Review of the Biological Opinion for the Management of the Russian River, California, Estuary

Dr Mike Bradford
Vancouver, BC
mbradfor@sfu.ca

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Executive Summary

This review considers the components of the June 11, 2007 Biological Opinion (BO) for the Russian River Water Supply and Flood Control Project that deal with the impacts of the current management regime on steelhead habitat within the estuary. In brief, the BO concludes that the current conditions and management of the estuary has lead to a "reduction in the estuary's carrying capacity for juvenile steelhead trout". The main line of argument for this conclusion is that under historical conditions the estuary would have closed and become a productive freshwater lagoon during the summer months. The combination of higher than natural inflows and repeated breaching of the estuary berm is considered to cause a deterioration of rearing conditions for steelhead.

In reviewing the analysis and supporting literature, I find the BO to be plausible, but not particularly well organized or supported by information currently available. I suggest that the Agency use "pathways of effects/influence" diagrams or other tools to organize the logic behind the various scenarios of active or passive estuary management. With this approach the strength of evidence to support each assumption can be made explicit and uncertainty can be incorporated in the analysis.

The assertion that the estuary would convert to a productive freshwater lagoon if it were left closed, which is key to the BO, is not well supported, and in fact seems to be contradicted by available information. I suggest the Agency use a more structured approach to predict conditions in the estuary. For example, I briefly reviewed available information on steelhead densities in closed, open and stratified estuaries. Information summarized in that review can be used to quantitatively support the claim that if the estuary did convert to a closed lagoon, a significant steelhead population could be supported in the estuary. Relatively simple modeling tools appear to be available to predict estuary conditions under differing scenarios of inflows and breaching; these should be used to predict the outcome of management regimes and the implications for steelhead habitat.

I conclude that to make full use of the best available information in developing the BO, the Agency should consider:

1. The use of a logic model to organize assumptions in the BO
2. A formal comparative analysis to capture and make use of data from other California estuaries.
3. Using existing hydrodynamic to predict conditions in the estuary under different management scenarios.
4. The use of a decision tree or other tool to evaluate the effects (and uncertainties) of differing management strategies and uncertain states of nature on steelhead habitats and other affected components of the Russian River system.

Introduction

The purpose of this expert review is to “evaluate and comment on the use of best available scientific and commercial information in the estuarine-related analysis of the draft Biological Opinion (BO) for the Russian River Water Supply and Flood Control Project”. The bulk of this review will focus on four “fundamental questions for the CIE reviewers” from the Statement of Work (attached), supplemented with some additional analyses.

California estuaries are unique habitats for anadromous salmon in the eastern Pacific basin. In many locations the estuaries become blocked by sand berms in the summer months, creating an impounded lagoon at the river mouth. When conditions are suitable these habitats are extensively used by rearing steelhead trout and other salmonids. This behaviour is not seen in the Pacific Northwest as juvenile steelhead usually migrate directly from freshwater rearing areas to the ocean in the spring months, using the estuary briefly as a transitional area for osmoregulatory adaptation (Melnychuk et al. 2007). Ward and Slaney (1990) estimated survival of hatchery steelhead released in the river, estuary and ocean and found no effect of release site on survival. These observations suggest estuaries may play a less significant role in the sheltered waters of the Pacific Northwest compared to the open coastlines of Oregon and California.

Based on the survey of the studies on California estuaries that were provided for this review and material in Heckel (1993), the estuaries may be classified into three types based in conditions in the summer months:

1. Freshwater: low river flows and calmer ocean conditions result in the development of a sand berm in the summer months that prevents seawater from entering the estuary. Saltwater trapped in the estuary is displaced by freshwater as a result of diffusion of the trapped seawater through the sand berm. The estuary is largely freshwater until fall storms open the berms again.
2. Meromictic or stratified: A berm develops in the summer but seawater remains trapped in the bottom of the estuary. Solar insolation heats the saline layer, and it usually becomes anoxic. A thin freshwater layer lies over the marine water.
3. Open/marine: the configuration of the estuary relative to the ocean prevents the development of a sand berm at its mouth. High freshwater inflows can also contribute keeping the berm open. Ocean waters in the estuary are recharged by the tides, keeping temperatures low and salinity and oxygen levels high. Freshwater is limited to the upstream end of the estuary, or as a thin lens over the seawater.

Estuaries may vary in their conditions from year to year, and within the season depending on the ocean conditions and the strength of the freshwater flows to the estuary. Long-term changes have likely also occurred some estuaries have been heavily modified, river streamflows have been altered, and sediment budgets within catchments have been affected by land use practices (resulting in infilling of the estuary).

The use of California estuaries by juvenile steelhead

A variety of fish sampling programs have estimated smolt abundances California estuaries. It is instructive to compare these in relation to the three estuary types, so I estimated steelhead densities using abundance data and estimates of estuary area. These are based on a quick review of the source material and sometimes very approximate estimates of estuary area, so are likely subject to revision in a more thorough analysis.

