Prepared in cooperation with the Bureau of Reclamation

Summary of Survival Data from Juvenile Coho Salmon in the Klamath River, Northern California, 2008

Open-File Report 2009-1019

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photograph of the Klamath River looking downstream near its confluence with the Salmon River, northern California. (Photograph taken by Steven Juhnke, U.S. Geological Survey, Cook, Washington, March 20, 2008).

Summary of Survival Data from Juvenile Coho Salmon in the Klamath River, Northern California, 2008

By John W. Beeman, Steven Juhnke, and Hal C. Hansel

Prepared in cooperation with the
Bureau of Reclamation

Open-File Report 2009–1019

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Beeman, J.W., Juhnke, Steven, Hansel, H.C., 2009, Summary of survival data from juvenile coho salmon in the Klamath River, northern California, 2008: U.S. Geological Survey Open-File Report 2009-1019, 6 p.

Contents

Figures

Tables

Conversion Factors

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
kilometer (km)	0.6214	mile (mi)
gram (g)	0.03527	ounce, avoirdupois (oz)

This page left intentionally blank

Summary of Survival Data from Juvenile Coho Salmon in the Klamath River, Northern California, 2008

By John W. Beeman, Steven Juhnke, and Hal C. Hansel

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, 2007, and 2008 as part of this process. This report describes the estimates of survival during 2008, and is a complement to similar reports from 2006 and 2007. In each year, a series of models were evaluated to determine apparent survival and recapture probabilities of radio-tagged fish in several river reaches between Iron Gate Hatchery at river kilometer 309 and a site at river kilometer 33. These results indicate most trends in survival among reaches were similar to those from 2006 and 2007, but the magnitudes of the estimated survivals were lower in 2008. The differences in survivals from Iron Gate Hatchery to river kilometer 33 in 2006 (0.653 SE 0.039), 2007 (0.497 SE 0.044), and 2008 (0.406 SE 0.032) were caused primarily by differences in survival upstream from the Scott River. This report is intended as a brief description of the survivals estimated from the fish released in 2008 to be used by others interested in the data.

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, hatchery and wild fish were used, but in 2007 and 2008, wild juvenile coho numbers were low and only hatchery fish were used. This multi-year study is 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 2008 study to date and is a complement to similar reports describing survival estimates in 2006 and 2007 (Beeman, 2007, 2008). The design and methods of the studies were similar in each year, and are briefly described below.

The study design was based on a need to estimate apparent survival probabilities of juvenile coho salmon in the Klamath River downstream from Iron Gate Dam using paired-release and single-release methods (Burnham and others, 1987); 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 within the study area, travel to areas outside the mainstem Klamath River and do not return, or those that remain within the study area after the radio tags deplete their battery and cease transmitting are counted as mortalities. All references to 'survival' in this document refer to apparent survival. Survival was estimated through all but the last of eight river reaches delineated by telemetry receiving equipment (fig. 1). Survival is not estimable in the last reach because only the joint probability of survival and recapture is known in the last reach in Cormack-Jolly-Seber models.

