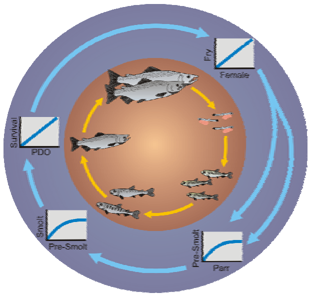
Technical Response Brief 8

Response to Comments on Technical Memorandum 8:
“Simulation of the Life Cycle of Klamath Coho from Adult Entry to Summer Rearing”

Klamath Coho Integrated Modeling Framework
Technical Memorandum Series



Prepared by:

Cramer Fish Sciences

Submitted to the Bureau of Reclamation, Klamath Basin Area Office

August 7, 2007

Cramer
Fish Sciences
600 N.W. Fariss Road
Gresham, OR 97030

Introduction

This Technical Response Brief (TRB) includes our response to technically substantive comments received on Klamath Coho Integrated Modeling Framework Technical Memorandum 8, *"Simulation of the Life Cycle of Klamath Coho from Adult Entry to Summer Rearing."* Technical Memorandum 8 is the last in the series of Technical Memorandums that focus on distinct topics relevant to a coho life-cycle model being developed for the Klamath Basin. Technical Memorandum 8 was distributed on May 8, 2007 to the following organizations: National Marine Fisheries Service (NOAA Fisheries), California Department of Fish and Game, US Fish and Wildlife Service (USFWS), US Forest Service, Karuk Tribe, Hoopa Valley Tribe, Yurok Tribe, Klamath Tribes, PacifiCorp, Trinity River Restoration Program, Green Diamond Resource Company and the University of California Davis.

A TRB has been prepared in response to comments received for each Technical Memorandum, so reviewers can see how their input has influenced model development. Many helpful comments were received on Technical Memorandum 8, both written and verbal. This TRB will not respond to all comments, but will address issues and concerns raised that have potential to substantially alter model outputs or their validation. Such issues might include identification of new data sets or a flawed assumption. All comments received, whether or not they are discussed in this TRB, were reviewed and may be used in the final model and report. A draft of the final report will be distributed for another round of review before it is finalized.

Summary of Technical Memorandum 8

Technical Memorandum 8 described how the Klamath coho life-cycle model will simulate life stages from river entry of adults in the fall through egg deposition, fry emergence and parr rearing into their first summer of life. The model is intended to capture the population dynamics of coho disbursed throughout the basin, with a particular focus on how those dynamics are likely to be affected by temperature and flow in the main stem of the Klamath River. The ultimate purpose of the model is to predict the relative differences in coho production that might result from variations in water management caused by the Reclamation Klamath Project.

The life-cycle model simulates the effects of temperature and flow in the main stem of the Klamath River on adult and juvenile coho salmon as they migrate through the Klamath River main stem. Adult coho salmon are affected by main stem temperatures as they enter the Klamath River and migrate upstream. The number of adults that survive to spawn is affected by temperature through its effects on prespawning survival. The number of smolts produced per spawner in each tributary and reach of the main stem is density dependent on summer rearing capacity for juveniles, as determined by habitat quality and temperature. A portion of juveniles emigrate from the tributaries as fry and enter the Klamath main stem. Fry and parr in the main stem are affected by Klamath River temperatures. The survival of juvenile coho in the main stem is density-dependent and affected by their ability to find thermal refugia in the river or in adjacent tributaries.

Response to Comments

Comments received addressed varied issues, including grammar, clarity, policy questions, and technical issues with the analyses. The following summary provides responses to general topics related to the analytical approach.

Adult Migration and Survival

Commenters noted that coho telemetry data suggests that adult coho spend an average of 19 days traveling between the upriver terminus of the estuary to the Trinity River confluence as opposed to the one week described.

We examined the transit time of coho salmon through the lower Klamath River (reach 6) using harvest timing of hatchery coho salmon in the Yurok fishery and subsequent passage of hatchery fish at Willow Creek weir (Trinity River) and Iron Gate Hatchery (IGH). Approximately 50% of the harvest of Trinity River hatchery fish in the lower Klamath River on average occurs during the last week of September and the migration of hatchery fish through the Willow Creek weir occurs about one week later (Figure 1). About 50% of the harvest of IGH coho salmon in the lower Klamath River occurs during the first week of October, and the timing at IGH occurs about 5 weeks later (Figure 2). This information suggests that coho salmon take about a week to migrate up to the Trinity River, and about 5 weeks to migrate from the estuary to Iron Gate Dam.

