Salmon Rearing Habitats in the Main Stem Klamath River

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EXECUTIVE SUMMARY

The issue of salmon rearing in the main stem Klamath River downstream of Iron Gate Dam has received considerable attention in recent years. It intensified when the "Southern Oregon/Northern California Coasts" (SONCC) coho salmon was listed as a threatened species in 1997. The listing prompted Endangered Species Act Section 7 Consultations for the operation of the federal Klamath Project in southern Oregon and northern California. On May 31, 2002, NMFS completed a Biological Opinion on operations of the Klamath Project. In formulating the document, NMFS relied heavily on a draft report entitled, "Evaluation of Interim Instream Flow Needs in the Klamath River – Phase II Final Report" by Hardy and Addley (2001). Within that draft Phase II Report the authors recommended instream flows for the survival and recovery of anadromous salmonids in the main stem Klamath River. Much of their information used to develop those recommendations was based on assumed rearing habitat needs for salmonids in the Klamath River. Specifically, NMFS used Chinook, coho, and steelhead "habitat suitability criteria" (HSC) from the draft Phase II Report as the underlying foundation for proposed instream flows from Iron Gate Dam.

Without supporting data, the draft Phase II Report relied on assumed habitat usage of Chinook fry in the main stem Klamath River as a surrogate for coho fry, despite well-known differences in habitat criteria between the species. This erroneous, unsubstantiated assumption brings into question the validity of conclusions in the NMFS Biological Opinion and the draft Phase II Report. Among the errors introduced within the HSC development, particularly for coho, was the apparent transposing of the known relationship between habitat quality associated with woody debris within river channels elsewhere to assumed preference of Klamath River salmon fry for inundation of live terrestrial vegetation above the banks of the Klamath River.

The main stem Klamath River possesses abundant large particle substrate, prolific aquatic vegetative growth on the riverbed, large amounts of emergent aquatic vegetation on the channel margins, and generally low water clarity, all of which can function as cover habitat depending on associated site-specific flow conditions. Hardy and Addley (2001) assumed those habitats were inferior in deference to potential habitats that could only be obtained by inundating woody terrestrial vegetation on the river banks with high flows. Instead of the management action of bringing the woody debris to the stream, the draft Phase II Report computer model runs bring the river to the woody terrestrial vegetation. It seems that the authors have misinterpreted the known rearing habitat characteristics for coho salmon in an attempt to re-create that habitat (in a theoretical sense) in the main stem Klamath River.

Authors of the draft Phase II Report introduced mathematical computations into computer modeled fish habitat that skewed outputs to conclude very high flows would create more rearing habitat. Their modifications have an enormous impact on the final output of estimated salmonid habitat without supporting evidence. The approach used in the draft Phase II Report greatly under-represents ideal habitats found in the main stem channel and the assumptions on rearing habitat presented in Hardy and Addley (2001) are nearly opposite of those derived from studies in other river systems. The best empirical evidence to date indicates that the draft Phase II Report's assumptions on main stem Klamath River rearing habitat do not accurately reflect a correct modeling of fish habitat conditions known

elsewhere to be suitable. Despite the statements in the draft Phase II Report, there is by no means a consensus as to what constitutes good or ideal rearing habitat in the Klamath River.

The development of the HSC for the Klamath River in the draft Phase II Report was severely constrained by data collection during high flow conditions and created unintentional bias in the results. This problem was further compounded by inappropriate sampling techniques that resulted in misinterpretation of fish utilization of habitats in the Klamath River. The consequence of inadequate data collection techniques was that a large disproportionate sampling of the edge habitat combined with high flow conditions occurred during the Phase II study. These circumstances would be a plausible explanation of why salmonid rearing in the Klamath River was erroneously presumed to be so different from that widely known to occur elsewhere. It would also explain why the draft Phase II Report's computer modeling results showed almost no rearing habitat within the main river channel.

Even though every type of sampling technique possesses some sort of bias, by using the survey methods described in this report, potential rearing habitats for salmonids in the main stem Klamath could be effectively assessed away from shore in the deeper, swifter areas of the main river channel and allow for a more equalized effort. This would help to balance the availability of microhabitat conditions sampled. Ultimately, habitat suitability criteria for salmon rearing that is more reflective of actual conditions would be generated, thereby reducing bias caused by the mode of sampling. Such work can be integrated with a system-wide investigation that focuses on other factors that may be important to support healthy fish populations, including fish habitat conditions in the Klamath River tributaries.

The mistakes made during the formulation of the draft Phase II Report and the resulting erroneous assumptions and conclusions by NMFS in the 2002 Biological Opinion could have been avoided through inclusion of other individuals with expertise on instream flow and salmonid biology. An improved understanding of the salmonid rearing habitats available in the main stem Klamath River in relation to habitats throughout the basin is necessary using a collaborative, scientific approach, but remains a concept not well received. Until that obstacle is overcome, it will be difficult to develop a more comprehensive and objective assessment of habitat needs for anadromous salmonids in the Klamath River.

INTRODUCTION

The issue of salmon rearing in the main stem Klamath River downstream of Iron Gate Dam has received considerable attention in recent years. It intensified when the "Southern Oregon/Northern California Coasts" (SONCC) coho salmon (*Oncorhynchus kisutch*) was listed as threatened species in 1997. The listing prompted Endangered Species Act Section 7 Consultations for the operation of the federal Klamath Project in southern Oregon and northern California.

Several one-year Biological Opinions concerning Klamath Project operations effects on coho have since been issued by the National Marine Fisheries Service (NMFS). At the request of the U.S. Department of Commerce, the National Research Council (NRC) evaluated the 2001 NMFS Biological Opinion and issued an interim report in 2002, effectively disagreeing with some (but not all) of NMFS' findings regarding coho salmon (NRC 2002).

On May 31, 2002, NMFS completed a Biological Opinion on operations of the Klamath Project. In formulating the document, NMFS relied heavily on a draft report entitled, "Evaluation of Interim Instream Flow Needs in the Klamath River – Phase II Final Report" by Hardy and Addley (2001) (Knowles 2002). Within that report (hereinafter called the "draft Phase II Report") the authors recommended instream flows necessary for the survival and recovery of anadromous salmonids in the main stem Klamath River. Much of their information used to develop those recommendations was based on assumed rearing habitat needs for salmonids in the Klamath River. Specifically, NMFS used Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon, and steelhead trout (*Oncorhynchus mykiss*) "habitat suitability criteria" (HSC) from the draft Phase II Report as the underlying foundation for proposed instream flows from Iron Gate Dam.[1] To its credit, the NMFS 2002 Biological Opinion recommended the development of additional information through "a strong science based program to either verify or reject the underlying assumptions in the Hardy and Addley draft Phase II Report".

The following discussion is intended to provide additional information to further advance the science on salmon rearing in the Klamath River. Although the focus of this report concerns coho salmon, other salmonids will be addressed as well, for reasons discussed later.

ASSUMPTIONS ON SALMON REARING HABITATS IN THE KLAMATH RIVER

The NMFS 2002 Biological Opinion provides the following discussion on coho rearing habitat characteristics:

> "Following emergence, fry move into shallow areas near the stream banks. As coho salmon fry grow larger, they disperse upstream and downstream and establish and defend a territory (Hassler 1987)."

1 "NMFS proposed flows (RPA flows) which were calculated based on use of the habitat suitability curves in the Hardy and Addley draft phase II report (2001) (see section 11.4.2 and Table 9)." NMFS (2002), p. 54.

> "During the summer, coho salmon fry prefer pools and riffles featuring adequate cover such as large woody debris, undercut banks, and overhanging vegetation. Juvenile coho salmon prefer to over-winter in large main stem pools, backwater areas and secondary pools with large woody debris, and undercut bank areas (Hassler 1987; Heifetz et al. 1986)."

The NMFS 2002 Biological Opinion describes the agency's assumptions on the importance of young-of-the-year coho salmon rearing habitat in the main stem Klamath River as rationale to justify high instream flows from Iron Gate Dam. That explanation is summarized as follows:

> "During the spring, Project operations substantially affect Klamath River flows in the Iron Gate Dam to Shasta River reach. In dry and critically dry water years, the influence of Iron Gate Dam releases extends further downstream. The amount of flow in the main stem river affects the amount of suitable habitat available for young-of-the-year coho salmon fry that either originated in the main stem or were displaced from their natal tributaries. The amount of suitable rearing habitat available for salmon and steelhead fry in the main stem may adversely affect their survival if sufficient habitat is not available for all salmonid fry in the main stem (including coho salmon) that must compete for similar appropriate conditions. Tributary access for young-of-the-year coho salmon that attempt to move from the main stem to tributaries may be adversely affected in the Iron Gate Dam to Shasta River reach, and further downstream during drier water years featuring low accretions to the main stem river in the spring. Young-of-the-year coho salmon that cannot find suitable rearing habitat will likely suffer decreased survival." (NMFS 2002, p. 47)

This is one of the primary reasons NMFS identified for concluding that Klamath Project operations jeopardize the continued existence of SONCC coho (Knowles 2002). Even though the main stem Klamath River does not possess the types of habitats found in smaller tributary streams preferred by coho,[2, 3, 4, 5] the NMFS 2002 Biological Opinion presumes that specific, high instream flows for coho rearing habitat are necessary in that area to avoid adverse effects on Klamath basin coho populations.[6]

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2 "Although there is some overlap of spawning habitats, coho salmon typically utilize smaller streams and gravel than do chinook." (Flosi and Reynolds 1991)

3 Typical coho spawning and rearing habitats are in "small, relatively low-gradient tributary streams." "While the larger chinook salmon requires big water, often low in a watershed, for spawning, coho are drawn to the next level of tributaries." (ODFW 1996)

4 "Coho salmon migrate up and spawn mainly in streams that flow directly into the ocean or are tributaries of large rivers." (Moyle 2002)

5 "The only freshwater habitat of the marine adults is the spawning stream which is usually a small, coastal, gravelly stream, or a similar tributary of a larger river." (Scott and Crossman 1973)

6 E.g.: "In summary, NMFS thinks that the proposed action during the March through June period will reduce habitat availability and instream flow. These effects to coho habitat could result in increased predation upon coho fry in the main stem, decreased feeding success of coho young-of-the-year, and reduced out migration success of smolts. These adverse impacts could decrease the survivorship of both young-of-the-year and smolts. As a result, the proposed action may cause reduction in the numbers and distribution of coho salmon in the Klamath River over time." (NMFS 2002)

The NMFS 2002 Biological Opinion's premise regarding coho rearing habitat in the Klamath River is not convincing and subject to considerable debate for the following reasons:

1) The potential importance of coho rearing habitat in the main stem river is not empirically established.
2) The NMFS Biological Opinion is in contrast to the preponderance of scientific evidence developed in other rivers and streams and the known widespread ecological regularity of rearing habitat characteristics for salmon.
3) The main stem Klamath River immediately downstream of Iron Gate Dam does not contain the standard habitat attributes for coho.

