Prepared in cooperation with the Bureau of Reclamation

Summary of Survival Data from Juvenile Coho Salmon in the Klamath River, Northern California, 2007

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U.S. Department of the Interior
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Cover: Photograph of Klamath River looking downstream near its confluence with the Salmon River, northern California. (Photograph taken by John W. Beeman, U. S. Geological Survey, April 11, 2007).

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Summary of Survival Data from Juvenile Coho Salmon in the Klamath River, Northern California, 2007

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Abstract

A study to estimate the effects of Iron Gate Dam discharge on ESA-listed juvenile coho salmon during their seaward migration to the ocean was begun in 2005. Estimates of survival through various reaches of river downstream from the dam were completed in 2006 and 2007 as part of this process. This report describes the estimates of survival during 2007, and is a complement to a similar report from 2006. Further analyses will be included in a separate report. In 2007, a series of models were evaluated to determine what survival and capture probabilities of radio-tagged hatchery fish were in several reaches between Iron Gate Hatchery at river kilometer 309 and a site at river kilometer 33. The results indicate trends in survival among reaches were similar to those found in 2006, but the survival in 2007 was lower than in 2006. The differences in survivals from Iron Gate Hatchery to river kilometer 33 in 2006 (0.653 SE 0.039) and 2007 (0.497 SE 0.044) were caused primarily by differences in survivals upstream from the Scott River. This document is a brief summary of 2007 survival results.

Introduction

In 2006, the U.S. Geological Survey (USGS) entered into a cooperative study to estimate the effects of Iron Gate Dam discharge on survival on juvenile coho salmon (*Oncorhynchus kisutch*) in the lower Klamath River, northern California. The purpose of the study was to provide information about the relation between survival of juvenile coho salmon and river discharge in the Klamath River downstream from Iron Gate Dam (river kilometer [rkm] 310). The study fish were part of the Southern Oregon Northern California Coasts Evolutionary Significant Unit of coho salmon listed under the Endangered Species Act in 1997. In 2006, both hatchery and wild fish were used, but in 2007, wild fish numbers were low and only hatchery fish were used. The study was a collaboration among the USGS and, listed in alphabetical order, the Karuk Tribe of California, the U.S. Fish and Wildlife Service, and the Yurok Tribe. Funding was from the Bureau of Reclamation, Klamath Basin Area Office. This is a brief report of results from the 2007 study to date and is a complement of a similar report describing survival estimates in 2006 (Beeman, 2007). The methods and design of the study in 2007 were similar to those used in 2006, and are briefly described below.

The study design in both years was based on a need to estimate apparent survivals of radio-tagged juvenile coho salmon in the Klamath River downstream from Iron Gate Dam using paired-release and single-release methods; both are based on Cormack-Jolly-Seber capture-mark-recapture models (Cormack, 1964; Jolly, 1965; Seber, 1965). Apparent survival is the probability that an animal remains available for recapture. In the context of this study, it is the joint probability that the animal is both alive and migrates through the study area. As such, fish that stop migrating, or travel to areas outside the mainstem Klamath River and do not return during the study are counted as mortalities. All references to ‘survival’ in this document refer to apparent survival.

In 2007 (April 10 to May 18), we released radio-tagged juvenile coho salmon of hatchery origin separated into treatment and control experimental groups. The radio tags used weighed 0.43 grams in air and had dimensions of 13.5 mm length, 5.3 mm width, and 3.3 mm height and had a 16 cm long trailing antenna. The treatment fish were released into the Klamath River at the hatchery (rkm 309) and the control fish were released into Klamath River at the Trees of Heaven campground (rkm 280; fig. 1). The control group release site was moved from mouth of the Shasta River (rkm 288) used in 2006 due to concerns about the potential for high water temperatures at that site to affect the survival of fish tagged late in the study period.

The purpose of the two experimental groups was to enable us to estimate survival of fish in the Klamath River from Iron Gate Hatchery to the Trees of Heaven site without the potential effects of latent tagging and handling mortality. The paired-release design permits this and is described in detail in Burnham and others (1987). Latent mortality from tagging and handling, if present and expressed shortly after release, is included in overall mortality in other designs, and can result in an overestimate of the mortality associated with the treatment of interest. This design was used in 2007 to be consistent with the 2006 study, despite the lack of evidence of tagging and handling effects from the 2006 study.

