piscivorous, since conditions favoring this "ontogenetic niche shift" would seem to be an important aspect of a flow regime that would support a population meeting the Order 98-05 criteria. However, the word "piscivorous" appears in Shepard et al. only in the title of one of the citations.

As noted above, the instream flow study was essentially similar to a PHABSIM study, but using field mapping instead of hydraulic modeling. According to Taylor et al. (2009a), p.6, 7:

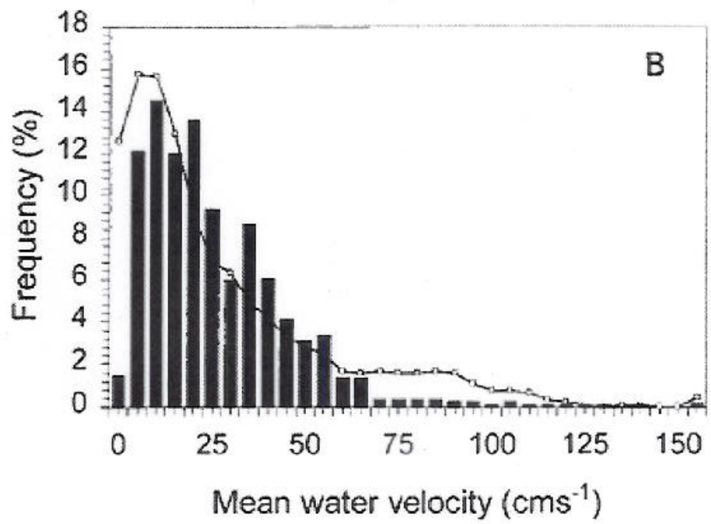
> The Rush Creek and Lee Vining Creek Instream Flow Study (IFS) was designed to quantify adult trout holding (primarily winter) and foraging (spring, summer, fall) microhabitat areas over a range of test flows, then assess trout microhabitat area in conjunction with water temperature, fish passage, and riffle hydraulics where trout food resources (benthic macroinvertebrates) are concentrated.

Among the steps taken to accomplish this, Taylor et al. developed "habitat criteria for larger (> 350 mm or about 14 inches) brown trout based on a review of the literature and measured criteria from actual locations of radio-tagged large brown trout in Rush Creek collected during the movement study." The literature cited most prominently was Heggenes (2002), which is also mentioned prominently by the companion studies. Unfortunately, it is not clear that the descriptions of and quotations from Heggenes (2002) accurately portray the actual paper and the data it reports. For example, at p. 9 in Taylor et al. (2009a):

> In his comprehensive evaluation of habitat selection by resident brown trout populations native to streams in Norway and Scotland, Heggenes (2002) found that macrohabitats favored by juvenile and adult brown trout were deep and slow-flowing pool areas. More specifically, quoting Heggenes, "On a microscale, however, the niche selected was rather narrow (i.e., brown trout occupied holding positions in slow-flowing water, usually in association with the riverbed)". When defining "association with the riverbed", he reported that the holding positions of nearly all brown trout observed during snorkeling surveys were within 0-15 cm (0-6 in) of the stream bottom, regardless of water column depth.

But, what is slow-flowing water? Figure 3B in Heggenes (2002) does show that the brown trout in his study avoided sites with mean column water velocity faster than about 65 $cms^{-1}$, or 2 $fts^{-1}$, and also still or very slowly moving water, but there is a wide range of velocity for which use does not seem to differ from availability. Moreover, it appears that only one of the fish observed by Heggenes was > 350 mm, so the relevance of these data for "habitat criteria for larger (> 350 mm or about 14 inches) brown trout …" is unclear.

Figure 3B from Heggenes (2002): the bars show use, and the lines show availability.




Moreover, and importantly for the instream flow study but unmentioned, a major finding of Heggenes (2002) was that microhabitat selection depends on discharge, which undercuts an important assumption of the method used by Taylor et al. (and also by PHABSIM studies), as pointed out by Heggenes in the last sentence of his abstract:

> *Abstract.*—Spatial and temporal hydraulic heterogeneity influence distributional patterns of species in streams. Ecological theory suggests flexible habitat selection strategies are favored in such unstable environments. The effects of varying hydraulic conditions on habitat selection by brown trout *Salmo trutta* in summer were studied in eight streams in Norway and Scotland. At normal summer flows, brown trout averaging 16 cm total length (SD = ± 5 cm, range = 3–43 cm) were selective in habitat use. The selection window was relatively narrow for focal water velocity (mean = 14 cm/s, median = 10 cm/s, 60.1% of observations ≤ 14 cm/s). Trout favored slower flowing pool areas, but selection ranges were wide (mean water column velocity = 24 ± 21 cm/s, range = 0–142 cm/s; mean depth = 69 ± 29 cm, range = 9–305 cm). Larger fish used deeper habitats; other variables did not correlate with size. Great overlaps in spatial niche used by the studied size-classes of trout indicated versatility in habitat selection (e.g., in response to varying hydraulic conditions). Considerable within and among stream variation in habitat selection, largely depending on habitat availabilities, was most pronounced for water depth (mean range = 40 ± 24 cm to 109 ± 48 cm). Focal water velocities, an exception that remained remarkably stable across streams, may be explained by the larger spatial scale in the distributional pattern of depths, compared with a micromosaic in water velocities. Temporal variation related to changes in water flows produced almost complete habitat shifts in mean water column velocity (from 2 to 33 cm/s, SD = 4–20 cm/s) and even focal water velocities (from 1 ± 3 cm/s to 17 ± 10 cm/s), whereas selection of water depths remained more stable. The results suggest in situ hydraulic variability affects fish behavior. The flexibility in behavioral responses also suggests the use of habitat and foraging models assuming similar habitat use at all streamflows may be flawed.