The results of this analysis (Table 1) show relatively consistent late-summer densities of juvenile steelhead can be expected in the freshwater lagoon-type estuaries; the average is about 0.3 fish/m^2. As individual fish can be 40-80g in mass; thus the density corresponds to biomasses in the range of 12-24 g/m^2. This is on the high side of juvenile salmonids biomasses for stream-rearing fish (Keeley 2003) and highlights that freshwater lagoon-type estuary conditions can be extremely productive.

Cannata (1998) provides the only density information for the meromictic estuary type, which yielded a density about one-tenth of the freshwater estuary type. He found that the saline layer in the estuary became very warm and anoxic once the lagoon had formed. The freshwater layer deepened somewhat with inflows, but only after breaching by fall storms were oxygen levels restored. Cannata noted that these conditions forced juvenile steelhead to use the upstream part of the estuary, which contributed to the low overall abundance of steelhead in this estuary.

Density estimates could not be calculated for two of the open estuaries but in both cases steelhead were observed to be not common in the catches and were restricted to the upstream regions or tributary mouths. Quinones and Mulligan (2005) estimated habitat-specific densities of steelhead trout in the open Smith River inlet, and found that they ranged from 0.001 fish/m^2 open areas in the lower estuary to 0.35 fish/m^2 in areas with cover in the upper estuary. Over the whole estuary the densities (0.005-0.01 fish/m^2) were considerably lower than Cannata's estimate for the closed but stratified Navarro estuary (Table 1).

River	Estuary Type	Area ($1000m^2$)	Steelhead (1000's)	Steelhead Density ($\#/m^2$)	Reference
Scott	Freshwater	8	2	0.25	Bond 2006
Mattole	Freshwater	180	25-30	0.15	Zedonis 1992
Pescadero	Freshwater/ Meromictic	30	9.9	0.30	Smith 1990
San Gregario	Freshwater	43	11	0.25	Smith 1990
Waddell	Freshwater	18	9-15	0.67	Smith 1990
Navarro	Meromictic	377	9	0.024	Cannata 1998
Russian	Meromictic?	585	few	v. low	SWCA 2006
Garcia	Open	200	few	v. low	Higgins 1995
Albion	Open	160	few	v. low	Maahs and Cannata 1998
Smith	Open	1171	5.4-13.4	0.005-0.01	Quinones and Mulligan 2005

Table 1. Summary of juvenile steelhead data from California estuaries. Estuary areas are from the original report or are very approximate estimates from Google Earth. Estuary type characterizes conditions in the summer/fall. Freshwater estuaries are typically blocked by sandbars and are largely freshwater from stream inflows. Meromictic estuaries contain a deep layer of seawater which can become anoxic; open estuaries are largely saline because sand berms do not form during the summer. Smith River estimate is based on estuary areas and densities in Quinones and Mulligan (2005); note that there appears to be an error in the habitat areas in the paper, in that the total estuary area in the paper is overestimated by a factor of one hundred. Most steelhead density estimates are for the late summer/fall.

Steelhead population dynamics

A second useful perspective is to use a population-dynamics approach to consider the relative importance of life stages and habitats to population production and abundance. For salmonids, this ideally would come from a freshwater spawner-recruit relations and estimates of ocean survival (e.g. Ward 2000), as well has habitat-specific survival rates for each life history variant. Unfortunately these data are scarce for steelhead, although some basic parameters are available.

Ocean survival rates of most Pacific salmon species usually varies between 1-10%, and the average rate of production of juveniles from freshwater habitats falls in the range of 50 to 100 smolts per spawner (Bradford 1995; Bradford et al. 2000). However, steelhead smolts are the largest and oldest of all Pacific species, and it be expected that ocean survival rates would be higher, and rates of freshwater production to be correspondingly lower. Ocean survival rates of 1-25% are noted by Ward (2000) for steelhead from Keogh River in BC, but there has been a significant downward trend in recent years. The rate of smolt production has ranged from 10-60 smolts/spawner. For the Columbia River, the ocean survival rate is much lower (3%) and the rate of smolt production (measured in the headwaters, at the first mainstem dam) is higher, at 40-

60 smolts/spawner (Yuen and Sharma 2005). Even before dam construction the production of smolts at ocean entry would be somewhat lower than this. Bond (2006) estimated ocean survival rates of 3% for riverine, and 8% for estuarine smolts from a small California River. If we assume ocean survival rates in the 3-10% range, then 10-30 smolts per spawner are needed for populations to sustain themselves (this would be increased if there was significant fishery-related mortality, and might be decreased by the additional contribution of iteroparity).

If the Russian River were historically able to sustain populations of 50 000 or more spawners (plus harvest), smolt production may have been in the range of 500 000 to 1 500 000 fish. If the estuary had been the freshwater lagoon-type historically, the likely production from the estuary, based on current density estimates for small estuaries of 0.3 fish/m^2, would only account for about 150 000 smolts. This highlights the likely significance of the watershed itself for the bulk of the historical smolt production.