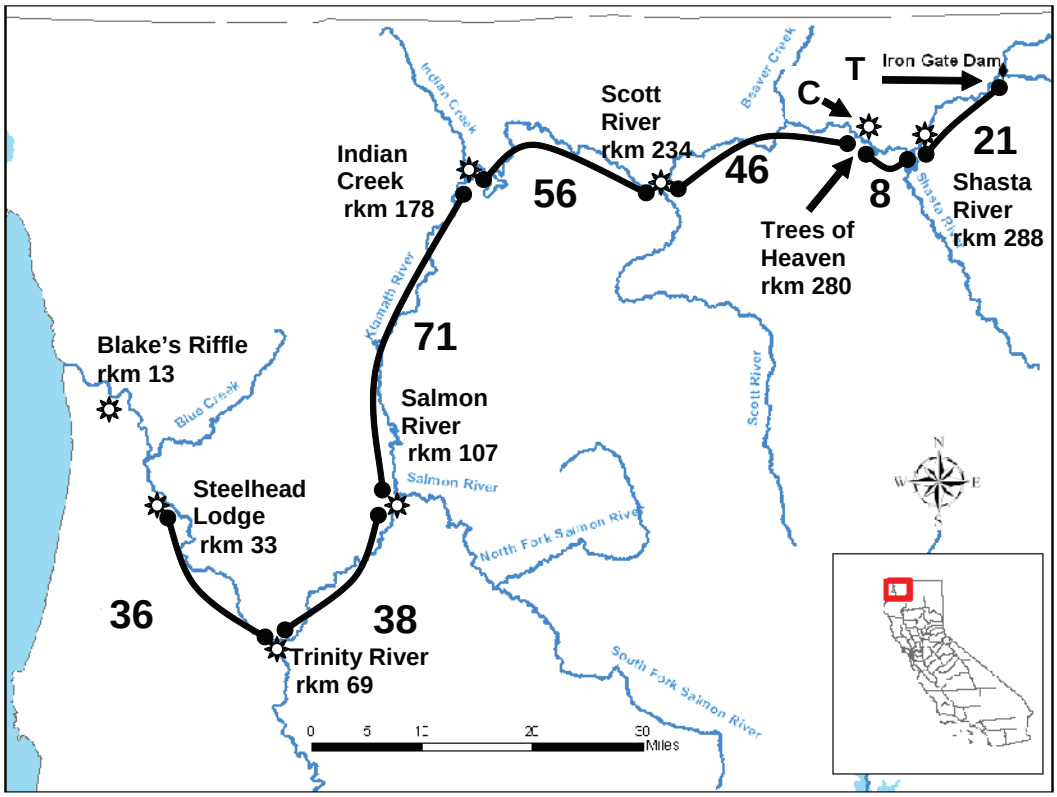

Figure 1. Study area of the Klamath River juvenile coho salmon survival study, northern California, 2007. Locations of treatment (T) and control (C) releases are indicated by arrows and detection sites are indicated by ☼. Bold numbers indicate the lengths of each reach in kilometers. Figure modified from U.S. Fish and Wildlife Service, Arcata, California, 2006.

Survival of Juvenile Coho Salmon from Iron Gate Hatchery to Trees of Heaven

Estimates of survival in this reach were the goal of the paired-release design, but they were not calculated in 2007 due to violations of model assumptions. One of the assumptions in this model is that treatment and control fish experience the same mortality factors in the common reach, which was from Trees of Heaven to the Scott River site (rkm 234) in 2007. This is generally met by altering release times of the two groups so their migration through the common reach occurs during a similar time period, or by having similar mortality factors during the different times the groups are in the reach. Neither of these conditions was met in 2007. Differences in timing and survivals through the common reach were evident. Thus, the paired-release model could not be used with these data, though it was appropriate during the 2006 study. The survivals of treatment and control groups through the various reaches in 2007 were therefore estimated using the single-release model.