The point in the last sentence of the abstract is emphasized by the title of the paper: "Flexible summer habitat selection by wild, allopatric brown trout in lotic environments." Indeed, the objective of the study was (p. 288):

> The objective of this study was therefore to quantify and investigate whether habitat selection among allopatric, wild brown trout varied with different summertime habitat conditions in streams, indicating a flexible generalist strategy, or reflected a narrow range of habitats across different times and localities, indicating a habitat specialist strategy. Habitat selection was studied in eight streams covering a wide range of different stream conditions in space and time to provide spatiotemporal heterogeneity (i.e., diverse habitat alternatives).

A major finding of the study was that as flow increased, trout moved into deeper, faster water. As noted by Heggenes (p. 296): "The results here indicate habitat use is wide and inconsistent, especially for focal velocities, at different streamflows or locations within stream or among streams. This finding strikes at the heart of studies such as Taylor et al. (2009a) or PHABSIM, since they depend on the assumption that microhabitat preference does not change with flow (Kramer et al.1997). Change in habitat selection by salmonids with discharge has also been shown for salmonids by other field studies (Vondracek and Longanekcer 1993; Shirvell

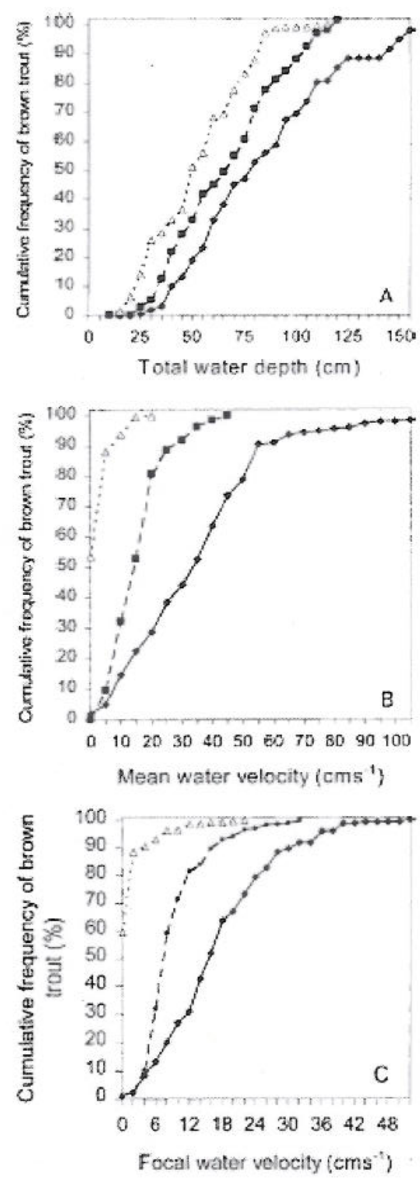



FIGURE 5.—Temporal changes in wild brown trout habitat use of **(A)** water depths, **(B)** mean water velocities, and **(C)** and focal water velocities, in relation to variable stream flows (low [triangles], normal [squares], high [diamonds]) in the Hjartdøla River (*N* 5 760). (Copied from Heggenes 2002.)

1994; Pert and Erman 1994; Greenberg 1994) and by laboratory-stream studies (McMahon and Hartman 1988; Campbell 1998; Holm et al. 2001; Kemp et al. 2003), and why this should be so has been clarified by simulations (Railsback et al. 2003). It is time to give up on this kind of method.

Finally, the telemetry study was intended in part to inform the instream flow study, particularly the suitability criteria used to assess winter habitat. It appears that the study produced data on winter habitat use during the day. However, salmonids are commonly reported to be nocturnal when water temperature is low (< ~10°C), and brown trout specifically can be nocturnal during winter (Heggenes et al 1993). Accordingly, even with the limitations of PHABSIM-like methods, the utility of the mobile telemetry data appears to be questionable.

In summary, the Rush and Lee Vining creek studies do not provide the SWRCB with useful guidance regarding the instream flow needs of the creeks. As one of those who champion adaptive management for instream flow assessment (Castleberry et al. 1996), I find this doubly unfortunate. Not only will the studies not be useful for their intended purpose, but they may well discourage the SWRCB from taking an adaptive approach in the future.

So what should be done now? Probably the thing to do is to pause and think, and to recognize that monitoring should address specific questions (Williams 2006, Ch. 15). Before the SWRCB changes the flow regime, it should have in hand a model or theory that can help explain both the size distribution of the current populations with the current flow regimes, and the size distribution of the historical populations with the historical flow regimes. The salmonid life-history models being developed by Marc Mangel (UCSC) and colleangues, or the dynamic energy budget models being developed by Roger Nisbet (UCSB) could be useful for this purpose. Relevant hypotheses can then be developed that can guide the development of "next-generation" flow regimes, and be tested by future monitoring. In the meantime, inquires into the life histories of the fish that do achieve large size in existing conditions could provide useful insights.

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Sincerely,

John Williams

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