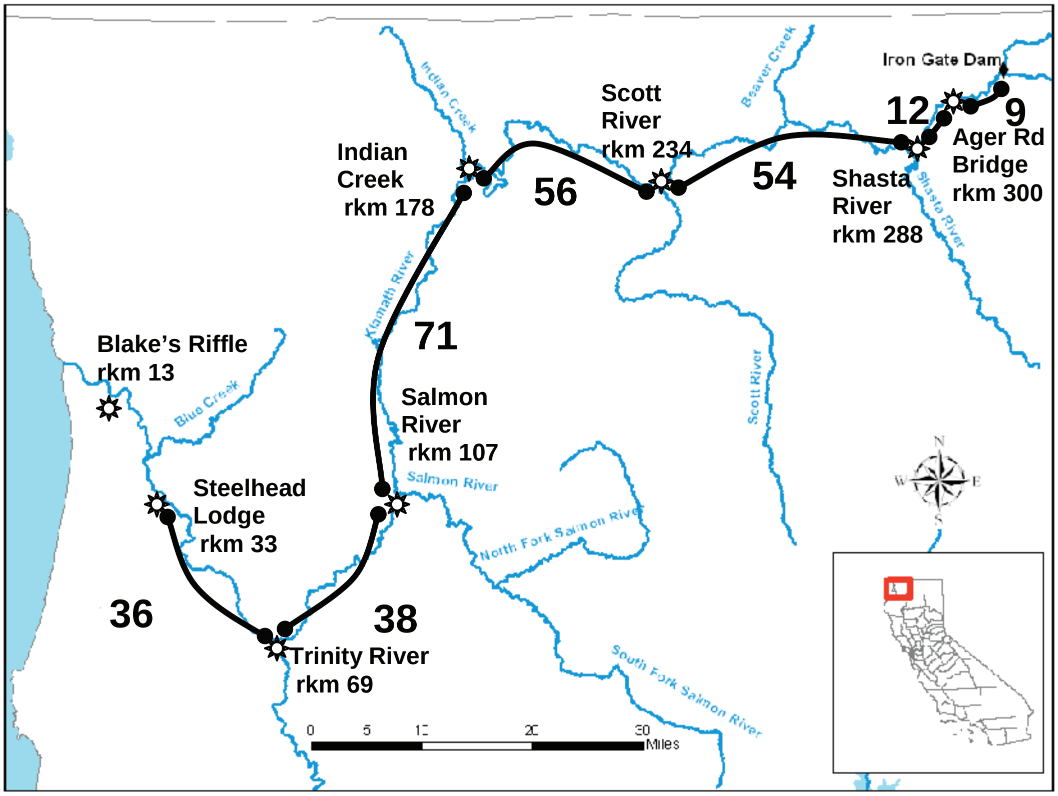

Figure 1. Study area of the Klamath River juvenile coho salmon survival study, northern California, 2008. Detection sites are indicated by ☼. Bold numbers indicate reach lengths in kilometers. Figure modified from U.S. Fish and Wildlife Service, Arcata, CA, 2006.

In 2008, we surgically implanted radio tags into juvenile coho salmon of hatchery origin from two sources. Most fish (n = 221 fish) were taken directly from a tank at the hatchery, but an additional group (n = 28 fish) were taken from the catch of a rotary trap located at rkm 293 operated by the U.S. Fish and Wildlife Service. The intent of the latter group was to determine if the migration behavior or survival of hatchery fish actively migrating downstream would be different from those taken directly from the hatchery. The basis of this question was the difference in migratory behaviors of hatchery-origin and wild-origin fish observed in 2006 (Beeman and others, 2007). The radio tags 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. All fish were released into the Klamath River near the hatchery (rkm 309) during several dates each week beginning on April 17, 2008, and ending on May 23, 2008. No fish were released downstream as in previous years due to differences in migratory behaviors and survivals of those released near the hatchery and those released near the Tree of Heaven campground (rkm 288) in 2007 (Beeman and others, 2008). Data were finalized several months after the last fish was released; the last fish detection was on June 24, 2008, but the tested radio transmitters lasted up to 91 days.

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 previous years. A series of a-priori models was created and ordered in terms of parsimony using program MARK (White and Burnham, 1999). The analysis included a suite of models describing recapture and survival probabilities of fish from the two groups in each of the common reaches. The models were ranked using a variant of Akaike's 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 (2002). An assessment of the presence of overdispersion was not applied to the data, because recapture probabilities were near 1.0 and thus, overdispersion could not be estimated and was believed to be minimal.

Estimates of survival were calculated after choosing the most parsimonious models for recapture and survival probabilities. All models of survival were based on a model of recapture probabilities varying by reach, which was supported by the data about twice as much as a model with additive effects of reach and group. The choice of either model of recapture probability was unimportant in terms of the estimates of survival or their variability, so the simpler model was used. The main difference between the models of recapture probabilities was caused by missing one of eight fish from the river trap group in one reach. Recapture probabilities ranged from 0.943 (SE 0.0.23) to 1.000 with an average of 0.988. A-priori models of survival included in the model set included the factors of group (hatchery tank or river trap) and river reach alone and in various combinations. Models 1 and 2 received 94.6 percent of the total AICc weight, indicating that the other models of survival were not supported by the data (table 1). Both models allowed survivals to vary among reaches and model 1 also allowed survivals to vary between groups. The similarity in the AICc weights of the two models indicate ambiguity in the importance of the group variable, which may have been affected by the small sample size of the river trap group. The survivals were therefore estimated after averaging all models in the set because there was no single model clearly superior to all others. In this procedure, the coefficients for each effect in each model are averaged across all models after weighting by the AICc weights (Burnham and Anderson, 2002).

Table 1. Model summary from analysis of apparent survival (Phi) and recapture probabilities (P) to estimate reach survivals of hatchery-origin juvenile coho salmon in study reaches of the Klamath River during spring 2008.