Survival of Juvenile Coho Salmon through River Reaches

Survival through each reach and over multiple reaches was estimated using the single-release design. The modeling approach was similar to that used in 2006. A series of models was created and ordered in terms of parsimony using the program MARK (White and Burnham, 1999). The analysis included a suite of models describing capture probabilities and survival of fish from the two experimental groups in each of the common reaches. The models were ranked using a variant of the Akaike Information Criterion that accounts for small sample sizes (AICc) to determine which models were best supported by the data. The general methods are described in Burnham and Anderson (1998). An assessment of the presence of overdispersion was not applied to the data, because the capture probabilities were near 1.0 and thus, overdispersion should be minimal and cannot be estimated.

A single model allowing survivals to vary between groups and among reaches was the most supported of the set evaluated (table 1). The model was based on a common capture probability of groups among sites (0.975 Standard Error [SE] 0.007), which was by far the most supported description of capture probabilities, though capture probability analyses are not discussed here. The most supported model of survival, model #1 in table 1, was based on a multiplicative effect of group and reach. It received 99% of the AICc weight, indicating that the other models were virtually unsupported by the data. This appeared to be due to the similarity of survivals of control (0.589 SE 0.045) and treatment (0.578 SE 0.044) groups from release to the Scott River site, and the disparity between these groups in subsequent reaches. This model received 991 times more support from the data than a similar model without a group effect (AICc weight of model #1 divided by that of model #3), indicating little model selection uncertainty and strong support for a difference between survivals of treatment and control groups in common reaches. This type of comparison, described as an "evidence ratio" by Burnham and Anderson (1998), is a measure of the strength of evidence of competing hypotheses given the data and the models. The multiplicative model of group and site also received 124 times more weight than an additive model with the same factors (model #1 vs. model #2). We chose to report survivals of treatment and control groups for each reach separately based on the weight of evidence for differences between them. Results from the control group were taken from the most supported model in table 1. A separate suite of models was used to estimate survivals and capture probabilities of treatment fish so that the hatchery to Shasta River and Shasta River to Trees of Heaven reaches could be included, as the control fish did not travel through these reaches. In this suite, the most supported model received over 99% of the AICc weight (table 2). This model allowed survival to vary among reaches and included a common capture probability among sites (0.983 SE 0.006).

Table 1. Model summary from analyses of apparent survival (Phi) and capture probabilities (P) to estimate reach survivals of treatment and control hatchery coho salmon from all release dates.

[Models are based on data from 246 hatchery fish released from April 10 through May 18, 2007. Model descriptions include factors allowed to vary within Phi and P, including reach and group (treatment or control). Rankings are based on AICc, a modification of Akaike Information Criterion for small samples. A '+' between factors indicates an additive effect. A '.' indicates a no effect (a single value fitted to all observations). The global model includes multiplicative effects of all factors]

Model number	Model	AICc	Delta AICc	AICc weights	Model likelihood	Number of parameters	Deviance
1	{Phi(Group*Reach),P(.)}	790.953	0.000	0.991	1.000	12	79.702
2	{Phi(Group+Reach),P(.)}	800.494	9.542	0.008	0.009	8	97.457
3	{Phi(Reach),P(.)}	804.846	13.893	0.001	0.001	7	103.849
4	{global model}	809.206	18.253	0.000	0.000	22	77.055
5	{Phi(Group),P(.)}	914.592	123.639	0.000	0.000	3	221.705

Table 2. Model summary from analyses of apparent survival (Phi) and capture probabilities (P) to estimate reach survivals of hatchery coho salmon from the treatment group from all release dates.

[Models are based on data from 123 hatchery fish released from April 10 through May 16, 2007. Model descriptions include those in which apparent Phi and P may vary among reaches (Reach) and those in which a single value is assumed for them all (".”). Rankings are based on AICc, a modification of Akaike Information Criterion for small samples. The global model includes multiplicative effects of all factors]

Model number	Model	AICc	Delta AICc	AICc weights	Model likelihood	Number of parameters	Deviance
1	{Phi(Reach), P(.)}	481.967	0.000	0.996	1.000	8	55.569
2	{Phi(Reach), P(Reach)}	493.491	11.524	0.003	0.003	14	54.636
3	{global model}	495.591	13.625	0.001	0.001	15	54.636
4	{Phi(.),P(.)}	515.605	33.639	0.000	0.000	2	101.424