Under a modern-day scenario, a spawner population of, for example, 5 000 fish will require a smolt production of 50 000 to 170 000 smolts to be sustainable under the 3-10% ocean survival rate scenario. Using Cannata's estimate of 0.024 fish/m^2 for a meromictic estuary yields a total estimate of 14 000 smolts. This abundance, even with the survival advantage noted by Bond (2006), is not sufficient to sustain the adult population under the scenario I have outlined. Significant smolt production is required for the river itself unless the Russian River estuary can convert to the freshwater type. However, if the estuary does convert to a freshwater lagoon the estuary could potentially support most of the smolts needed to sustain the population at recent smaller population levels.

Many of the estimates and assumptions used in the preceding calculations are likely very inaccurate, and could be revised with local knowledge. The main point of this analysis is to highlight that it is usually possible and worthwhile to conduct rough quantitative analyses to support generalizations about population dynamics and the significance of different life history types and habitats. Because the assumptions behind these calculations are explicit and readily modified with new knowledge, this approach is more scientifically defensible approach than a more narrative one.

The Russian River estuary

The Russian River appears to be the meromictic type, developing an anoxic saline layer after closure of the berm. When the berm is open, the estuary is dominated by marine influences. Tidal inflows maintain salinity and oxygen concentrations, and the freshwater layer is shallow and variable. Closure of the estuary deepens the freshwater layer, and prevents tidal circulation in the deeper saline layers. The saline layer increases in temperature, and oxygen levels rapidly decline. Depending on the bathymetry of the estuary the development of an anoxic layer likely reduces both benthic and pelagic invertebrate productivity in the estuary.

The presence of high salinity water appears to limit the use of the estuary by juvenile steelhead to upstream areas or creekmouths. The absence of extensive steelhead use in open estuaries was also observed by Higgins (1995) and Maahs and Cannata (1998). Steelhead abundance in the Russian River also appears be low- in the Navarro River (density 0.024 fish/m^2;

Table 1) the average CPUE of steelhead per 30m beach seine was 7.8/set, and for the Russian River in 2004 and 2005 it ranged from 2-3/set. For the open Garcia River estuary, the average was about 2.7/set (Higgins 1995). For the enclosed Mattole estuary, Zedonis (1992) noted that catch rates declined from 180 fish/set in July to 6 fish/set in October. Further attempts to estimate the abundance of steelhead smolts in the Russian River estuary would be of great utility in determining the present-day significance of this habitat to overall smolt and adult production.

REVIEW QUESTIONS

1. Does the site specific data for the Russian River, referenced supporting literature and analysis in the draft BO provide reasonable support for the conclusion that the regulated elevated streamflows and systematic breaching of the Russian River estuary collectively cause an adverse effect on rearing habitat for steelhead in the lower Russian River?

The conclusion reached by the draft BO is based on an assessment of current estuary conditions, which are affected by the current breaching and inflow conditions, relative to what might have occurred historically when inflows were small and breaching did not take place.

Under the current management regime the estuary is usually kept open during the summer and fall, except brief periods when the mouth closes, prior to the mechanical bar breaching. The recent monitoring programs suggest that when the estuary is open there is a shallow layer of freshwater (about 1-2 m depth) over saline waters that are recharged by the tides (SCWA 2006). This recharging reduces oxygen depletion in the deeper waters. It is inferred that littoral zone productivity in the estuary may be limited by the shallow freshwater layer and the large tidal fluctuations in salinity that occur in the 1-3 m depth range (BO p.93). Predation risk is inferred to be higher because steelhead are restricted to surface waters in the estuary.

The conclusion that habitat quality in the estuary is reduced as a result of the management regime is reasonable (or perhaps “plausible”), but could be better supported by information that is currently available. For example, there is a footnoted reference (Entrix 2004) on page 93 of the BO regarding secondary production that is not in the reference list. It seems that the information in this report could be described more fully as direct evidence for reduced productivity. I note that surveys in the Russian River in 1992/93 in Heckel (1993) seem to suggest more invertebrates were present when the bar was open than when it was closed.

The assertion that estuary conditions are currently impacted by the management regime in the BO is partially based on the limited use of the estuary by steelhead smolts. The numbers of steelhead trout captured during the beach seining programs appear relatively small compared to other California estuaries, which may be related to the limited amount of productive freshwater habitat. Many years of catch rate data are now available (fish/seine set) for the Russian River estuary, and there are similar data for other California estuaries. My quick survey of this information above does support the inference that the Russian River estuary has relatively low levels of steelhead abundance compared to lagoons. However, catch rates are similar to the other open or meromictic estuaries. I would suggest that since similar gear has been employed in most of the estuary studies, the available CPUE data be summarized to support inferences about the relative productivity of the Russian River estuary. This analysis could be used to evaluate the current use of the estuary relative to other estuaries that are naturally open or stratified in the summer.

The Role of Breaching

The biological opinion about the effects of breaching is predicated on the key assumption that the estuary would revert to a freshwater lagoon if the river inflows were lower and the bar remained closed for longer period of time (p 82). The evidence and arguments supporting this assumption are not well developed, and this weakens the case being put forward in the BO.