Additionally, the principal coho rearing habitats are within small coastal streams or tributaries to larger rivers. The agency's prior status review on coho states: "coho typically spawn and rear in small tributaries" (Weitkamp et al. 1995). As a factual matter, the principal coho rearing habitats are within the numerous Klamath River tributaries - which is not surprising given the well-known characteristics of coho rearing habitat (Figures 1 and 2):

> "Rearing areas generally used by juvenile coho salmon are low gradient coastal streams, wetlands, lakes, sloughs, side channels, estuaries, low gradient tributaries to large rivers, beaver ponds and large slack waters (PFMC 1999). The more productive juvenile habitats are found in smaller streams with low-gradient alluvial channels containing abundant pools formed by large woody debris (LWD)." California Department of Fish and Game (CDFG) (2002)

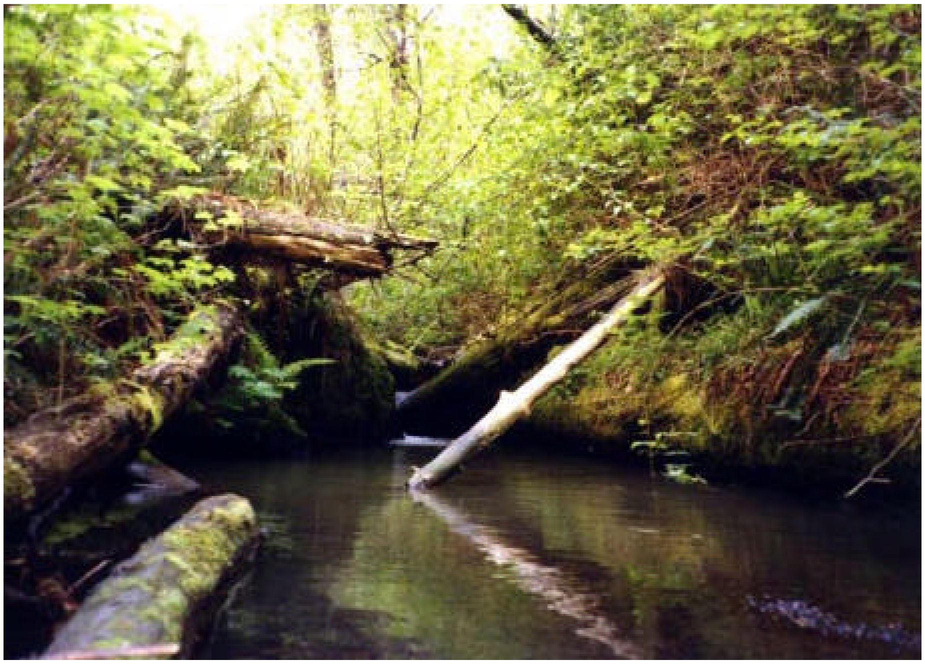

Figure 1. Example coho salmon habitat in Little River, a northern California coastal stream (Vogel 1992). Photo by the author. Note large woody debris. Abundant coho were found in this stream (D. Vogel, unpublished data).

Figure 2. Example coho salmon habitat in Little River, a northern California coastal stream (Vogel 1992). Photo by the author. Note large woody debris. Abundant coho were found in this stream (D. Vogel, unpublished data).

Researchers have established that young Chinook and coho salmon do not interact well and use significantly different habitats[7] (Sandercock 1996; Healey 1996). The draft Phase II Report acknowledges the potential problems with species interactions in the same niche, but nevertheless ignores the topic when using the same habitat suitability criteria among species.

Because NMFS used the draft Phase II Report as the principal basis for assumptions on salmonid rearing habitat, this critique of that document will provide:

1) An assessment of its information, presuppositions, and conclusions; and
2) Challenge to some of the more important basic underlying biological premises.[8]

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7 Tiffan et al. (2002) describe fall Chinook salmon as "unique among anadromous salmonids in that they spawn and rear in main-stem habitats rather than in tributaries".

8 As a caveat, I found that the draft Phase II Report is highly ambiguous in critical portions of the document and much of the supporting information was lacking or insufficient. Therefore, the critique provided here is based on my interpretation of the available information and information provided from other relevant resources.

THE DRAFT PHASE II REPORT BY HARDY AND ADDLEY (2001)

The draft Phase II Report by Hardy and Addley (2001) was developed "to make revised interim instream flow recommendations necessary to protect the aquatic resources within the main stem Klamath River between Iron Gate Dam and the estuary" (Hardy and Addley 2001). Although it is not customary to rely on information used in draft reports, NMFS did so in formulating the agency's 2002 Biological Opinion on Klamath Project operations and, therefore, the draft Phase II Report will be discussed.

The draft Phase II Report was based on hydraulic measurements, biological data, channel morphology and other features, and computer modeling. Details on the methods for the study are provided in the draft Phase II Report. Arguably, the most important final parameters ultimately used in the entire field study and computer modeling exercise were data and assumptions concerning juvenile salmonid rearing habitats (i.e., chinook, coho, and steelhead fry) in the main stem Klamath River, at least during the majority of seasons. Other aspects of the draft Phase II Report, such as spawning habitats, did not measurably contribute as much toward overall assumptions and recommendations on Iron Gate Dam instream flows in their entirety.

Considerable direct and indirect emphasis was placed on SONCC coho salmon in the draft Phase II Report because of its threatened status. On-site field staff had considerable difficulty locating sufficient numbers of young-of-the-year coho salmon in the main stem Klamath River to develop site-specific habitat information.[9] This circumstance could be attributable to the fact that the SONCC coho populations are depressed, their principal habitats are in the tributaries[10], or perhaps a combination of these reasons. However, the low abundance of young coho in the main stem Klamath is not surprising. Coho habitats in larger main stem river channels are not as productive because small streams possess the greatest proportion of marginal slack water to midstream area (Sandercock 1996).

Without supporting data, the draft Phase II Report relied on assumed habitat usage of Chinook fry in the main stem Klamath River as a surrogate for coho fry[11] despite well-known differences in habitat criteria between the species.[12] This erroneous, unsubstantiated assumption brings into question the validity of conclusions in the NMFS Biological Opinion and the draft Phase II Report. Since field workers on the draft Phase II study did collect substantial (but limited in scope for the study purposes)

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9 "No coho fry observational data were available for a comparison of modeling results to be made within the main stem Klamath River." Hardy and Addley (2001), p. 186.

10 E.g., "Their [coho] success as a species may be partly attributed to their utilization of a myriad of small coastal streams and to their aggressiveness and apparent determination to reach the small headwater creeks and tributaries of larger rivers to spawn." (Sandercock 1996).

11 "However, based on the simulation results for chinook fry and coho fry, and known life history strategies, we believe that the simulation results to be competent to use in the instream flow evaluations. Habitat simulation results for coho closely parallel the results shown for chinook fry in terms of the spatial distribution and magnitudes of suitable habitat." Hardy and Addley (2001), p. 186.

12 "In many of the larger river shared by the two species, the Chinook tends to spawn in the mainstream, while coho prefer the smaller tributaries nearby." (Miller and Brannon 1982).

data on Chinook fry rearing in the main stem Klamath River, this ultimately had the greatest effect on the overall instream flow recommendations in the draft Phase II Report (4-5 months within a calendar year, depending on location in the river). Together, the fry life stage for chinook, coho, and steelhead was the foundation for at least half of the monthly instream flow recommendations (8 months or more when including the steelhead yearling life phase).

Physical Habitat Simulation System (PHABSIM)

The draft Phase II Report used PHABSIM (Physical Habitat Simulation System) to assess habitat and river flow changes in the main stem Klamath River for coho, Chinook, and steelhead. PHABSIM is a suite of computer-based modeling programs and is a major part of the Instream Flow Incremental Methodology[13] (IFIM) developed by the U.S. Fish and Wildlife Service (USFWS) in the late 1970s. PHABSIM uses hydraulic simulation models to predict changes in features of fish habitat (velocity, depth, substrate, cover, or channel index) for ranges in unmeasured flow. The modeling program relies on univariate fish habitat suitability criteria (HSC) curves for depth, velocity, and channel index which is multiplied by the surface area for a section of stream to generate a habitat index called Weighted Usable Area. Using a species' HSC, PHABSIM estimates changes in physical habitat as a function of flow (USGS 2001).[14] Much of the proceeding discussion focuses on the HSC for fry and juvenile salmonid rearing because of its significant effect on the NMFS 2002 Biological Opinion and fundamental flaws in critically important biological assumptions used in the modeling effort of the draft Phase II Report.