The survivals of treatment fish were greater than those of control fish in the reaches they had in common during 2007 (table 3). As in 2006, survivals of both groups were lower in the upper reaches than in the lower reaches. The survival of treatment fish in the Trees of Heaven to Scott River reach was 0.814 (SE 0.042) and that of the control group was 0.589 (SE 0.045), indicating a clear difference between their survivals in the first reach they had in common. Survival of treatment fish from Iron Gate Hatchery to Steelhead Lodge was 0.497 (SE 0.44). Survival from Trees of Heaven to Steelhead Lodge was 0.700 (SE 0.058) for treatment fish and 0.301 (SE 0.041) for control fish. The survival from Iron Gate Hatchery to Steelhead Lodge in 2006 was 0.653 (SE 0.039; treatment and control fish from wild and hatchery origins were pooled for this estimate in 2006 due to their similarity; results have been updated from the 0.684 value cited in Beeman, 2007).

Table 3. Estimated apparent survivals and profile likelihood confidence intervals of radio-tagged juvenile coho salmon in study reaches of the Klamath River during spring 2007.

[Results are based on data from 123 hatchery fish released near Iron Gate Hatchery (the treatment group) and 123 hatchery fish released near Trees of Heaven campground (the control group) from April 10 through May 18, 2007. Results from the Iron Gate Hatchery release site are based on the top model in table 2 and those for the Trees of Heaven release site are based on the top model in table 1. Data over multiple reaches was calculated as the product of the reach estimates with variance estimated using the delta method (Seber, 1982)]

Reach number	Description	Reach length (km)	Apparent survival	Standard error	95% confidence interval	
					Lower	Upper
Release Site = Iron Gate Hatchery (rkm 309)						
1	Hatchery to Shasta River (rkm 288)	21	0.773	0.038	0.694	0.842
2	Shasta River to Trees of Heaven (rkm 280)	8	0.917	0.029	0.849	0.963
3	Trees of Heaven to Scott River (rkm 234)	46	0.814	0.042	0.723	0.887
4	Scott River to Indian Creek (rkm 178)	56	0.959	0.024	0.894	0.991
5	Indian Creek to Salmon River (rkm 107)	71	0.910	0.035	0.827	0.963
6	Salmon River to Trinity River (rkm 69)	38	1.000	4.03E-06	0.969	1.000
7	Trinity River to Steelhead Lodge (rkm 33)	36	0.986	0.016	0.932	1.000
	Hatchery to Steelhead Lodge	276	0.497	0.044	0.410	0.584
	Trees of Heaven to Steelhead Lodge	247	0.700	0.058	0.586	0.814
Release Site = Trees of Heaven (rkm 280)						
3	Trees of Heaven to Scott River (rkm 234)	46	0.589	0.045	0.500	0.674
4	Scott River to Indian Creek (rkm 178)	56	0.778	0.050	0.671	0.865
5	Indian Creek to Salmon River (rkm 107)	71	0.765	0.057	0.642	0.864
6	Salmon River to Trinity River (rkm 69)	38	0.930	0.040	0.827	0.984
7	Trinity River to Steelhead Lodge (rkm 33)	36	0.925	0.043	0.814	0.982
	Trees of Heaven to Steelhead Lodge	247	0.301	0.041	0.220	0.382

Summary

Estimates of survival in 2006 and 2007 had some similarities and some differences. The trend of lower survival in upper reaches than in lower reaches was common in 2006 and 2007 studies. The survival of radio-tagged juvenile coho salmon in the Klamath River downstream from Iron Gate Dam in 2007 was lower in fish held and released at Trees of Heaven than those held and released near Iron Gate Hatchery. The reasons for this are unknown at this time, but will be investigated by examining migration rates of the groups, the prevalence of disease organisms in the holding and release areas, and other biotic and abiotic factors. The survivals from Iron Gate Hatchery to Steelhead Lodge were lower in 2007 (0.497 SE 0.044) than in 2006 (0.653 SE 0.039), caused primarily by differences in survivals upstream from the Scott River.

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