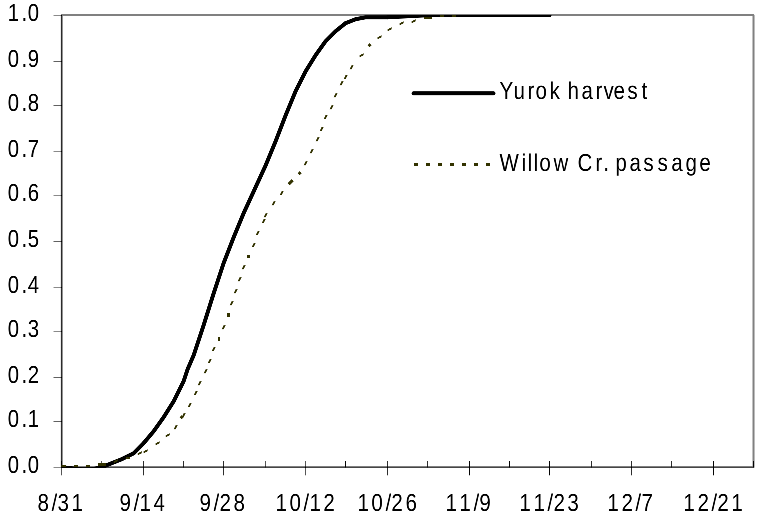


Figure 1. Cumulative proportion of Trinity River hatchery coho salmon harvest in the Yurok tribal fishery compared to the passage of hatchery fish at Willow Creek weir (Lower Trinity River), 2000-2005.

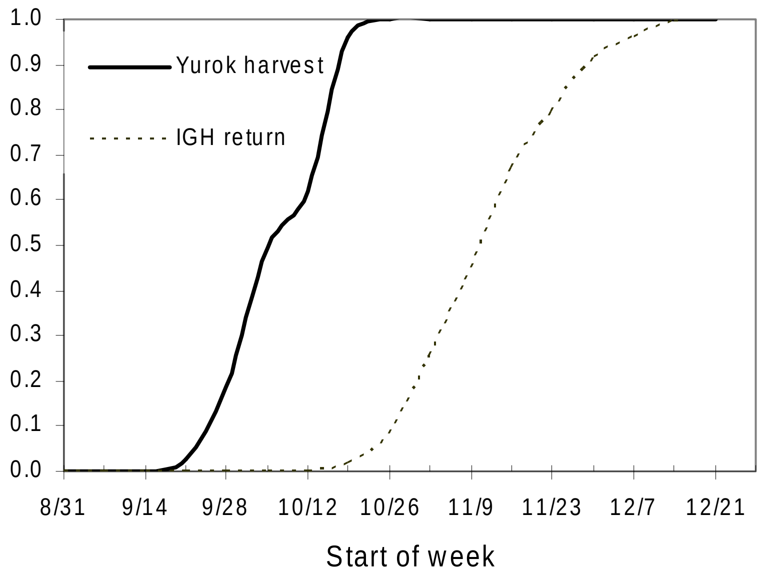


Figure 2. Cumulative proportion of Iron Gate hatchery coho salmon harvest in the Yurok tribal fishery compared to the return at the hatchery, 2000-2005. Data from 2002 was excluded because no IGH hatchery coho were sampled in the fishery due to low numbers of coho returning to IGH that year.

The lower Klamath coho telemetry studies indicate that transit time through reach 6 may be longer than indicated using fishery and upstream passage timing, but the telemetry study tracked few coho. The 2004 telemetry study conducted in the Lower Klamath River suggested that coho salmon take an average of 19 days to move from the estuary to the Trinity River confluence (Josh Strange, written communication). However, only two of the five radio-tagged coho that migrated up from the estuary were tracked up to the mouth of the Trinity River (Strange 2006). In addition, handling of adult salmon in riverine studies has been shown to delay upstream migration of tagged fish after release (Bernard et al. 1999). This handling induced behavior can bias estimated transit times. Given these circumstances, we are more confident in the estimate of travel time developed from timing of peak passage as we described.