Klamath River Habitat Suitability Criteria Curves

As one component of the draft Phase II Report, HSC for coho, Chinook, and steelhead life stages[15] were developed and used for the computer modeling effort to evaluate how incremental changes in river flow affect fish habitat in the main stem. Hardy and Addley (2001) correctly state:

> "HSC represent how suitable a particular gradient of depth, velocity, substrate, cover, etc. is to a target species and life stage. HSC typically represent the suitability of a particular factor (i.e., depth) on a scale between 0.0 and 1.0. A suitability value of 0.0 represents a condition (i.e., depth) that is wholly not suitable, while a 1.0 indicates a condition that is 'ideally' suitable." Hardy and Addley (2001), p. 114.

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13 "The Instream Flow Incremental Methodology (IFIM) is a decision-support system designed to help natural resource managers and their constituencies determine the benefits or consequences of different water management alternatives." Bovee et al. (1998), p. 1.

14 A more complete description of PHABSIM is provided in Bovee et al. (1998): PHABSIM is "an integrated collection of hydraulic and microhabitat simulation models designed to quantify the amount of microhabitat available for a target species over a wide range of discharges. PHABSIM combines empirical descriptions of the structural features of the channel, simulated distributions of depth and velocity, and habitat suitability criteria for the target species. This combination reveals a functional relationship between streamflow and the area of microhabitat available for the target species, per unit length of stream."

15 The species and life stages in the draft Phase II report included: steelhead fry and 1+, Chinook spawning, fry, and juvenile, and coho fry and juvenile. Hardy and Addley (2001), p. 113.

Although common, use of HSC curves has been controversial since its inception for PHABSIM modeling (USGS 2001, p. 128). The unorthodox development and modification of the specific HSC in the draft Phase II Report is questionable as well for reasons described here.

Several significant errors were introduced in the development of the Klamath River salmonid HSC which requires a re-evaluation of the empirical bases for the criteria and the manner in which they were employed for the PHABSIM computer modeling exercise in the draft Phase II Report.

The importance of the HSC is emphasized by the U.S. Geological Survey (USGS):

> "Successful implementation of PHABSIM requires the acquisition of accurate and realistic habitat suitability criteria for the target organism(s) being evaluated. Perhaps more important than accuracy and realism, however, is buy-in from the stakeholders. Because the output from PHABSIM is extremely sensitive to even subtle differences in habitat suitability criteria, establishing the credibility of the criteria can be of utmost importance." USGS (2001), p. 74.

The HSC curves used in the Klamath study were not "preference" curves. Preference curves are derived from observational data on habitat use corrected for habitat availability (USGS 2001) whereas the suitability curves as used in the draft Phase II Report were developed from a combination of information found in professional literature, observations of habitat use (unadjusted for availability), and opinions. Although Hardy and Addley (2001) correctly assert that this method of HSC is commonly employed in PHABSIM studies, there were important errors incorporated into the HSC that created premature conclusions.

Individuals involved with the Phase II study found that it was particularly difficult to develop site-specific HSC for some species and life stages in the main stem Klamath River. This circumstance was attributable to either limited numbers of fish present at the time or because of limitations in the technique to obtain HSC data. In an attempt to develop HSC for the Klamath River, Hardy and Addley (2001) describe several techniques that evolved during the study in order to generate the required HSC for ultimate computer modeling. Final HSC used in the modeling exercise were a combination of site-specific data, professional opinions, transfer of HSC developed elsewhere, transfer of HSC between species, and additional modifications not fully described in the draft Phase II Report.

Hardy and Addley (2001, p. 116-119) provide an extensive discussion of the "ecological basis of habitat suitability criteria" to explain the reasons for developing specific HSC for different species and life stages. Although the authors accurately describe the fundamental ecological reasons for such an approach, they did not apply it for the draft Phase II modeling exercise when it came to cover habitat suitability. For example, they state:

> "If two or more species utilize the same or nearly the same combination of resources and environmental conditions (niche) at the same time and in the same locations, the potential exists for the more competitive of the two species to exclude the other from the system or from much of its fundamental niche." (Hardy and Addley 2001, p. 117)

And later in the draft Phase II Report they state:

> "No Coho fry observational data were available for a comparison of modeling results to be made within the main stem Klamath River. However, based on the simulation results for Chinook fry and coho fry, and known life history strategies, we believe that the simulation results to be competent to use in the instream flow evaluations. Habitat simulation results for coho closely parallel the results shown for Chinook fry in terms of the spatial distribution and magnitudes of suitable habitat." (Hardy and Addley 2001, p. 186)

The latter claim is not upheld by any empirical evidence and is in direct conflict with the authors' previously stated argument supporting the niche rationale for different species occupying different habitat conditions. In other words, readers of the draft Phase II Report are initially led to believe that different species and life stages occupy different niches and then, further on, informed (erroneously) that the niches can be the same.

One technique to develop HSC curves for the main stem Klamath River used by Hardy and Addley (2001) was through the use of "envelope curves" based on scientific literature and professional judgment. The authors point out that, "This is perhaps the most commonly applied technique for HSC 'development' for instream flow assessments in the U.S. and internationally." Although the draft Phase II Report largely adopts this method for some species and life stages, it departs significantly from the approach for rearing when assuming the same characteristics for coho and Chinook and application of "cover". One of the more unusual speculative and debatable assertions of the draft Phase II Report is how markedly different some of the ultimate HSC developed for the Klamath were from those developed elsewhere. Despite the authors' arguments to use "envelope curves" from a composite of numerous HSC curves developed elsewhere, they deviated substantially from their rationale to alter some HSC to the point of radical inconsistency with widely accepted HSC. For example, habitat characteristics and life history attributes for fry rearing in the draft Phase II Report are inconsistent with that described in CDFG's California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998). The significantly modified HSC used in the draft Phase II Report partially explains why the modeling results are skewed to conclude that very high flows supposedly create more fry rearing habitat in the main stem Klamath River.

An inconsistent facet of the assumptions on salmonid rearing HSC used in Hardy and Addley (2001) is the presumed "transferability" of selected habitat attributes from other watersheds to the Klamath River.[16] The draft Phase II Report argues that fry salmon rearing habitat in the Klamath River is in

16 "For several species and life stages (i.e., chinook juvenile, coho fry, and steelhead fry) a procedure for developing

contrast to results of research on salmonids performed elsewhere. Although the arguments presented are ambiguous and not easily followed in the draft Phase II Report, the authors postulate that the normal wetted perimeter of the main stem river channel is significantly inferior to potential habitat provided through inundation of terrestrial vegetation above the active river channel. This assumption is based on limited surveys performed in an attempt to develop HSC for Klamath River fish species. Although empirical evidence to support the premise is lacking in the report, the authors use vague general statements (as explained below) to support their arguments.

Among the errors introduced within the Klamath HSC, particularly for coho, was the apparent transposing of the known relationship between habitat quality associated with woody debris within river channels elsewhere [e.g., in beaver ponds, (Beechie et al. 1994)] to assumed "preference" of Klamath River fry for inundation of live terrestrial vegetation above the banks of the Klamath River. As used in the draft Phase II Report, if one assumes that ideal fry rearing habitat is associated with woody vegetative material in streams, one way to "generate" more habitat is through modeling computer-generated high flows where the river floods over its banks up into live riparian woody vegetation. However, that approach is a misapplication of known HSC for juvenile salmonid rearing habitat. For example, during field sampling by the USFWS and CDFG in the Sacramento River, California during the floods of 1983, juvenile salmonids were captured within walnut orchards on the banks of the river; it would be a misnomer to assume that walnut orchards are "preferred" habitat by salmonids. This latter circumstance is a function of water velocity refuge and displacement of juvenile salmonids from the usual and customary in-channel habitats where the fish would otherwise be found. The USGS (2001) warns that it is important to recognize the biological context of developing HSC under stream conditions less than ideal because such an approach could result in revealing only what the species can tolerate instead of what constitutes good habitat.

The draft Phase II Report places paramount concern for provision of cover for salmonid fry as a means to protect fish from predators. Coho fry can be highly vulnerable to predators without appropriate habitat conditions (Sandercock 1996) and therefore the draft Phase II Report's general rationale has validity. However, the effect of predation on coho varies by predator species and geographical area (Sandercock 1996). Hardy and Addley (2001) do not describe those predators that may be a concern in the main stem Klamath. Furthermore, and most importantly, Hardy and Addley (2001) apparently overlooked the abundant cover habitat present within the main stem Klamath River channel in deference to assumed superior cover habitat caused by over-bank flooding and inundation of terrestrial riparian woody vegetation (as illustrated in Figure 3).

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envelope HSC from literature-based curves was developed." Hardy and Addley (2001), p. 262.

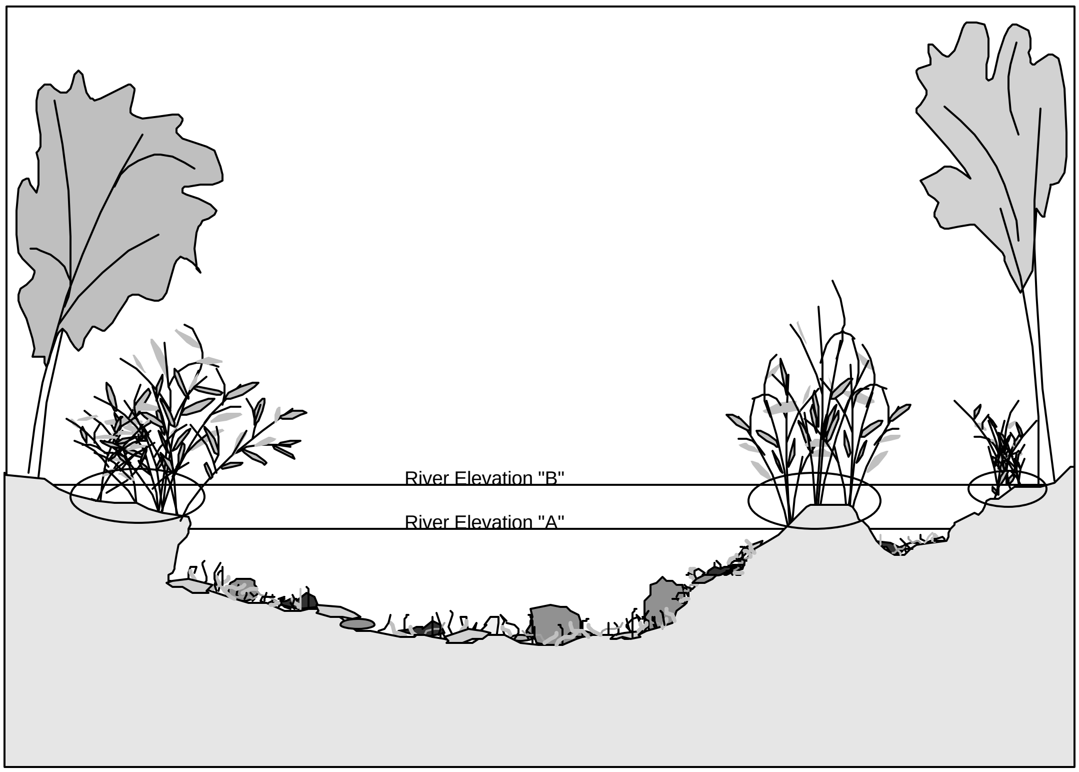

Figure 3. Example cross-sectional profile of a river channel showing two water surface elevations: "A" -- river within an elevation not inundating terrestrial vegetation and "B" -- river at an elevation flooded over the banks into terrestrial vegetation.