The bar forming and lagoon development processes are described in general by Smith (1990) and for the Russian River by Goodwin et al. (1993). The development of freshwater conditions in the estuary is contingent on the displacement of denser saline water in the estuary by river inflows. The primary pathway for this displacement is the seaward seepage of saline water through the barrier bar and beach (Smith 1990). The rate of conversion in the estuary will depend on the bathymetry of the estuary, the volume of saline water, the cross section and porosity of the bar, the hydrostatic pressure created by riverine inflows and the difference in elevation between the estuary and the ocean. In the small estuaries surveyed by Smith (1990), the conversion to freshwater took only a few weeks when stream inflows were strong; in drought years the conversion was much slower or did not occur at all.

It is unclear whether the observations regarding lagoon formation made at the very small lagoons are applicable to a larger estuary such as the Russian River. In a small watershed, the ratio of the cross section of the bar, through which saltwater will seep outward, to the total volume of saline water is likely much larger than in a large, long estuary, where the cross section of the bar is proportionately smaller. The lagoons studied by Smith were less than 10% of the size of the Russian River.

An interesting contrast is provided by the Mattole River estuary, which is relatively large, and usually forms a freshwater lagoon that supports a large population of steelhead juveniles (Table 1; Busby et al. 1988). Maps provided in Busby et al. (1988), as well as satellite imagery, suggest that this estuary develops a long (600-800m) bar that provides a large interface between the main body of the estuary and the ocean. This bar, the inflows from the river, and the bathymetry of the estuary apparently lead to the rapid development of a productive freshwater lagoon in the estuary (notwithstanding recent high temperature events).

For the Russian River, the BO proposes that the estuary would convert to a freshwater lagoon under historical inflows and the absence of breaching. I examined the water quality information for periods of bar closure for 2005, and for some of the earlier years based on reports posted on the Russian River website. After 14 days of closure in October 2005, data from the fixed sondes (which I assume are at a constant distance from the bottom) show the absence of tidal fluctuations on salinity for the surface probes and evidence of a thickening of the freshwater layer. There appeared to be little effect on salinity at the deepest sonde. Salinity decreased gradually at the midwater sonde at the Penny Island station, but this decrease was only about 2 ppt/week. These results seem to suggest that the conversion rate of the estuary may be slow, perhaps because of the low flux of saline water seaward through the bar. There is some data in Heckel (1993) that is consistent with this hypothesis. By comparison, in 1987 the Mattole estuary closed in "May" (no date specified), and by May 26 virtually the entire estuary had converted to freshwater conditions (Busby et al. 1988).

I conclude from this brief review that there is considerable uncertainty about the assertion that the Russian River would form a freshwater lagoon under historical conditions of low inflows and long periods of closure. The BO would be better supported through the use of a more systematic approach to developing the lines of evidence for this assertion.

The Role of Inflows

The summer flows in the Russian River are substantially augmented by an interbasin transfer and may be 5-10 times higher than historical flows. The significance of the higher than natural inflows on lagoon formation depends on the rate of seepage at the bar. In smaller estuaries, lagoon formation can be enhanced by early bar closure that then results in the capture of discharge from spring rain flows, contributing to the rapid conversion of the estuary (Smith 1990). In years of late closure and low flows because of dry conditions, lagoon conversion is delayed. Higher flows raise water levels in these estuaries, increasing hydrostatic pressure and enhancing seepage. Estuary water levels later in the season reflect the balance between low summer inflows, seepage, and evaporation (Smith 1990).

In the Russian River estuary, the higher than natural inflows result in a rapid increase in water levels after bar closures. Water level increases of 0.2 to 0.5 m/day have been observed (Heckel 1993), leading to the need to breach the bar to protect low-lying properties within a few days after bar closure. It was not clear in the material that I reviewed what would happen if breaching did not occur, I assume that eventually these inflows would cause the bar to be naturally breached. Heckel (1993) provides some survey data that shows the berm attaining heights of 12-15 feet above the guage. Using the estuary volume-stage relation in Heckel, a simple volume calculation indicates it would take another 5-6 days for the estuary to go from 8' (the approximate elevation for mechanical breaching) to 13-15' under inflows of 200cfs (assuming no losses due to evaporation or seepage). Presumably at these elevations, natural breaching will occur. It seems unlikely that the estuary would convert to a freshwater lagoon in this time period given the observation noted earlier of the slow rate of conversion from saline to freshwater conditions in the estuary.

Heckel (1993, p.48) contains a simple mass balance model that was used, after calibration, to predict water surface elevations in the estuary after bar closure. This model contained terms for inflows, and losses due to evaporation, aquifer recharge and bar seepage, but the details and parameters are not evident in the report. Nonetheless, it would not be a difficult task to use the basin bathymetry and a few other key parameters to more realistically evaluate the relationship between river inflows and increase in estuary water surface elevation under a range of assumptions about seepage losses from the bar. Such an analysis would support inferences made about the effects of the higher than natural inflows on estuary conditions and the need for breaching, and whether adjustments to the inflows would yield significant benefits to estuary conditions for steelhead. At the moment it is difficult to determine from the BO whether a reduction in inflows to the estuary would result in more rapid conversion to a freshwater lagoon (and assumed higher productivity) before the berm would be naturally overtopped and breached.