We recognize that there is considerable uncertainty around our simulations of adult transit times through the Klamath River. Our analysis assumes that hatchery and natural coho salmon have similar migrations throughout the basin, which may not be accurate. To assess the effect of this uncertainty on our model predictions, we will run the model with different migration rates and report on how the model predictions change in response.

Klamath Main Stem Spawning

Commenters pointed out that the peak annual flows used in our analysis included events outside of the incubation period, and therefore we overestimated the occurrence of scouring flows that would effect coho eggs and alevin. In addition, they suggested that scour mortality should also apply to tributaries. Commentors provided for our consideration a recent US Forest Service report by May et al. (2007) on redd scour in the Trinity River.

A small number of coho salmon spawn in the main stem of the Klamath River each year, but the origin of these fish and the survival of their eggs are unknown. Between 2001 and 2005, a total of 46 coho redds (range = 6 to 21 per year) were counted in the Klamath River main stem. All of the redds were located within 1.5 km of a tributary, and most were concentrated within 20 km downstream of Iron Gate Dam (Magneson and Gough 2006). Because of the close proximity of IGH to Iron Gate Dam, and similar observations of main stem spawners close to hatcheries immediately downstream dams in other rivers (McPherson and Cramer 1981, Lestelle 2007) suggest that these fish are likely hatchery strays. Regardless of the source of these fish or the cause of their low productivity, their extreme low numbers over many years of observation tend to confirm our assumption that main-stem spawning produces few recruits.

Coho salmon spawn mainly in small streams or side channels to larger rivers (Edie 1975, Lichatowich 1999, Behnke 2002, Moyle 2002, Lestelle 2007). These locations typically have smaller channels (3-14 m) and lower flows with moderate gradient; mostly 1-2% but as high as 4% (Edie 1975, Lestelle 2007). In contrast, Chinook salmon typically occupy the lower portion of larger tributaries and the main stem of larger rivers (Edie 1975). However, larger salmon such as Chinook adapt to higher flow conditions by building larger deeper redds in larger substrate relative to smaller salmon (Quinn 2005). Under drought conditions when access into smaller tributaries is blocked, coho salmon will spawn in larger numbers of main stem rivers (Lestelle 2007). In addition, they have been observed to spawn in significant numbers in main stem rivers where hatcheries are located in close proximity to the river downstream of a dam (McPherson and Cramer 1981, Brown and Moyle 1994, Lestelle 2007).

We presented calculations of redd scour potential in the Klamath main stem in Tech Memo 8 only to illustrate the general mechanism (scour) that biologists and geomorphologists have ascribed to the cause for few coho spawning in large channels. We asked our fisheries hydrologist on the consultant team, Dr. Martin Fox, to review the USFS Trinity scour report as it relates to his analysis that we reported in Tech Memo 8. He found that the USFS report was thorough and provided evidence that refuted some of the specific assumptions he had made. However, to account for uncertainty in his assumptions about the process of gravel scour, he had assumed a large diameter (2 inches) of gravel as the median size used by coho. Dr. Fox revised his assumptions and calculations to be congruent with information presented by May et al. (2007). As a prelude to those new calculations, he offered the following perspective:

> *"I am in full agreement that salmon often spawn in locations less vulnerable to scour if available. Roughness elements such as wood can form pools and subsequent tail-out habitats, where shear stress is often lower in these habitats than in riffles. However, regulated rivers often lack roughness elements such as large wood and subsequently may not offer optimal spawning locations for all salmon. Furthermore, optimal gravel sizes are needed for successful redd excavation and incubation, which often dictates spawning locations, as do other features such as cover, upwelling groundwater, shade, and other features. As a result, a proportion of spawning will also occur in main-stem riffle reaches unprotected in the channel margins and subsequently are vulnerable to scour. This is the case in most other systems as well, and there is no information that suggests Klamath offers a greater proportion of protective habitats for spawning, particularly for coho.*

> *Thus, using a reach-average shear stress to predict scour is reasonable as well as prudent in assessing egg mortality during incubation."*