The main stem Klamath River possesses abundant large particle substrate (e.g., large cobbles and boulders), prolific aquatic vegetative growth on the riverbed, large amounts of emergent aquatic vegetation on the channel margins, and generally low water clarity, all of which can function as cover habitat depending on associated site-specific flow conditions. Hardy and Addley (2001) assumed those habitats were inferior in deference to potential habitats that could only be obtained by inundating woody terrestrial vegetation on the river banks with high flows (Figure 3, ovals shown at River Elevation "B"). In doing so, the manner in which Hardy and Addley (2001) weigh the definition of cover is a significant departure from that commonly used by other researchers elsewhere who recognize the biological benefits of instream cover (e.g., Arey and Gilroy 1993a, 1993b, 1993c, Arey et al. 1992a, 1992b, Arey et al. 1993a, 1993b, 1993c, Douglas Parkinson & Associates 1990, Hampton 1988, Mayo 1992, USFS 1992, 1993) such as that provided by features in the Klamath River as stated above. Nevertheless, some individuals assert that the draft Phase II Report argument for inundation of riparian vegetation is the "best available science" indicating that which is "critical for the survival of rearing fry." (Hillemeier 2003)

Coho salmon are known to use large woody debris in small tributary streams as cover habitat. This reason, among many, is why protection of riparian corridors and addition of woody debris into streams are considered beneficial management actions for the species[17] (Bjornn and Reiser 1991, Flosi and Reynolds 1991, Moyle 2002, Murphy et al. 1986, Olson 1993, Shirvell 1990). Removal of woody debris has been shown to reduce coho populations (Bryant 1981). Large woody debris within the main stem Klamath River channel is naturally rare. If one uses the assumption that coho fry and juveniles are present in the main stem in significant numbers and that those coho must have woody material (of any type) for cover habitat for survival, a PHABSIM computer run would show that high flows are necessary to inundate the river banks in order to reach the woody material. In other words, instead of the management action of bringing the woody debris to the stream, the draft Phase II Report model runs bring the river to the woody terrestrial vegetation. It seems that the authors have misinterpreted the known rearing habitat characteristics for coho in an attempt to re-create that habitat (in a theoretical sense) in the main stem Klamath River. This circumstance is another reason why the PHABSIM modeling results of the draft Phase II Report findings are skewed to the presumption that very high flows would supposedly create more fry rearing habitat in the main stem Klamath River.

The assumptions of fry rearing habitat presented in Hardy and Addley (2001) are nearly opposite of those derived from studies in the Trinity River (among others mentioned in this report). After completion of a long-term instream flow evaluation of this large tributary to the Klamath River, the USFWS found that fry habitat was restricted by morphological features of the river channel, not terrestrial vegetation on the river banks. In the Trinity River (unlike the Klamath River), long-term decreased flows due to a large trans-basin diversion to the Sacramento River caused riparian vegetation (e.g., willows) to encroach into the previously active river channel which reduced shallow edge habitats utilized by salmon fry (Figure 4).[18]

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17 It is important to note that there are also other types of instream structure also known to be beneficial for coho fry. For example, House and Boehne (1985) found that rehabilitation of East Fork Lobster Creek, Oregon using gabion placement resulted in increased pool quantity, size, and depths and a corresponding increase in coho fry densities.

18 "Construction and operation of the Trinity River Diversion resulted in a change in channel morphology from one of gently sloping point bars to a narrow trapezoidal channel contained within steep riparian berms. This change in channel morphology eliminated most of the gently sloping point bars of the pre-dam alluvial channel that provided open, shallow, low-velocity gravel bar habitats for rearing salmonid fry." (USFWS and Hoopa Valley Tribe 1999)

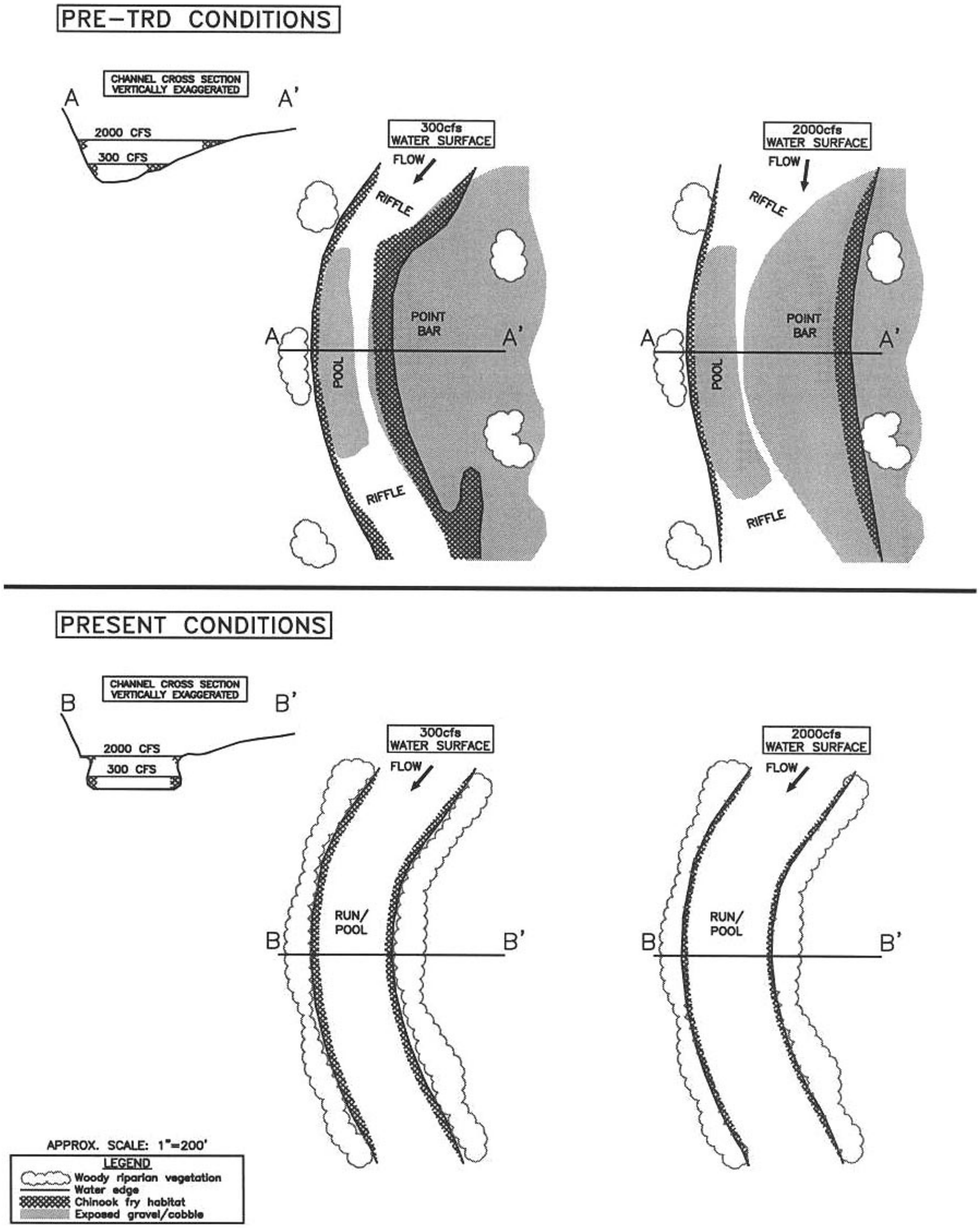

Figure 4. Idealized pre-Trinity River Diversion (TRD) point bar showing relative surface area of fry Chinook rearing habitat in comparison with present conditions of riparian encroachment and narrow channel configuration (original figure from USFWS and Hoopa Valley Tribe 1999).

To overcome this limitation, the USFWS recommended mechanical measures (e.g., bulldozers) to eliminate riparian berms and expand shallow edge habitats preferred by salmon fry for rearing (Figure 5).