[Models are based on data from 221 fish from a tank at Iron Gate Hatchery and 28 fish taken from a rotary trap at Klamath River kilometer 293. All fish were released in the Klamath River near the hatchery between April 17 and May 23, 2008. Rankings are based on AICc, a modification of the Akaike's Information Criterion for small samples. A '+' between factors indicates an additive effect, a '*' between factors indicates a multiplicative effect, and a '.' indicates a single value fitted to all observations]

Model number	Model	AICc	Delta AICc	AICc weights	Model likelihood	Number of parameters	Deviance
1	{Phi(group+reach),P(reach)}	992.583	0.000	0.617	1.000	16	26.736
2	{Phi(reach),P(reach)}	993.838	1.255	0.329	0.534	15	30.046
3	{Phi(group*reach),P(reach)}	997.462	4.879	0.054	0.087	23	17.137
4	{Phi(group),P(reach)}	1,034.719	42.137	0.000	0.000	10	81.147
5	{Phi(.),P(reach)}	1,036.936	44.353	0.000	0.000	9	85.397

The model-averaged results indicate that the survivals were similar between groups, but varied among reaches. Survival estimates of the river trap group were consistently, albeit slightly, lower than those of the hatchery tank group (table 2). This is consistent with the similarity in AICc weights of models 1 and 2, and indicates ambiguity in the support for differences between the groups based on the data and models. Survival probabilities through the various reaches were lowest in the Shasta River-to-Scott River reach and highest in the Salmon River-to-Trinity River reach. The trends in survivals among the reaches were similar between groups and were similar to those from the previous years of study in all but one area (Beeman, 2007, 2008). The exception was upstream from the Scott River, where survivals were lower in 2007 and 2008 than in 2006. The estimates of survival between release and the Scott River from 2006, 2007, and 2008 (hatchery tank groups only) were 0.837 (SE 0.026), 0.577 (SE 0.045), and 0.538 (SE 0.032), respectively (Beeman, 2007, 2008).

Table 2. Estimated apparent survivals and confidence intervals of radio-tagged juvenile coho salmon of hatchery origin in study reaches of the Klamath River during spring 2008.

[Results are based on data from 221 fish from a tank at Iron Gate Hatchery and 28 fish taken from a rotary trap at Klamath River kilometer 293. All fish were released in the Klamath River near the hatchery between April 17 and May 23, 2008. Results are based on model-averaging the models in table 1. Data over multiple reaches were calculated as the product of the reach estimates with variances estimated using the delta method (Seber, 1982)]

Reach number	Description	Reach length (km)	Apparent survival	Standard error	95% confidence interval	
					Lower	Upper
	Group = Hatchery Tank					
1	Release to Ager Road Bridge (rkm 300)	9	0.857	0.023	0.812	0.902
2	Ager Road Bridge to Shasta River (rkm 288)	12	0.878	0.023	0.832	0.923
3	Shasta River to Scott River (rkm 234)	54	0.715	0.034	0.649	0.781
4	Scott River to Indian Creek (rkm 178)	56	0.920	0.024	0.873	0.966
5	Indian Creek to Salmon River (rkm 107)	71	0.929	0.024	0.882	0.976
6	Salmon River to Trinity River (rkm 69)	38	0.946	0.022	0.902	0.990
7	Trinity River to Steelhead Lodge (rkm 33)	36	0.934	0.024	0.886	0.982
	Release to Shasta River	21	0.752	0.028	0.697	0.807
	Release to Scott River	75	0.538	0.032	0.474	0.601
	Release to Steelhead Lodge	276	0.406	0.032	0.343	0.468
	Group = River Trap					
1	Release to Ager Road Bridge (rkm 300)	9	0.812	0.054	0.707	0.918
2	Ager Road Bridge to Shasta River (rkm 288)	12	0.828	0.059	0.711	0.944
3	Shasta River to Scott River (rkm 234)	54	0.642	0.079	0.486	0.797
4	Scott River to Indian Creek (rkm 178)	56	0.885	0.052	0.783	0.988
5	Indian Creek to Salmon River (rkm 107)	71	0.908	0.046	0.818	0.998
6	Salmon River to Trinity River (rkm 69)	38	0.916	0.058	0.802	1.030
7	Trinity River to Steelhead Lodge (rkm 33)	36	0.914	0.045	0.826	1.002
	Release to Shasta River	21	0.672	0.066	0.544	0.801
	Release to Scott River	75	0.431	0.068	0.298	0.565
	Release to Steelhead Lodge	276	0.290	0.056	0.180	0.400