May et al. (2007) suggests that the Shield's parameter must be greater than 0.06 for scour to occur to Chinook redds. This value was based on the use of tracer stones of 64 mm (~2.5 inches) in diameter. While this may be a common particle size for Chinook, coho typically spawn in gravels of smaller median diameter such as 1 inch and even down to ½ inch (Schuett-Hames et al. 1999). Therefore, the Shield's parameter of 0.06 may be too high for determining the point of full scour to coho egg pockets. Furthermore, coho egg pocket depths are smaller than Chinook, thus the 30 cm referenced for Chinook egg pockets may not be representative of the depth that scour can occur for coho. Chinook egg pocket bottom depths reported by Evenson (2001) in the Trinity River were 30 cm, where the top of the egg pocket is typically around 15 cm based on the work of DeVries (1997). DeVries cites 20 cm as the mean depth of coho egg pockets, and suggests that loss of eggs from Chinook salmon redds will begin when scour reaches 15 cm. If scour were to expose the top of the egg pocket, mortality to the eggs is likely to occur through factors other than direct scour (e.g. predation, solar exposure, percussion from bedload entrainment, etc.). Certainly, if scour to 15 cm will impact Chinook redds, it will likely have a greater impact to the typically more shallow egg pocket of coho redds. Based on 1) the fact that coho will often utilize smaller gravels than Chinook in which to spawn, 2) the depth of scour to impact the egg pocket in coho is much shallower than the 30 cm described for Chinook in May et al. (2007), I recommend looking at a Shield's parameters of 0.04 in addition to 0.06. Indeed, Fig 14b of May et al. (2007) suggests that the Shields parameter for approximately 20 cm of scour (coho) is near 0.04.

Using a D_{50} of one-inch spawning gravel diameter as the particle of interest and re-calculating the Shield's equation with Shield's parameters of 0.03 (initial particle movement), 0.04 (partial particle movement) and 0.06 (complete particle movement), one can evaluate the ranges of potential conditions in which scour to coho redds can occur (Figure 1). The number of days having discharges high enough to achieve these three levels of redd scour during the incubation period (12/1 to 3/15) within the water year (Oct 1 to Sept. 30) over the period of record is depicted in Figure 2. Although the Klamath River cross sections used in these calculations do not represent all sites in which coho might spawn, the calculations illustrate why large mainstem environments are not a typical spawning location for coho salmon; there is a substantial risk of egg scour in the hydraulic environment of large rivers.

Further, actual measurements of conditions where coho redds were found in the Klamath main stem showed that the coho spawned in depths and velocities at or above the upper end of their preferred habitat range:

"Based on the limited data collected from these surveys, coho salmon that spawn in the main stem of the Klamath River build larger redds in deeper water than coho salmon found in other rivers. Main stem Klamath River coho salmon also build redds where water velocity is near or above the upper end of the preferred range." (Magneson and Gough 2006).