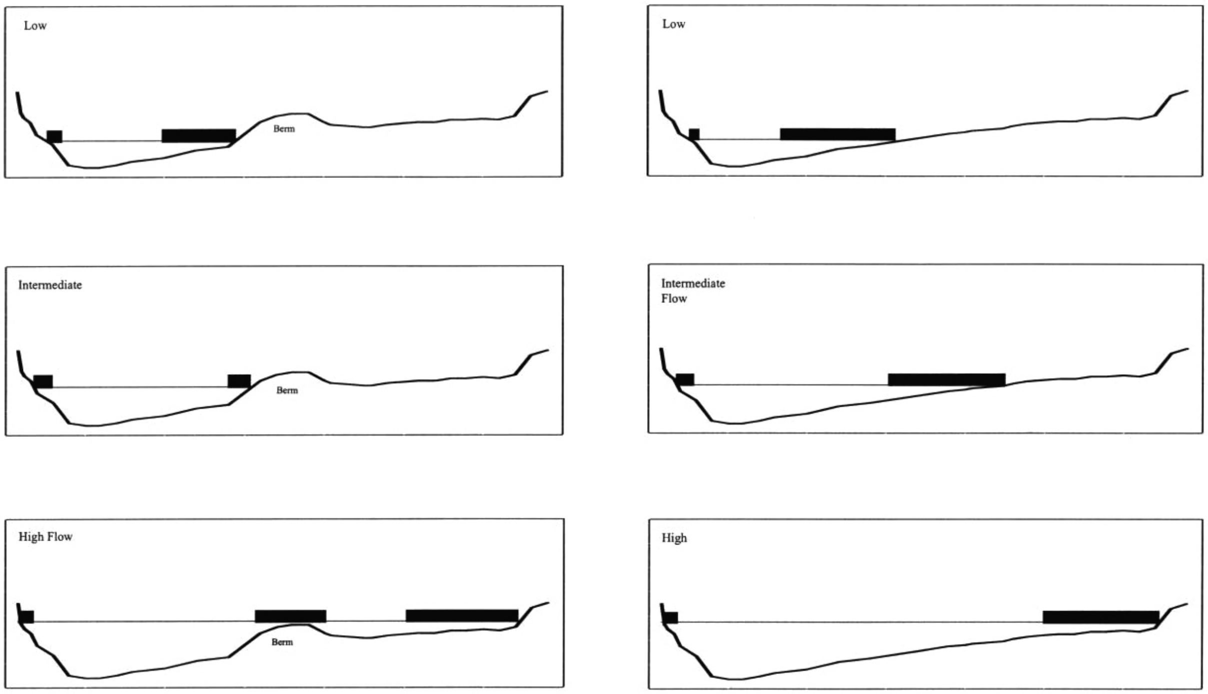

Figure 5. Representation of the existing Trinity River channel with a riparian berm and the rehabilitated channel with salmonid fry rearing habitat (represented by the boxes) at low, intermediate, and high flows (original figure from USFWS and Hoopa Valley Tribe 1999).

In the Trinity River Flow Evaluation Final Report, the USFWS and Hoopa Valley Tribe (1999) concluded:

> "The broadening and gradual sloping of the narrow trapezoidal channel allowed the river flows to spread out and water velocities to decrease, providing suitable depths and velocities for rearing salmonids regardless of flow magnitude. Bands of suitable habitat along the stream margin were relatively consistent at all flows and migrated up and down the gently sloping bank relative to changes in flow. Because the river often experiences substantial changes in flow during winter storms, providing suitable habitat throughout a range of flows is necessary to prevent habitat bottlenecks."

Obviously, the conclusions as to what constitutes suitable salmonid fry rearing habitat for the Trinity River are in sharp contrast to those presented in the draft Phase II Report on the Klamath River.

Habitat Computations (Composite Suitability Indices)

In PHABSIM, the suitability of each variable in the modeled range of conditions for each "cell"[19] of the river channel study site is combined to generate a "composite suitability index" (CSI). The most common method in PHABSIM is a multiplicative aggregation of HSC for velocity, depth, and channel index (USGS 2001). For example:

$$CSI = Depth_{SI} * Velocity_{SI} * Channel\ Index_{SI}$$

Where CSI is composite suitability index and SI is the suitability index for depth, velocity, and channel index or cover obtained from the species HSC curves.

Hardy and Addley (2001) used a valid variation[20] of the customarily-used CSI computation by using the geometric mean of the habitat variables:

$$CSI = (Depth_{SI} * Velocity_{SI} * Cover_{SI})^{1/3}$$

The use of the geometric mean implies a compensation effect between the suitability values. If one of the variables is low and the others are high, the low variable has a reduced effect on the computation of the composite suitability. For example, use of the geometric mean could be used for fish that fare well in marginal habitats as long as two of the three habitat variables are high (USGS 2001).

Although use of the geometric mean is valid in PHABSIM (assuming biological reasons justify doing so), the draft Phase II Report does not describe the reasons for use of this computation. This is important because rearing salmonids can have a relatively narrow range in utilization of depths, velocity, and channel features. The geometric mean can "dampen out" the effects of those variables in modeled outputs. The USFWS found that it was important to recognize all the important habitat attributes of Chinook fry to support the recommendation of reconfiguring the river channel to provide suitable combinations of depths, velocities, and channel substrate (Figure 5) (USFWS and Hoopa Valley Tribe 1999). Focusing on only one habitat feature (e.g., cover) could result in no significant benefits if the other desirable attributes (e.g., depths, velocity, substrate) are treated with greatly diminished value within computer modeling assumptions. For example, Sheppard and Johnson (1985) found that water depth and velocity may be more important than substrate type in habitat selection by subyearling coho salmon.

As postulated in the draft Phase II Report, if a modeled area was found to be more than two feet from cover habitat, the composite suitability of that area was assumed to represent zero habitat (Hardy and Addley 2001)[21]. This viewpoint has been challenged by numerous observations of other researchers

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19 "These habitat cells represent the basic computational cells used by the various habitat programs to derive relevant indices of available habitat." USGS (2001), p. 87.

20 But in this author's estimation, use of the geometric mean is probably infrequently used in PHABSIM modeling for other IFIM studies similar to the Klamath River Phase II study.

21 "If a cell was more than two feet from escape cover, the composite suitability of the cell was set to 0.0 (i.e., no

(discussed below[22]) and negates one of the most useful benefits of the PHABSIM modeling effort to characterize ranges of habitat conditions for fish instead of simplistic "present or absent" scenarios. Although "distance to cover" is a plausible variable to use in some fish species and fish life stage HSC, the variable should be considered as a continuous function instead of binary as used in the draft Phase II Report. For example, if a particular species life stage has a known utilization or affinity to cover, that utilization is likely to vary depending on stream flow conditions. With low stream flow conditions, the cover attributes (e.g., velocity breaks, turbulence, bubble curtain, depth, etc.) may dictate a relatively close proximity of a fish to the cover feature. For example, Hampton (1988) found that surface turbulence served as cover for fry and juvenile steelhead, Chinook, and coho in the Trinity River and was particularly important for steelhead and Chinook juveniles. As stream flow increases, the cover characteristics change, extending the probable range of the fish's utilization to the cover structure through an expanded range of the cover attributes (e.g., greater turbulence, increase in bubble curtain, depth, etc.), a function not recognized in the draft Phase II Report.

One of the largest errors introduced in the draft Phase II Report is the "Escape Cover Dependent Modeling" exercise. In this instance, Hardy and Addley (2001) departed significantly from accepted IFIM/PHABSIM modeling protocol and added a "cover type modifier"[23] for modeling salmonid fry habitat.

$$CSI = (Depth_{SI} * Velocity_{SI} * Cover_{SI})^{1/3} * \text{Cover Type Modifier}$$

The authors assumed that the cover type modifier should be set to 0.17 if the escape cover was substrate (e.g., a large rock or any other type of natural fry habitat substrate structure customarily found in a river channel) and set to 1.0 if the escape cover was inundated streamside vegetation[24] (only occurs if the river flow is high enough to flood over the usual wetted channel perimeter into terrestrial vegetation). Such an approach greatly under-represents ideal habitats found within the main stem channel.

Additionally, the approach diminishes the underlying biological foundation of the HSC. For example, as customarily used in PHABSIM modeling for the IFIM, the $Cover_{SI}$ variable already encompasses the

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habitat." Hardy and Addley (2001), p. 158.

22 The draft Phase II Report's use of the term "cover" is much more restrictive and unique than commonly used in the scientific literature. For example, Bjornn and Reiser (1991) state: "Some of the features that may provide cover and increase the carrying capacity of streams for fish are water depth, water turbulence, large-particle substrates, overhanging or undercut banks, overhanging riparian vegetation, woody debris (brush, logs), and aquatic vegetation." In another example, Moyle (2002) states: "Juvenile coho are generally at highest densities in deep (≥1 m), cool pools with plenty of overhead cover, especially in summer, but they use a wide variety of habitats if cover, depths, temperature, and velocities are appropriate. They are typically associated with instream cover (such as undercut banks, logs, and other woody debris) close to areas that are productive for feeding. Juvenile show pronounced shifts in habitat with season, especially in California streams [citations in original document]. In spring, when stream flows are moderate and fish are small, they are widely distributed through riffles, runs, and pools."

23 Not to be confused with the customary treatment of the channel index variable for cover in PHABSIM.

24 "The combined suitability of the node is then adjusted by the cover type modifier derived form whether the cover element contained vegetation (i.e., suitability of 1.0) or substrate (i.e., suitability of 0.17)." Hardy and Addley (2001), p. 165.

biological bases incorporated into the modeling program.[25, 26] If the depth, velocity, and cover for the species life stage are all ideal (or 1.0 in the life stage HSC), the composite suitability index would be 1.0 [i.e., $(1.0*1.0*1.0)^{1/3}$]. However, when factoring in the unorthodox "cover type modifier" of 0.17, the CSI is reduced to 0.17. Conversely, if the depth, velocity, and cover for the species life stage are all substandard and considerably less than ideal (e.g., 0.3 in each of variable HSC), the composite suitability index would be 0.027. However, when factoring in the unorthodox "cover type modifier" of 1.0, the CSI would be 0.3 [i.e., $(0.3*0.3*0.3)^{1/3}*1.0$] or twice the CSI that would otherwise be considered ideal in other rivers. As previously mentioned, the use of the geometric mean of the habitat variables has the high probability of further exacerbating the error between probable "actual" habitat and theoretical modeled habitat by under-representing other habitat variables, such as velocity, into the composite suitability index.