Summary

The estimates of survival in 2008 were similar to those from 2006 and 2007 in reaches downstream from the Scott River. The trend of lower survival in upper river reaches has been observed in each year of the study. The survival of radio-tagged juvenile coho salmon in the Klamath River downstream from Iron Gate Dam in 2008 was slightly greater in hatchery-origin fish taken directly from a tank at Iron Gate Hatchery compared to those that were collected from a rotary screw trap in the Klamath River at rkm 293, although only 28 fish were in the latter group. Survival probabilities from Iron Gate Hatchery to Steelhead Lodge were similar in 2007 (0.497 SE 0.044) and 2008 (0.538 SE 0.032; hatchery tank group), but were slightly lower than those from 2006 (0.653 SE 0.039). Data from 2008 corroborate data from 2007. The primary differences in survival estimates among the 3 years are due to a greater survival upstream from the Scott River in 2006.

Acknowledgments

We would like to thank the California Department of Fish and Game staff at the Iron Gate Hatchery for providing fish and space for this study. The study would not have been possible without the work of the collaborators: the U.S. Fish and Wildlife Service, Arcata Fishery Resource Office assisted with study design and logistics, tagged fish, and downloaded data; the Karuk and Yurok Tribes downloaded data and performed receiver maintenance; and the USGS Columbia River Research Laboratory assisted with study design, implemented receiver systems, and performed data analysis. The Bureau of Reclamation funded the USGS under contract 06AA204092. Eric Janney of USGS and Nina Hemphill of Bureau of Reclamation made helpful recommendations about the report.

References Cited

Beeman, J.W., 2007, Summary of survival data from juvenile coho salmon in the Klamath River, northern California, 2006: U.S. Geological Survey Open-File Report 2007-1023, 6 p.

Beeman, J.W., 2008, Summary of survival data from juvenile coho salmon in the Klamath River, northern California, 2007: U.S. Geological Survey Open-File Report 2008-1022, 5 p.

Beeman, J.W., Stutzer, G.M., Juhnke, S.D., and Hetrick, N.J., 2007, Survival and migration behavior of juvenile coho salmon in the Klamath River relative to discharge at Iron Gate Dam, 2006: Final report prepared by U.S. Geological Survey, Cook, Washington and U.S. Fish and Wildlife Service, Arcata, California for the U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, contracts 06AA204092 and 07AA200181, Klamath Falls, Oregon.

Beeman, J.W., Juhnke, S., Stutzer, G., and Hetrick, N., 2008, Survival and migration behavior of juvenile coho salmon in the Klamath River relative to discharge at Iron Gate Dam, 2007: U.S. Geological Survey Open-File Report 2008-1332, 72 p.

Burnham, K.P., and Anderson, D.R., 2002, Model selection and multimodel inference: A practical information-theoretic approach: Springer Verlag, 488 p.

Burnham, K.P., Anderson, D.R., White, G.G., Brownie, C., and Pollock, K.H., 1987, Design and analysis methods for fish survival experiments based on release-recapture: American Fisheries Society Monograph 5, American Fisheries Society, Bethesda, Maryland, 737 p.

Cormack, R.M., 1964, Estimates of survival from the sighting of marked animals: Biometrika, v. 51, no. 3/4, p. 429-438.

Jolly, G.M., 1965, Explicit estimates from capture-recapture data with both death and immigration-stochastic model: Biometrika v. 52, no. 1/2, p. 225-247.

Seber, G.A.F., 1965, A note on the multiple-recapture census: Biometrika, v. 52, no. 1/2, p. 249-259.

Seber, G.A.F., 1982, The estimation of animal abundance and related parameters: Macmillan, New York, 654 p.

White, G.C., and Burnham, K.P., 1999, Program MARK: survival estimation from populations of marked animals: Bird Study 46 Supplement, p. 120-138.

This page intentionally left blank.

Publishing support provided by the Tacoma Publishing Service Center

For more information concerning the research in this report, contact the
Director, Western Fisheries Research Center
U.S. Geological Survey, 6505 NE 65th Street
Seattle, Washington 98115
http://wfrc.usgs.gov/

Beeman and others— **Summary of Survival Data from Juvenile Coho Salmon in the Klamath River, Northern California, 2008**—Open-File Report 2009-1019