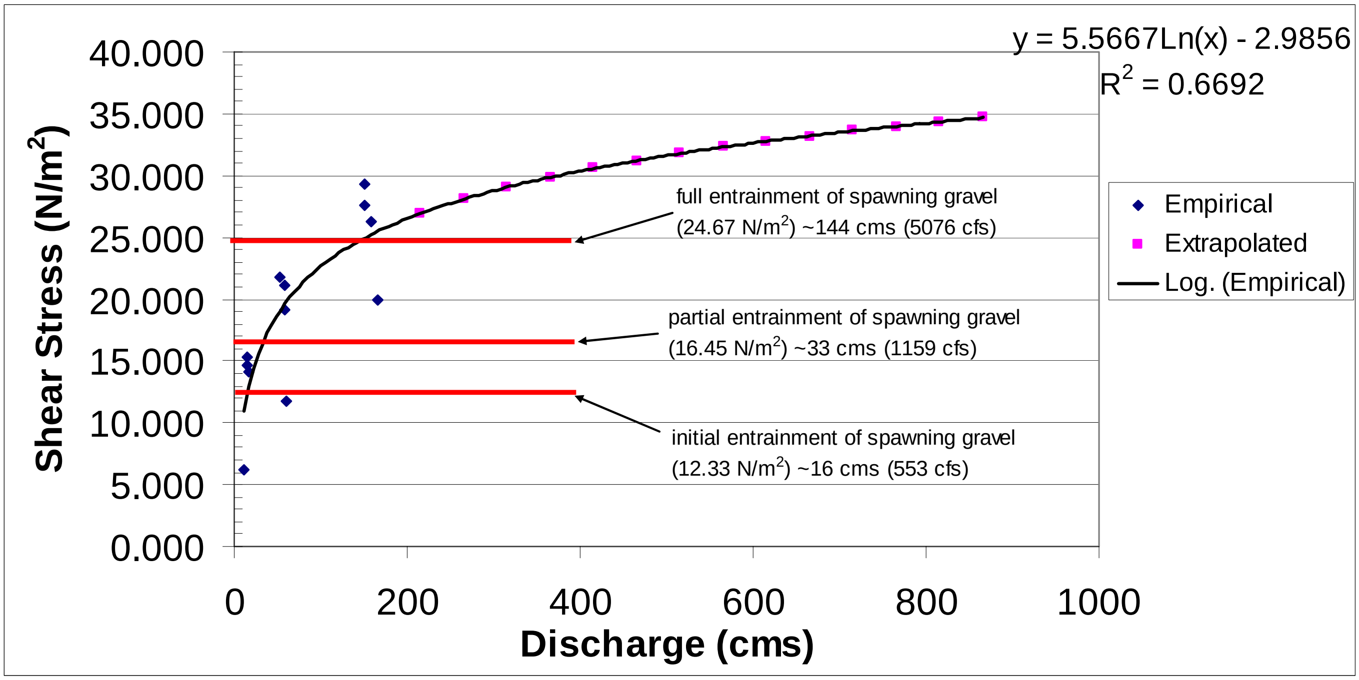


Figure 1. The relationship of shear stress to discharge based on channel geometry at four cross-sections (empirical). The extrapolated data extends to approximately the highest flow observed during the period of record (29,400 cfs WY 1964), which is approximately a 50-year flood. The red bars indicate levels of potential scour to the egg pocket of coho based on Shield's parameters of 0.06 (full entrainment), 0.04 (partial entrainment), and 0.03 (initial entrainment).

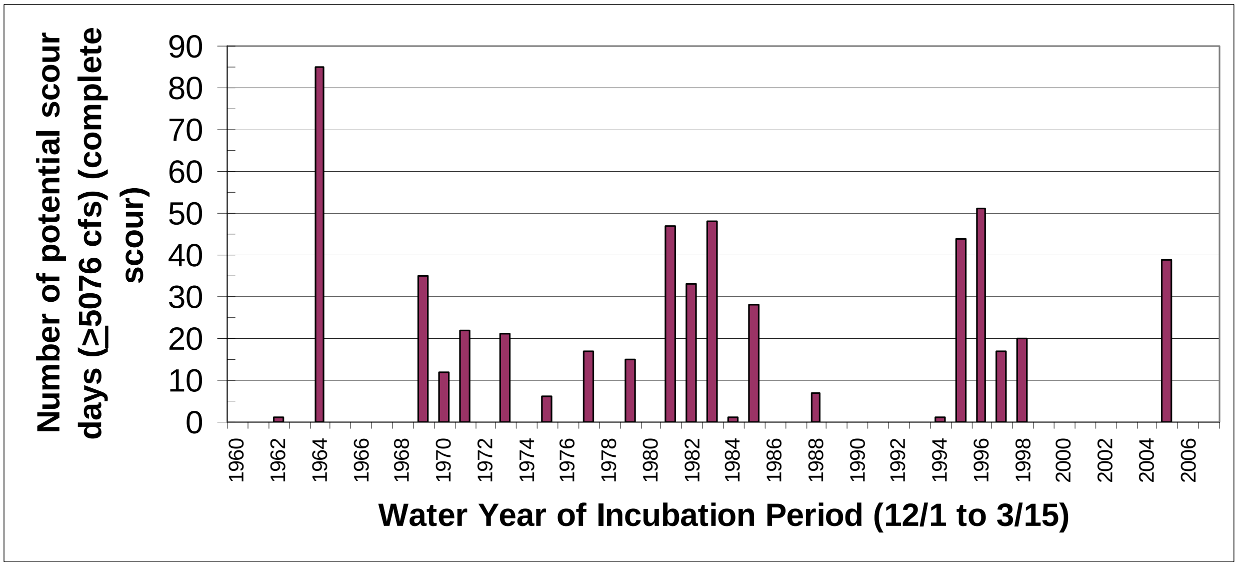


Figure 2. The number of water-year days having discharges that will cause complete scour to coho spawning gravels (a one-inch median grain diameter) during the incubation period.