Therefore, use of the "cover type modifier" in the draft Phase II Report has an enormous impact on the final output of estimated salmonid habitat in the main stem Klamath River without supporting evidence to justify its use. In the simplest of terms, if actual fish rearing habitat in the main stem Klamath River was ideal with substrate as cover habitat, it would actually be modeled as greatly inferior compared to presumed habitat created when computer-modeled flow flooded over the usual wetted river channel perimeter into woody live vegetation on the river banks. If that circumstance reflected biological reality, it would not have been necessary to perform an IFIM study and PHABSIM modeling in the first case; simple empirical observations of high flow conditions could have sufficed.

Despite the warnings of pitfalls associated with selection of HSC late in the instream flow evaluation planning process (USGS 2001, p. 8), the Klamath HSC, the associated HSC modifications, and altered composite suitability indices computations were apparently developed late in the study.[27] Unfortunately, such an approach, developed late in the study, to the exclusion of other stakeholders, and without documentation leaves the ultimate results suspect.

Salmon Rearing Habitat in the Klamath River and Other Rivers

The best empirical evidence to date indicates that the draft Phase II Report's assumptions on main stem Klamath River juvenile salmon rearing habitat do not accurately reflect a correct modeling of conditions known elsewhere to be suitable. It is therefore important to consider the relevance of salmon rearing

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25 "Microhabitat in PHABSIM is defined by water depth, velocity, and channel index. Channel index represents substrate, cover, or other similar immobile variable(s) important in defining the physical habitat requirements of the target species." USGS (2001), p. 7.
26 Additionally, conditional criteria such as biological interaction between changes in flow and cover can be incorporated into the channel index of the PHABSIM software to compute composite suitability indices (USGS 2001).
27 "USU conducted a number of initial habitat modeling runs using different HSC criteria and different approaches to illustrate the various methods that could be used to derive the composite suitability factors. The Technical Team reviewed simulation results involving these potential approaches. Based on the technical evaluation of the various simulation results, the Technical Team (and USU) determined that the best approach for representing the observed behavior of fry in the Klamath River was to calculate available habitat using an escape cover based channel index coding scheme in combination with a modification to computational algorithm of the standard habitat model within PHABSIM (i.e., HABTAE). (Hardy and Addley 2001, p. 157)

habitat examples to prompt caution in the NMFS 2002 Biological Opinion's and draft Phase II Report's conclusions. These documents do not cite examples of knowledge derived or interpreted elsewhere on the topic but will be provided here to assist in balancing opinions on rearing habitats.

Another perspective to assess salmonid rearing habitat in the main stem Klamath River is: "If the only suitable habitat is up on the banks within terrestrial vegetation as presumed in the draft Phase II Report, why are the in-channel habitats unsuitable, particularly when other rivers clearly provide suitable in-channel rearing habitat?" It is instructive and scientifically sound to compare findings elsewhere because of several key points:

1) Other research findings directly challenge and are in sharp contrast to Hardy and Addley (2001);
2) Other research findings could have profound effects on the highly debatable results of the draft Phase II Report; and
3) Outputs from PHABSIM models to predict fish habitat are "extremely sensitive to even subtle differences in habitat suitability criteria" (USGS 2001).

Other studies in large rivers indicate that sub-yearling (fry[28] that are approximately 50 mm in length) Chinook rearing habitat decreased with increased flow because of a combination of undesirable depths at channel margins, unsuitably high water velocities, and reduction in lateral slope areas utilized by young fish (Tiffan et al. 2002). In the Hanford Reach of the Columbia River, Tiffan et al. (2002) found that decreases in near shore lateral slope and water velocities associated with decreased flow increased the probability of habitat use and actual Chinook fry observed. Additionally, they found that high flows inundated many islands thereby reducing or eliminating rearing habitat that had been present at lower flows. No relationship was noted between Chinook fry usage and submerged terrestrial vegetation in the Hanford Reach of the Columbia River (based on observations and underwater videography) prompting Tiffan et al. (2002) to conclude that its importance for Chinook rearing remains unknown. In another instance, but for a small stream, Fuller (1990) found that recently emerged Chinook fry exhibited high utilization of habitats created by boulders placed in Hurdygurdy Creek in northern California. The assumptions and conclusions on salmonid rearing habitat in the draft Phase II Report and in the NMFS Biological Opinion differ markedly from those in a recently completed, extensive instream flow evaluation conducted between 1984 and 1997 on the Trinity River. Unlike the assumptions in the draft Phase II report, researchers found that Chinook fry in the Trinity River were predominately found associated with in-channel structure for cover [e.g., cobble substrates, undercut banks, woody debris (the latter not to be confused with the draft Phase II Report's use of above-bank terrestrial vegetation)] (USFWS and Hoopa Valley Tribe 1999). During my research with the USFWS in the main stem Sacramento River, I found high utilization of salmon fry associated with in-channel features such as aquatic vegetation, large cobbles and boulders, bedrock outcroppings, and undulations in the river bed.

28 Agencies involved with Klamath River fishery resource issues use a 55 mm length as the threshold between fry and juvenile salmon.

Good salmonid rearing habitat is undoubtedly present near the channel banks of many large rivers. The Alaska Department of Fish and Game estimated that over 80 percent of ideal juvenile Chinook salmon rearing habitat[29] was found within a 6-foot wide corridor adjacent to the banks of the Kenai River (Liepitz 1994). Much of my prior research with the USFWS on the Sacramento River also found large numbers of Chinook fry and abundant rearing habitat in the river channel adjacent its banks (USFWS, unpublished data). However, conducting assessments in salmonid rearing habitat in large river channels is problematic because of the difficulty of sampling in deep, swift water (CDFG 1989, Vogel 1993).

Despite the statements in the draft Phase II Report, there is by no means a consensus as to what constitutes good or ideal rearing habitat in the Klamath River. For example, the assumptions on salmonid rearing habitat characteristics used by Hardy and Addley (2001) are very different from those used elsewhere in the Klamath River basin (e.g., Arey and Gilroy 1993a, 1993b, 1993c, Arey et al. 1992a, 1992b, Arey et al. 1993a, 1993b, 1993c, Douglas Parkinson & Associates 1990, Hampton 1988, Krakker 1991, Lintz and Kisanuki 1992, Mayo 1992, USFS 1992, 1993, USFWS and Hoopa Valley Tribe 1999).

Technique Used to Evaluate Juvenile Salmon Rearing Habitat

The development of the HSC for the Klamath River in the draft Phase II Report was severely constrained by data collection during high flow conditions. No data collected during low flow conditions were reported. Hardy and Addley (2001) correctly point out that this circumstance had the potential to bias the data, but dismissed the valid concern based on one "personal communication" to suggest that HSC data collected during high flows are the same as lesser flow[30] conditions.[31] Furthermore, the information is only of value as long as it is available, particularly when the conclusions depart so significantly from results of research performed elsewhere. Unfortunately, that information is not provided in the draft Phase II Report. Until data are collected in other than high flow conditions, the rearing HSC are suspect. The problem associated with collecting data only in high flow conditions is that an investigator could confuse optimal conditions with those that were only tolerable (Manly et al. 1993, as cited by USGS 2001). For example, unlike the draft Phase II Report, CDFG (1989) recognized this problem during an instream flow study on the Sacramento River and collected salmon rearing HSC data for PHABSIM over a wide range of flow conditions, not just during high flows.

Field efforts to attempt evaluation of salmonid rearing habitat in the main stem Klamath River proved to be very difficult (Hardy and Addley 2001, CDFG 2001). Individuals working to develop HSC for fry and juvenile salmonids on the main stem Klamath attempted to use direct underwater observations at

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29 Liepitz (1994) described optimal juvenile Chinook rearing habitat in the Kenai River as "water velocities less than 1.0 feet per second, undercut banks with overhanging vegetation, and gravel/cobble substrates".

30 Est. >1,700 cfs

31 "It should be noted that the field data collection for chinook fry were obtained at a relatively high flow rates (sic) during the first two field seasons. This had the potential to bias these HSC toward higher flow rate conditions. Chinook fry observations obtained during spring 2001 field sampling by USFWS field personnel at substantially lower flow rates, indicate very little bias if any in these HSC. Chinook fry depth and velocity utilization and their association with inundated streamside vegetation appears to be consistent with the existing Chinook fry HSC developed for the study [Tom Shaw, personnel (sic) communication]." Hardy and Addley (2001), p. 125-126.

locations off shore, but encountered the usual problems associated with snorkeling or SCUBA diving in deep, swift water. They used a lighter version of underwater video equipment available for such a task, but unfortunately did not employ the technique appropriately to allow for successful fish observations. They moved the underwater video apparatus in a downstream direction, instead of an upstream direction (CDFG 2001, Rode 2002, S. Williamson, USGS, personal communication) which undoubtedly explains why they had few fish observations. Fish near the riverbed are very easily disturbed when approached in a downstream direction precluding the ability to observe the fish in a natural setting. Discussion on successful methods of data collection in hostile riverine environments is discussed in the next section.

The consequence of inadequate data collection techniques was that a large disproportionate sampling of the edge habitat combined with high flow conditions occurred during the Phase II study. These circumstances would be a plausible explanation of why fry rearing in the Klamath River was erroneously presumed to be so different from that known to occur elsewhere. It would also explain why the draft Phase II Report's computer modeling results showed almost no rearing habitat within the main river channel.

Hardy and Addley (2001) appropriately emphasize that the HSC used in the draft Phase II Report "are considered interim in light of the continued instream flow assessment work being undertaken as part of the long-term strategic flow study headed up by the USFWS. It is anticipated that these HSC will continue to be refined as additional information becomes available over time." The following discussion presents some ideas on how the Klamath River HSC could be improved.