2. Were relevant published and unpublished studies on the relative productivity of freshwater lagoons and estuaries and the use of freshwater lagoons by steelhead and other salmonids missed?

I accessed a few more documents from the Internet than were provided for this review; many of those were useful. I was unable to find a copy of Valentine (1989; the estuary bar seepage model), which would seem particularly germane to this topic. I believe it would also be useful to survey the literature for stock-recruit or population dynamic studies of steelhead. While these are relatively few, key population parameters such as the number of smolts produced per female spawner (and their age structure) are particularly useful for establishing habitat requirements for populations. I provided a brief review in an earlier section. The Agency may wish to familiarize itself with information and approaches for Atlantic salmon, for which there is much more information, and whose life histories and habitat requirements in freshwater are relatively similar to steelhead.

Perhaps more significantly, I believe the Agency could make more use of existing studies to better support its reasoning in the BO. Though the SOW suggests the data on coastal California estuaries to be limited, I found the studies I was provided were relatively rich in content. In Table 1 I conducted a quick analysis of steelhead densities in those studies, and other overview analysis are also possible. The following are a few suggestions of analyses that could be conducted on existing studies for comparative analyses:

1. Supplement Table 1 with information on stream size, summer flows, and amount of habitat to allow a rough comparison of the amount of freshwater versus estuary habitat in each basin.
2. Include spawner estimates (even if approximate) for the years for which estuary smolt densities were estimated.
3. Estimate the relative abundances of age 0, 1, 2+ migrants to the estuary across rivers to characterize the variation in migration timing among systems (possibly in relation to system conditions).
4. Compare growth rates or size-at-age in relation to estuary conditions, fish density or other factors.
5. Compile beach seine catch/effort statistics and use the mark-recapture data to calibrate them to allow interpretation of other surveys (such as the Russian River) where density estimates are not available.
6. Estimate the rate of lagoon formation or freshwater layer deepening (where possible). Assess the significance of freshwater inflows using a mass balance approach (if possible).

3. The draft BO states on page 172 that the "systematic breaching of the estuary reduces the estuary's carrying capacity for juvenile steelhead." Is this a reasonable and adequately supported statement?

At first glance this seems like an entirely reasonable assertion, as the increased rate of breaching would seem to result in a more disrupted estuary environment than would otherwise be the case. On further consideration, I believe the support for this statement could be better organized to make a more convincing case.

My concern comes from trying to determine what the "estuary's carrying capacity for steelhead" is being reduced from; i.e., what is the baseline? Under the current conditions of high summer inflows, my very quick analysis above suggested that estuary water levels would quickly reach the top of the berm, perhaps in less than a week after it had reached the elevation at which the current artificial breaching usually occurs. Presumably, once breached naturally, the sequence of estuary draining would be similar to what has been observed in the recent monitoring studies. If this scenario is realistic, then the question is: how much of an increase in steelhead productivity is occurring during that extra week when the freshwater layer is thickening and inundating terrestrial areas? How much of a cumulative effect would this have on steelhead carrying capacity over the summer, given that bar breaching is likely to occur naturally, albeit slightly less frequently than under the present management regime?

A more uncertain scenario is the situation in which the summer inflows are reduced to levels more similar to those that may have occurred naturally. In this case, the rate at which estuary water levels will rise is much slower, and an equilibrium may be reached before the water levels reach critical levels. Modelling may help provide insight into this process. I do not know if inflows can be reduced significantly or if the negative impacts that are likely in the river's mainstem from reduced flows will be a larger concern.

The impact of breaching when inflows are low on steelhead habitat will depend on the estuary conditions that develop under closed conditions. If the estuary becomes dominated by stratified conditions with a hypoxic saline layer (as suggested by the recent monitoring results) with a 1-2 m layer of freshwater ,then the review of information for other systems (Table 1) suggests that the quality of habitat for steelhead will be low, and that relatively few steelhead will use the estuary. In this case, the breaching of the estuary will have only a small impact on the steelhead population, as there would a lesser difference in the number of smolts using the estuary.

In contrast, if the estuary develops a freshwater lagoon (with low inflows), as is speculated to occur in the BO, then the estuary should have the capacity to support a large population of steelhead smolts, as is evidenced by the density estimates in Table 1. Under this scenario, breaching the estuary and disrupting the lagoon is more likely significantly reduce habitat quality in the estuary. I conclude then that the BO needs to provide a more convincing argument than that found on page 83 to convince the reader that the estuary historically was the freshwater lagoon type, and that those conditions would occur of artificial bar breaching did not occur.