All of these limitations lead to the same conclusion we reached in Tech Memo 8; coho spawning in the main stem Klamath River may work for a few years in sequence, but is not sustainable over the long term.

Movement of Fry and Parr from Shasta and Scott Rivers

Commenters asked us to back calculate the number of fry and parr migrants from the Shasta and Scott Rivers using the proposed equation to evaluate the performance of this methodology. As a result of this analysis, we revised our methods to simulate migrant fry and parr from the Shasta River.

We applied the equations in Technical Memorandum 8, to predict the number of migrant fry and parr leaving the Shasta and Scott Rivers. The equation in Tech Memo 8 Figure 10 for predicting the number of fry migrants was incorrect and should read: $y = 549.28\ \mathrm{km}^{-0.5972}$. Estimates of age 0 juvenile coho migrations were available for the Shasta River in 2004-2006, and for the Scott River in 2005-2006 (Chesney et al. 2007, Bill Chesney, personal communication). These predictions are based on the number of female spawners the previous year. Annual estimates of the number of spawners were available for the Shasta River for 2003-2005 (Hampton 2004-2006). Spawner estimates were not available for the Scott River, but redds are counted there annually (Quigley 2005-2006). We used methodology described in Technical Memorandum 1 “Estimation of Returns of Naturally Produced Coho to the Klamath River” to expand annual redd counts to an approximate range of spawners for the Scott River in 2004 and 2005. The results of applying these spawner abundances to prediction of age 0 migrants are given in Table 1.

Table 1. Predicted versus observed numbers of age 0 coho salmon migrating from the Shasta and Scott Rivers.

Brood			Predicted age-0 migrants			Observed age-0 migrants		
year	Adults	Females	fry	parr	smolt	fry	parr	Smolt
Shasta River = 119 km habitat								
2003	187	103	2,959	7,660	2,581	42	460	633
2004	373	205	5,901	15,279	4,714	3,121	9,411	3,049
2005	69	38	1,092	2,826	1,227	33	367	470
Scott River = 340 km habitat								
2004	2,000-3,000	1,100-1,700	18,595-28,737	48,141-74,400	NA	22,482	58,016	NA
2005	30-120	15-70	254-1,183	656-3,064	NA	436	1,364	NA
Revised Shasta River ($\mathrm{fry} = 6.065 * e^{0.0285 * \mathrm{females}}$)								
2003	187	103	114	294	518	42	460	633
2004	373	205	2,099	5,435	1,958	3,121	9,411	3,049
2005	69	38	18	46	449	33	367	470

The methods described in Technical Memorandum 8 accurately predicted the number of fry and parr migrating from the Scott River, but consistently overestimated migrants from the Shasta River (Table 1). In addition, stream diversions have resulted in a loss of suitable habitat and displacement of rearing coho salmon from the lower Shasta River, such that most spawning is believed to be near the upper accessible portion of the basin (Chesney et al. 2007). Although the Scott River has reduced water quality during the summer, it has more tributaries spaced through the basin that produce coho than the Shasta River. Thus, we reason that the over prediction of fry and parr migrants in the Shasta River is a result of conditions unique to that drainage.

We reanalyzed the Shasta River data to provide a better means to simulate fry movement out of this system. The number of migrant fry generated from up to 100 female spawners is very low, but then increases exponentially with increasing spawners (Figure 3). The equation resulting from fitting the data on fry abundance to a power function of spawner abundance is:

$$\text{Migrant fry} = 6.065 * e^{\,0.0285*\text{females}}$$

This equation better predicted the number of age 0 migrants from the Shasta River (Table 1); however, there were only three data points to fit a relationship with. We will review this relationship annually, and update the equation as additional data becomes available.