Empirical Examples of Salmonid Rearing Habitats and Successful Observation Methods

It is relatively easy to sample fish and habitats near channel banks, explaining why much of the available information has been acquired from those areas (e.g., as demonstrated in the draft Phase II Report). Based on underwater observations in large rivers, off-shore habitats may have importance for salmonid rearing (Vogel 2002). Simply because some individuals claim they cannot find rearing salmonids within the main channel of the Klamath River because of inefficient sampling techniques does not mean the habitats or fish are not present.

Approximately 20 years ago, I developed a procedure for SCUBA divers to survey riverbeds in the middle of a large river during relatively high flow conditions (10,000-14,000 cfs). It was originally developed as part of my effort to help Search and Rescue teams locate drowning victims in the Sacramento River. Ultimately, I expanded the work through my research on salmonids and as Chairman of the USFWS Diving Control Board for six western states. I modified the technique to perform detailed riverbed substrate mapping in extensive main stem river reaches downstream of dams (Figure 6). In this latter investigation, two SCUBA divers were towed on diving planes in an upstream direction along longitudinal transects behind a jet boat using a hard-wired underwater communications system (Vogel and Taylor 1987). Despite the rigors of the deep (10 - 40 feet) and swift water at relatively high flows, divers were able to observe large numbers of fry and juvenile salmonids (Chinook and steelhead) rearing within the main river channel, far removed from channel edges. Schools of young-of-the-year fish were found behind deep-water salmon redds, bridge piers, large rocks, and aquatic vegetation (Vogel and Taylor 1987). The survey method allowed for fish observations in locations that otherwise would not have been possible. Large schools of juvenile late-fall and winter-run Chinook salmon fry near the riverbed were common (Vogel 1988). Locating fish in those environments is very difficult[32] and requires specialized equipment, training, and considerable experience (Vogel 1991). Having spent hundreds of hours performing underwater research on fish in rivers and streams, it is not surprising that individuals working on the Klamath River were unable to accomplish such a task.

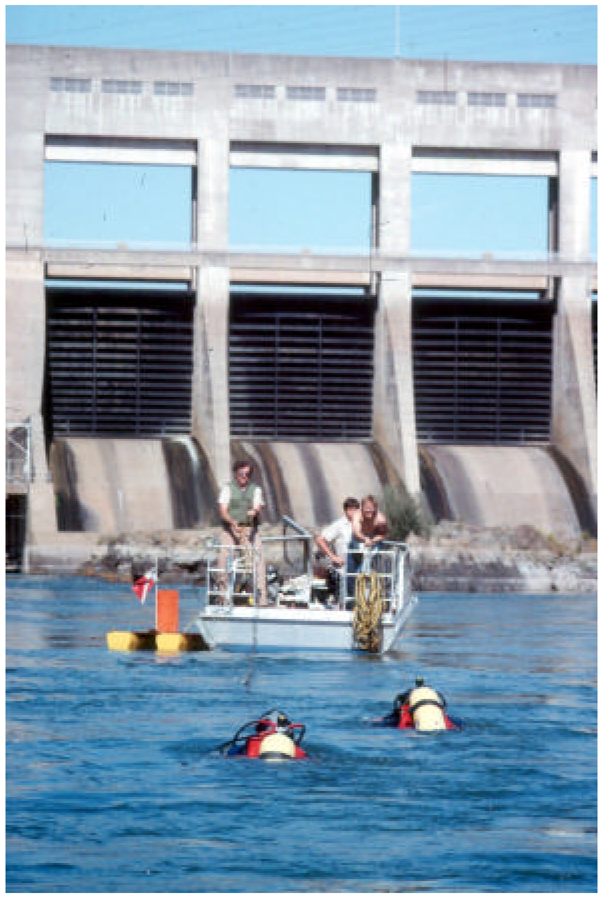

Figure 6. SCUBA divers preparing for riverbed surveys immediately downstream of Keswick Dam on the Sacramento River in water depths up to 40 feet. Author (SCUBA diver in left foreground) is "hard-wired" to the jet boat with a tow line and underwater communications cable. The two divers used planing boards to descend to and ascend from the riverbed in the fast currents.

Recently, I further modified the technique of performing riverbed and fish surveys in swift water using underwater videography. The method utilizes a high-resolution, color underwater video camera mounted on an aluminum frame with two 30-pound river survey weights to position and orient the camera in an upstream direction (Figure 7). The camera and camera frame are adjusted vertically by using a battery-powered winch mounted on the bow of an inboard jet boat. The underwater video

32 For example, the ability to hold one's breath for extended periods to minimize fish disturbance caused by exhaust bubbles.

images are seen in real time with a monitor and are recorded via a hard-wire connection to the surface. Concurrent GPS readings are recorded on video to document camera location. Visual images from the monitor and the winch manipulation allow rapid adjustments of camera position near the riverbed. The technique has proven to be ideal for fish observations in otherwise inhospitable riverine conditions. Another advantage is that it allows all individuals (other scientists, stakeholders, etc.) to view the fish and habitats, greatly reducing potential subjectivity and debate regarding the HSC. Its application on the main stem Klamath River would provide meaningful information on potential fish usage not developed because of the limitations previously described.

Figure 7. Three underwater camera systems used by the author to record underwater observations of fish and habitats in rivers. Camera at top center is configured for riverbed substrate surveys. The system is described in the report. Two 30-lb. streamlined weights hold and orient the camera in very fast water. Cameras at bottom and right are self-contained units for use by SCUBA divers.

Following are samples of still images of young salmonids captured from dozens of hours of underwater video recordings by the author using underwater video systems. Figures 8 - 18 are images from separate fish observations.

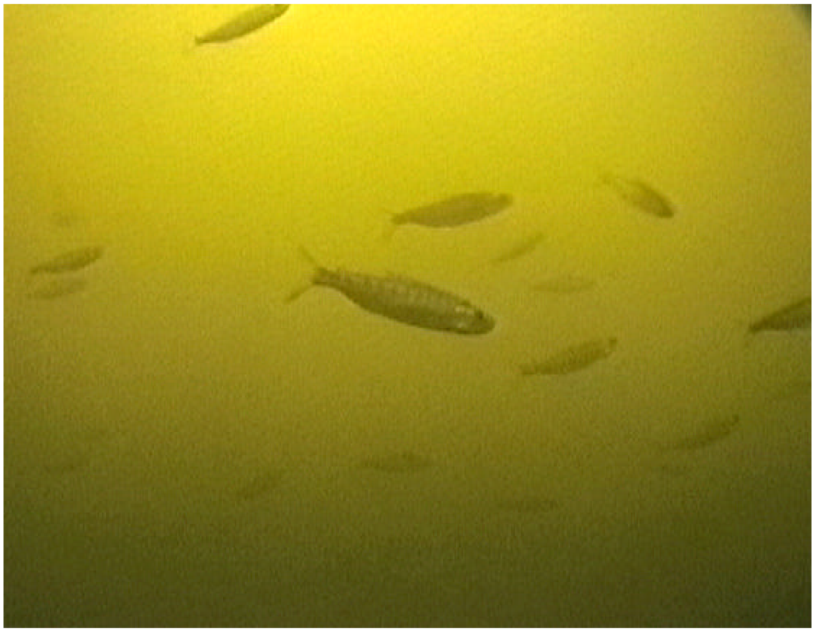

Figure 8. Large school of juvenile Chinook salmon observed near the riverbed of the Sacramento River during a river flow of 5,000 cfs in 25-foot water depth. Photo by the author.

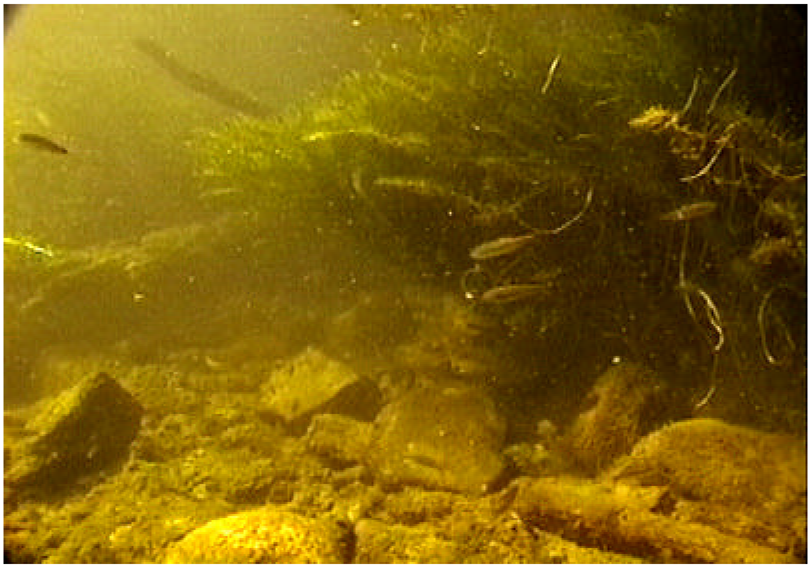

Figure 9. Chinook salmon fry observed on the bed of the Sacramento River during a river flow of more than 10,000 cfs. Fish were at a depth greater than 10 feet and more than 50 feet from the river bank. Note proximity of rooted aquatic vegetation. Photo by the author.