4. What uncertainties related to the estuary analysis were not addressed that might affect the BO substantively?

Predicting the future, or the outcome of management actions, in any ecological situation is fraught with uncertainty that often can never be fully resolved. One useful approach is to break down the assumptions into manageable pieces and evaluate the strength of evidence that supports them (Jones et al 1996). This approach is a key component of evidence-based medicine and is receiving attention in ecological contexts (Sutherland et al 2004). For example, in an ecological setting, the categories for the strength of evidence might be:

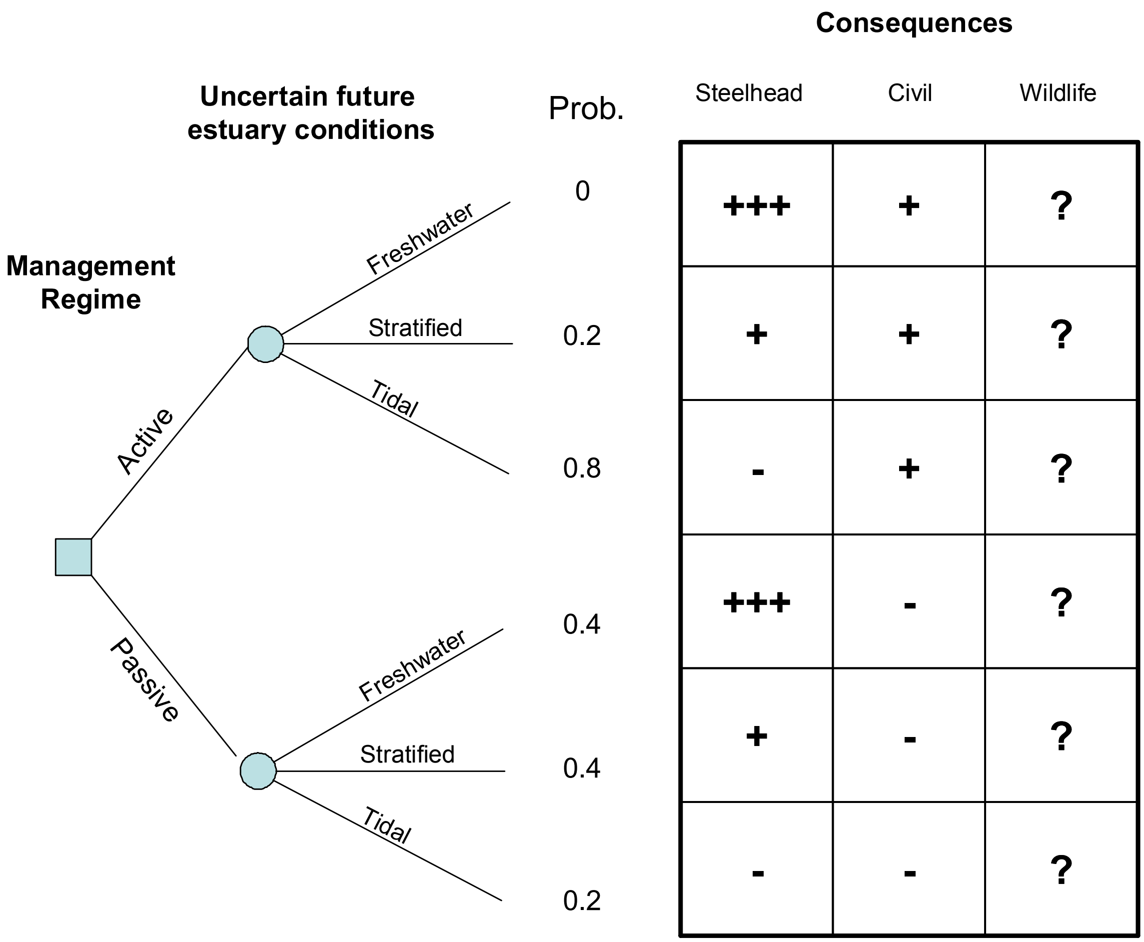
Grade	Descriptor
A	Very Strong- evidence based on data and observations from the site in question (i.e. Russian River monitoring studies)
B	Strong- extrapolations based on studies at similar, but perhaps not identical sites (i.e., California estuary studies)
C	Moderate—inferences drawn from laboratory studies, modeling etc.
D	Weak—expert opinion, anecdotal reports, first principles in ecology, physiology etc.

In cases where the evidence for a line of reasoning is relatively weak, there should be explicit consideration of the alternatives or "alternative states of nature". A decision tree can then be used to map out both the management actions and the alternative states of nature. This type of analysis does not need to be quantitative (i.e. estimating the probability of uncertain events, and the effects of management actions on performance measures), but it can be very useful for displaying the assumptions and uncertainties in an analysis such as the BO. Below, I have sketched in a decision tree for the estuary management problem. This example is only a demonstration, and the values and probabilities it contains are for discussion purposes only. Jones et al. (1996) fully describes this approach in a habitat context, and a description of decision analysis and structured decision-making processes can be found in texts such as Clemen and Reilly (2001).

Admitting uncertainty in the BO changes the approach to one based on risks, rather than a certain prediction of a future state or outcome of a management action. In the Russian River context, there is both uncertainty in the current productivity or carrying capacity of the estuary, and uncertainty about the state of the estuary if the management actions were significantly altered. In the decision tree I have given almost equal odds to the state of the estuary under an altered management regime- these odds might be refined with more data, modeling or analysis. From the perspective of the steelhead population as a whole, there is uncertainty about the significance of the estuary for production (as well as uncertainty about the implications to the population of a change in estuary management) that can be dealt with in a similar fashion as in Figure 1.