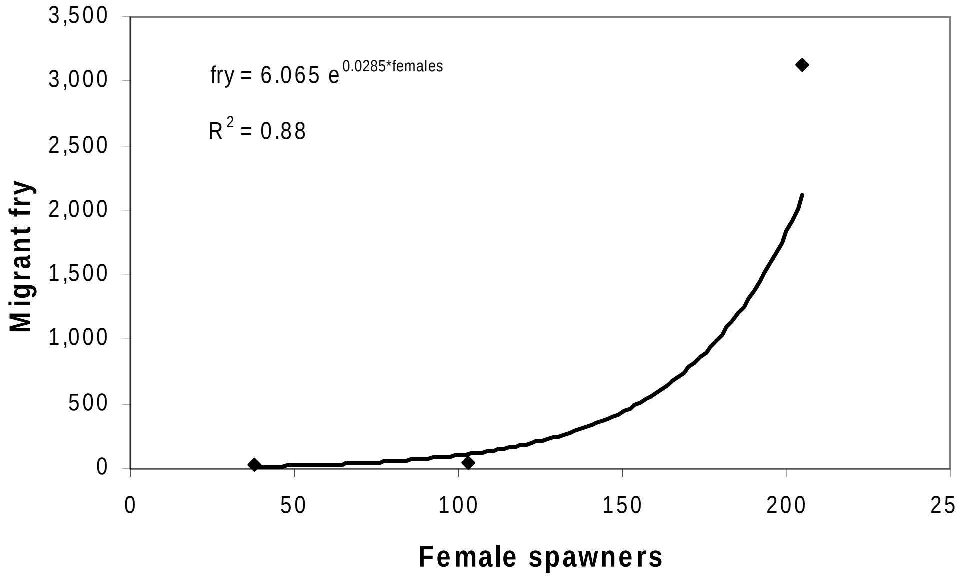


Figure 3. Relationship between migrant fry and female spawners in the Shasta River, brood years 2003 to 2005.

Summer redistribution of juveniles into non-natal tributaries

Commenters suggested that movement of fry and parr should not be limited by distance (either up or downstream) but by gradient.

We agree that fry and parr are free to move wherever they are able. The life cycle model is not designed to predict individual behaviors, but rather to track the predominant behaviors represented by the majority of fish. The intention of modeling is to predict the average expected outcome of coho population trends in response to different management scenarios, particularly management of flows in the main-stem Klamath River.

We found no data that clearly establish limitations on summer movement of juvenile coho moving up tributaries. Commenters cited some data with other species and some regarding fall migrations of coho. Fall migrations are made by larger fish and at cooler temperatures than would be true for juveniles moving into tributaries during early summer, so it could be misleading to assume that observed behaviors during fall migration can be applied to summer migration up tributaries.

The best observations we found for summer movement up tributaries were for juvenile spring Chinook. Lindsay et al. (1986) found that the average upstream limit of juvenile Chinook salmon in 30 tributaries of the John Day River was 1.9 km (range 0-12 km). As cited in Tech Memo 8, we have observed juvenile chinook moving up to 0.5 km up cool tributaries of the lower Rogue River where access was fully open for further upstream movement. In the Klamath River main stem, only a few of the thermal refugia have consistently been observed to hold juvenile coho. The thermal refuges created by Beaver Creek and Tom Martin Creek have consistently held the most juvenile coho, and both are near source streams known to produce coho (Sutton 2007). Other thermal refugia distant from coho source streams (e.g. Elk Creek and Red Cap Creek) are not utilized by juvenile coho (Benson and Holt 2006, Karuk unpublished report).

References Cited

Behnke, R. J. 2002. Trout and salmon of North America. Free Press, Simon and Shuster, Inc. New York, NY.

Benson, R.L., and J.E. Holt. 2006. Daytime use of the Red Cap Creek thermal refuge by juvenile steelhead and Chinook salmon in the Klamath River, August 2005. Yurok Tribal Fisheries Program Technical Report KR-06-01. Klamath, CA.

Bernard, D.R., J.J. Hasbrouck, and S.J. Fleischman. 1999. Handling-induced delay and downstream movement of adult Chinook salmon in rivers. Fisheries Research. 44(1):37-46.

Brown, L. R., and P. B. Moyle. 1991. Status of coho salmon in California. Report to the National Marine Fisheries Service. Department of Wildlife and Fisheries Biology, University of California, Davis, CA

Chesney, W.R., B. J. Cook, W. B. Crombie, H. D. Langendorf, and J. M. Reader. 2007. Shasta and Scott River juvenile salmonid outmigration study, 2006. Annual Report. California Department of Fish and Game.

DeVries, P. 1997. Riverine salmonid egg burial depths: Review of published data and implications for scour studies. Can. J. Fish. Aquat. Sci. 54:1685-1698.

Edie, B. G. 1975. A census of juvenile salmonids of the Clearwater River basin, Jefferson County, Washington, in relation to logging. Master’s Thesis. University of Washington, Seattle, WA.