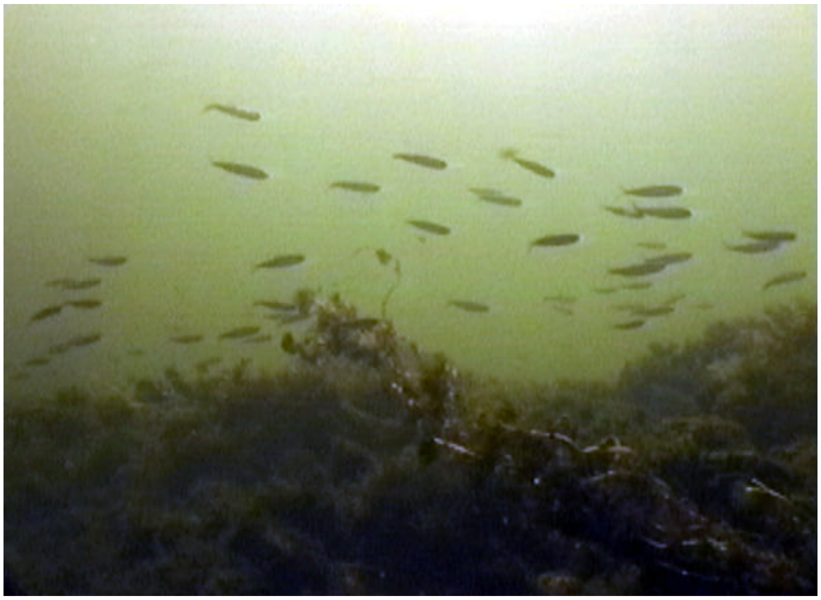

Figure 10. Large school of chinook salmon fry observed on the bed of the Sacramento River during a river flow of more than 10,000 cfs. Fish were at a depth greater than 10 feet and more than 50 feet from the river bank. Note proximity of rooted aquatic vegetation. Photo by the author.

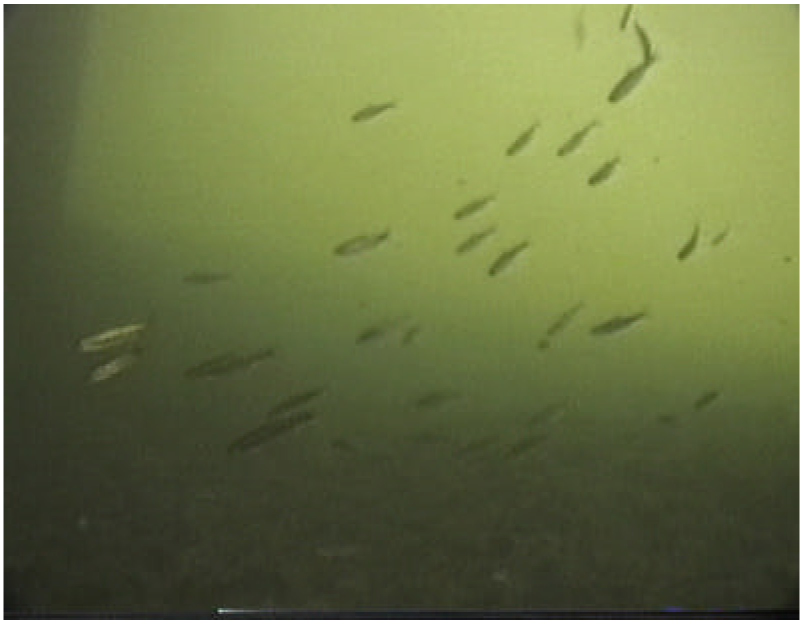

Figure 11. Chinook salmon fry observed on the bed of the Sacramento River during a river flow of more than 10,000 cfs. Fish were in a scour hole approximately 15 feet deep, adjacent to a bridge pier (upper left), and more than 50 feet from the river bank. Photo by the author.

Figure 12. Steelhead fry behind a large cobble/small boulder in Hurdygurdy Creek, a tributary to the Smith River in northern California. Photo by the author.

Figure 13. Steelhead fry among large cobble in Hurdygurdy Creek, a tributary to the Smith River in northern California. Photo by the author.

Figure 14. Steelhead fry behind a boulder in Hurdygurdy Creek, a tributary to the Smith River in northern California. Note surface turbulence and bubble curtain. Photo by the author.

Figure 15. Small school of steelhead fry among gravels and cobbles in Hurdygurdy Creek, a tributary to the Smith River in northern California. Photo by the author.

Figure 16. Large school of juvenile Chinook near the bottom of a 60-foot deep pool in the main stem Smith River, northern California. Photo by the author.

Figure 17. Steelhead fry among cobbles in the main stem Klamath River. Photo by the author.

Figure 18. Juvenile steelhead among cobbles in the main stem Klamath River. Photo by the author.

CONCLUSIONS AND RECOMMENDED APPROACH FOR THE KLAMATH RIVER

Although rearing habitat characteristics for young salmonids are well known and have been studied extensively in other rivers and streams, habitats have not been adequately assessed in the main stem Klamath River. Although some data have recently been collected in this area for Chinook fry, these efforts were limited because of high flow conditions and sampling was primarily restricted to edge habitats and within flooded terrestrial vegetation. These circumstances, in combination with inadequate sampling in more customary main stem in-channel habitats led to faulty assumptions on salmonid rearing used in the draft Phase II Report by Hardy and Addley (2001) and subsequently in the NMFS 2002 Biological Opinion.

Even though the main stem Klamath River does not possess habitats found in smaller tributary streams preferred by coho salmon, the NMFS 2002 Biological Opinion nevertheless presumes (using erroneous assumptions in the draft Phase II Report) that specific, high instream flows are necessary in the main stem Klamath River to avoid adverse effects on Klamath basin coho populations. The severe limitations associated with the biological assumptions used in the draft Phase II Report greatly diminished the worth of an otherwise potentially useful hydraulic modeling effort by Hardy and Addley (2001). The NMFS 2002 Biological Opinion's premise on coho rearing habitat in the Klamath River is not convincing and subject to considerable debate because of a lack of empirical data and conflicting arguments about the ecological regularity of habitat suitability criteria for salmonid rearing.

The mistakes made during the formulation of the draft Phase II Report and the resulting incorrect assumptions and conclusions by NMFS in the 2002 Biological Opinion could have been avoided through inclusion of other individuals with expertise on instream flow and salmonid biology.

The lack of adequate knowledge of salmonid rearing habitats within larger main stem channels is not unique to the Klamath River.[33] These circumstances are not surprising because of the considerable difficulty in collecting salmonid rearing information in large river channels (Hampton 1988, Vogel 1993).

One of the recommendations in the draft Phase II Report states:

> "Additional data on fish observations at each of the study sites should continue on a seasonal basis. This is particularly true for steelhead fry, coho fry, and coho juveniles. These data would be important to ultimately improve the envelope base habitat suitability curves or development of site-specific habitat suitability curves for these species and life stages. The revised curves could then be used to refine or update the flow recommendations for each river reach." Hardy and Addley (2001), p. 263.

These recommendations are appropriate.[34] However, salmonid rearing habitats in the main stem Klamath River remain largely unexplored and additional work should:

1) Include other life stages (such as Chinook fry because of the manner the life stage HSC was used in the draft Phase II Report);
2) Employ methods for observing fish in large rivers using survey techniques developed elsewhere;
3) Sample in lower flow conditions than those experienced; and
4) Sample other main stem habitats either insufficiently sampled or not sampled at all during the draft Phase II study.

An improved understanding of the salmonid rearing habitats available in the main stem Klamath River in relation to habitats throughout the basin is necessary using a collaborative, scientific approach, but remains a concept not well received. In formulation of the IFIM, the USGS recognized the detriments of HSC development from stakeholder groups "stacking the deck" with like-minded colleagues and emphasized the value of bringing in outside experts, use of neutral parties, and numerous other techniques to improve the validity of HSC development for PHABSIM studies. To date, technical input to stakeholders involved with the draft Phase II process by outside experts and other stakeholders has not been welcomed. Until that obstacle is overcome, it will be difficult to develop a more comprehensive and objective assessment of habitat needs for anadromous salmonids in the Klamath River.

33 E.g., Beechie et al. (1994) found that they lacked sufficient knowledge of usage of juvenile coho in the main stem Skagit River in Washington to develop management recommendations.

34 "NMFS recognizes that Hardy and Addley (2001) habitat suitability criteria, upon which it relied to deriving long-term flow target found in Table 9 may change as the report progresses through public comment and peer review to a final report, and that even then new information from the science program embodied in this RPA [Reasonable and Prudent Alternative] could refine that information further." (NMFS 2002, p. 54)

As pointed out by the USGS:

> "To simply adopt whatever curves are available after hydraulic modeling is complete may greatly hinder meaningful interpretation of habitat model outputs. Consensus about the HSC among project proponents, regulatory agencies, and other stakeholders early in the project planning process is often essential to successful completion of a PHABSIM study." USGS (2001), p. 8.

Unfortunately, this process was not followed in formulation of the draft Phase II Report.[35]

Even though every type of sampling technique possesses some sort of bias, by using the survey methods described in this report, potential rearing habitats for salmonids in the main stem Klamath could be effectively assessed away from shore in the deeper, swifter areas of the main river channel and allow for a more equalized effort. This would help to balance the availability of microhabitat conditions sampled. Ultimately, habitat suitability criteria for salmon rearing that is more reflective of actual conditions would be generated, thereby reducing bias[36] caused by the mode of sampling.[37] Such work can be integrated with a system-wide investigation that focuses on other factors that may be important to support healthy fish populations, including fish habitat conditions in the Klamath River tributaries.

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35 "In the IFIM context, it is essential for all parties to agree on the HSC to be used for the study and to agree on their transferability." USGS (2001), p. 9.

36 "In the context of microhabitat utilization this bias means that individuals will be forced to use suboptimal conditions if optimal conditions are unavailable. By observing only the conditions used most often in a given stream, an investigator could confuse optimal microhabitat with conditions that were merely tolerable." USGS (2001), p. 74.

37 "In PHABSIM, it is equally important to describe habitat variables used over a broad range as to find narrow habitat preferences. Sometimes, these criteria appear as thresholds, above or below which there is little selection. The empirical frequency distribution of used microhabitat may be artificially narrow, either because the range of available conditions was narrow or because of the method used to fit the criteria to the data. Such artificially narrow criteria can make PHABSIM output unrealistically sensitive to changes in discharge." USGS (2001). It is readily apparent that this circumstance occurred in the draft Phase II report.

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