To summarize my response to this question, I find that the BO does not explicitly deal with the uncertainties that are imbedded in its findings. I suggest that the line of reasoning behind the BO be articulated as in Jones et al. (1996) and the uncertainties and alternatives for each set of assumptions be considered explicitly in the analysis. For those assumptions or components for which the evidence is weaker, this uncertainty should be noted, and likelihood of alternative states or outcomes should be identified. Peterman (2004) provides a review of the use of risk-based decision making tools for fisheries management; many of those approaches could be employed in the current setting.

Figure 1. A hypothetical decision tree for the Russian River estuary management problem. The square node indicates a decision point, which in this case is berm breaching. The round node represents uncertain future results that might result from the management action. For simplicity the states of nature have been discretized into 3 estuary states. Probabilities are trial estimates of the occurrence of each estuary state, and depend on the management regime. The consequence table contains the values to be considered in the decision, only a few are illustrated for simplicity. Ticks and x's represent positive and negative outcomes. Flow management could be added to the decision tree an independent decision node and a corresponding set of branches.



Conclusions

There is a considerable body of information that the Agency has available to it to evaluate the effects of the estuary management regime on juvenile steelhead habitat. To fully exploit that information in manner consistent with the goal of "the use of best available scientific information" I suggest the Agency consider the following steps designed to improve the defensibility of the BO's conclusions:

1. Use a logic model or pathways of effects diagram to organize assumptions in the BO.
2. Where possible use formal comparative analysis to capture and make use of data from other California estuaries.
3. Consider more quantitative tools for modeling the effects of management activities on estuary conditions.
4. Make use of a decision tree or other tool to evaluate the effects (and uncertainties) of differing management strategies and uncertain states of nature on steelhead habitats and other affected components of the Russian River system.

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Attachment A - Statement of Work for Dr. Michael Bradford

**Assessment of the Estuarine Analysis for the
Russian River Water Supply and Flood Control Biological Opinion**

Background

The purpose of this independent review is to evaluate and comment on the use of the best available scientific and commercial information in the estuarine-related analysis of the draft (dated June 11, 2007) Biological Opinion (BO) for the Russian River Water Supply and Flood Control Project. It is hoped that this review will help ensure that the best available information is used in this biological opinion. The review will focus on the technical aspects of the estuarine-related portions of the NMFS draft biological opinion; the review will not determine if NMFS conclusions regarding the project's potential to adversely modify critical habitat or jeopardize the continued existence or recovery of listed salmonids are correct.

The Southern and Central Coastal sections of California have a Mediterranean climate that significantly affects physical and water quality dynamics of estuaries. A combination of ocean wave action and the absence of significant rainfall between late May and early November contribute to the formation of closed, freshwater lagoons at river mouths. Wave action builds up sandbars at river mouths; low summer inflow to the lagoons percolate through the bar, thus maintaining closed freshwater systems. Limited research indicates that, in this region where summer flows in headwaters are naturally very low, freshwater lagoons provide highly productive and important rearing habitats for steelhead (*Oncorhynchus mykiss*) and possibly Chinook salmon (*O. tshawytscha*).

The ongoing and proposed operations of the Russian River reservoirs cause sustained, unnaturally high flows to the estuary from approximately May through early November. During this period, the elevated flows can cause natural bar breaching at the river's mouth, with resulting water quality cycles that can be deleterious to juvenile salmonids. The elevated summer inflows also contribute to high water surface elevations that threaten to flood a few properties bordering the Russian River estuary. Project operators address the potential threat of property flooding by breaching bars that form at the river's mouth, thereby maintaining the estuary as an open system with nearly marine conditions in the middle and lower segments of the system.

In conducting Section 7 consultations, NMFS is obligated to use the best scientific and commercial data available to evaluate whether projects jeopardize the continued existence of species listed under the Endangered Species Act. However, for such analyses, NMFS is not obligated to independently develop new scientific data. NMFS draft BO for the Russian River Water Supply and Flood Control Project reviewed scientific literature concerned with the role of small estuaries and freshwater lagoons as rearing habitat for steelhead. Information on estuarine use and population dynamics of steelhead and other salmonids in Mediterranean climates is very limited; most is from unpublished manuscripts and graduate theses. Most published information on steelhead use of estuaries is based on populations from more northerly regions where year-round rainfall supports relatively high summer flows and rearing habitat in upland watersheds. NMFS draft BO directly addresses estuarine issues in three separate sections: the Baseline (Section V., pp 82-83, 92-94, 98, and 102), the Effects (Section VI.G), and the Integration and Synthesis (Sections VIII.A.2, and VIII. B.2).

Fundamental Questions for the CIE reviewers

- Does the site specific data for the Russian River, referenced supporting literature, and analysis in the draft BO provide reasonable support for the conclusion that the regulated elevated inflows and systematic artificial breaching of the Russian River estuary collectively cause an adverse effect on rearing habitat for steelhead in the lower Russian River (*i.e.*, in the estuary/potential lagoon system)? If not, what relevant scientific information should be considered?