Hampton, M. 1988. Development of habitat preference criteria for anadromous salmonids of the Trinity River. U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, CA.

Evenson D.F. 2001. Egg pocket depth and particle size compostion within Chinook salmon redds in the Trinity River, California. M.S. thesis, Humboldt State University, CA.

Hampton, M. 2004. Shasta River Fish Counting Facility, Chinook and coho salmon observations in 2003, Siskiyou County, CA. California Department of Fish and Game. Northern California Coast – North Coast Region. Yreka, CA.

Hampton, M. 2005. Shasta River Fish Counting Facility, Chinook and coho salmon observations in 2004, Siskiyou County, CA. California Department of Fish and Game. Northern California Coast – North Coast Region. Yreka, CA.

Hampton, M. 2006. Shasta River Fish Counting Facility, Chinook and coho salmon observations in 2005, Siskiyou County, CA. California Department of Fish and Game. Northern California Coast – North Coast Region. Yreka, CA.

Karuk. *unpublished*. Coho salmon in Klamath River thermal refugia, three years of observations. Draft report. Karuk Tribe.

Lestelle, L. 2007. A review of coho salmon (*Oncorhynchus kisutch*) life history patterns in the Pacific Northwest and California. Prepared for the U.S. Bureau of Reclamation, Klamath Basin Area Office. Prepared by Biostream Environmental, Poulsbo, WA.

Lichatowich, J. 1999. Salmon without rivers – A history of the Pacific salmon crisis. Island Press, Washington D.C., Covelo, CA.

Lindsay, R.B., W. J. Knox, M.W. Flesher, B.J. Smith, E.A. Olsen, and L.S. Lutz. 1986. Study of wild spring Chinook salmon in the John Day River system. ODFW report. Portland, OR.

Magneson, M. D., and S. A. Gough. 2006. Mainstem Klamath River coho salmon redd surveys 2001 to 2005. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report DS 2006-07, Arcata, California.

May, C.L., B. Pryor, T.E. Lisle, T., and M.M. Lang. 2007. Assessing the Risk of Redd Scour on the Trinity River. Final Report Submitted to the Trinity River Restoration Program. U.S. Forest Service, Pacific Southwest Research Station, Arcata, CA

Moyle, P. B. 2002. Inland fishes of California. University of California Press, Berkeley, CA.

McPherson, B. P., and S. P. Cramer. 1981. Rogue basin evaluation program, juvenile salmonids studies. Oregon Department of Fish and Wildlife, Progress Report, Fish Research Project DACW57-77-C-0027, Portland, OR.

North Coast Regional Water Quality Control Board. 2006. Action plan for the Shasta River watershed temperature and dissolved oxygen total maximum daily loads. Available at http://www.swrcb.ca.gov/rwqcb1/programs/tmdl/shasta/060707/FinalShastaTMDLActionPlan.pdf

Quigley, D. 2005. Scott River watershed adult coho spawning ground surveys, November 2004 – January 2005. Prepared by the Siskiyou RCD for the U.S. Fish and Wildlife Service and California Department of Fish and Game.

Quigley, D. 2006. Scott River watershed adult coho spawning ground surveys, November 2005 – January 2006. Prepared by the Siskiyou RCD for the U.S. Fish and Wildlife Service and California Department of Fish and Game.

Schuett-Hames, D., R. Conrad, A. Pleus, and M. McHenry. 1999. TFW Monitoring Program method manual for the salmonid spawning gravel composition survey. Prepared for the Washington State Dept. o Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-001. DNR #101. March.

Strange, J. 2006. River entry and migration behavior of adult coho in the Klamath River Basin: 2004 Radio Telemetry Study. Final Progress Report. Yurok Tribal Fisheries Program. 47 p.

Strange, J. 2007. Adult Chinook salmon migration in the Klamath River Basin: 2006 Telemetry Study Draft Report. Yurok Tribal Fisheries Program. University of Washington, School of Aquatic and Fishery Sciences. Hoopa Valley Tribal Fisheries. 87 p.

Sutton, R. 2007. Klamath River thermal refugia study, 2006. U.S. Bureau of Reclamation, Mid-Pacific Region, Technical Memorandum No. 86-68290-01-07, Klamath Falls, CA.