- Were relevant published and unpublished studies on the relative productivity of freshwater lagoons and estuaries and the use of freshwater lagoons by steelhead and other salmonids missed? If so, what key studies were missed?

- The draft BO states on page 172 that the "systematic breaching of the estuarine bar reduces the estuary's carrying capacity for juvenile steelhead". Is this a reasonable and adequately supported statement?

- What uncertainties related to the estuarine analysis were not addressed that might affect the BO substantively?

General Requirements

The CIE shall provide three independent scientists for this review. Expertise is required in anadromous salmonid biology and ecology, hydrology, and the ecology of estuaries in Mediterranean climates (*i.e.,* estuarine systems that periodically form freshwater lagoons during the low flow season). No consensus opinion among the CIE reviewers is sought.

The activities required under this Statement of Work shall be conducted electronically, so no travel is needed.

CIE reviewers shall review the following document which is the focus of the questions listed above:

- Draft Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance conducted by the U.S. Army Corps of Engineers and the Sonoma County Water Agency in the Russian River watershed. National Marine Fisheries Service. June 2007.

To aid the reviewers, we are providing copies of the following unpublished manuscripts cited in NMFS BO:

1. SCWA. 2006. Russian River estuary fish and macro-invertebrate studies, 2005. Sonoma County Water Agency, Santa Rosa, CA. 35 pp.

2. SCWA. 2006. Russian River estuary sandbar breaching 2005 monitoring report. Sonoma County Water Agency, Santa Rosa, CA. 58 pp.

3. Smith, J. 1990. The effects of the sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Wadell, and Pomponio Creek estuary/lagoon systems, 1985-1089. Department of Biological Sciences, San Jose State University, San Jose, CA. 38 pp + tables and figures.

4. Higgins, P. 1995. Fisheries elements of a Garcia River estuary enhancement feasibility study. Mendocino County Resource Conservation District. 22 pp + appendix.

5. Cannata, S.P. 1998. Observations of steelhead trout (*Oncorhychus mykiss*), coho salmon (*O. kisutch*) and water quality of the Navarro River estuary/lagoon May 1996 to December 1997. Humboldt State University Foundation. 48 pp, + tables and figures.

6. Maahs, M., and S.P. Cannata. 1998. The Albion River estuary, its history, water quality, and use by salmonids, other fish and wildlife species. Prepared for the Humboldt County Resource Conservation District and Coastal Land Trust.

7. Zedonis, P. 1992. The biology of the steelhead (*Oncorhychus mykiss*) in the Mattole River estuary/lagoon. Masters Thesis. California State University-Humboldt.

8. Bush, R.A. 2003. Juvenile steelhead and residence and growth patterns in a California coastal lagoon. Center for Integrated Watershed Science and Management, University of California, Davis.

9. Bond, M.H. 2006. Importance of estuarine rearing to central California steelhead (*Oncorhychus mykiss*) growth and marine survival. Masters Thesis. University of California Santa Cruz. 39 pp.

The above material will be provided by the NMFS Southwest Regional's (SWR) contact persons: Dick Butler Dick.Butler@noaa.gov and Bill Hearn William.Hearn@noaa.gov

Each reviewer's duties shall not exceed a maximum total of 10 days – approximately 5 days for report and literature review and 5 days to produce a written report of the findings. Each reviewer may conduct their analyses and writing duties from their primary work location. Each report is to be based on the individual reviewer's findings, and no consensus report shall be accepted.

The itemized tasks of each reviewer consist of the following.

1. Read the draft Russian River Biological Opinion with a focus on the estuarine component of the analysis.

2. Consider additional scientific information as necessary.

3. No later than February 15, 2008, each CIE reviewer shall submit their independent peer-review report addressing each task in this Statement of Work to Dr. David Die at ddie@rsmas.miami.edu and Mr. Manoj Shivlani at mshivlani@rsmas.miami.edu

Submission and Acceptance of CIE Reports

No later than February 29, 2008, the CIE shall provide via e-mail the final independent CIE reports and the CIE chair's summary report to the COTR William Michaels (William.Michaels@noaa.gov) at NOAA Fisheries. The COTR and alternate COTR Dr. Stephen K. Brown (Stephen.K.Brown@noaa.gov) will review the CIE reports to determine that the Term of Reference was met, notify the CIE program manager via e-mail regarding acceptance of the reports by December 30, 2007, and then distribute the reports to the SWR contact person.

ANNEX I: REPORT GENERATION AND PROCEDURAL ITEMS

1. The report shall be prefaced with an executive summary of comments and/or recommendations.

2. The main body of the report shall consist of a background, description of review activities, summary of analyses and comments, and conclusions/recommendations.

3. The report shall also include as separate appendices the bibliography of materials reviewed and a copy of the statement of work.

Please refer to the following website for additional information on report generation: http://www.rsmas.miami.edu/groups/cimas/report_Standard_Format.html