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Mainstem Klamath River Coho Salmon Redd Surveys 2001 to 2005

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Abstract. Results of annual coho salmon *Oncorhynchus kisutch* redd surveys conducted on the mainstem Klamath River in November and December, 2001 through 2005 are summarized. The survey reach covers 136.5 river kilometers (rkm) located between Iron Gate Dam (IGD; rkm 310.3) near Hornbrook and the Indian Creek confluence at Happy Camp, California (rkm 173.8). A combined total of 38 coho salmon redds were observed within the survey reach for all five years combined. In 2001, eight additional redds were observed in the mainstem Klamath River downstream of the lower boundary of the study reach at Indian Creek. Within the survey reach, the highest annual redd count occurred in 2001 ($n = 13$). Seven redds were observed in 2003 and 6 redds were documented annually in 2002, 2004, and 2005. Coho salmon redds were observed in the mainstem Klamath River between November 15 and December 18, with the majority of new redds (63%) counted in mid December. About 68% of observed redds were located within 20 rkm of IGD and all redds were constructed within 1.5 rkm of a tributary mouth. Mean redd area (3.6 m^2), mean pit depth (0.61 m), mean mound depth (0.38 m), mean adjacent depth (0.55 m), and focal velocity range (0.49-1.05 m/s) were greater than values reported in the literature for other systems, but sample sizes were too low for statistical comparison.

Introduction

The Klamath River Basin (Figure 1) historically supported large runs of Chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, and steelhead trout *O. mykiss*. These species contribute to economically and culturally important subsistence, sport, and commercial fisheries. Generations of Indians have fished in the drainage, with historic catches of salmon, steelhead, lamprey, and sturgeon providing the mainstay of the Indian economy in the area (Leidy and Leidy 1984).

Coho salmon historically inhabited most major river systems of the Pacific Rim from central California to northern Japan (Laufle et al. 1986). However, extinctions of local populations of coho salmon have been documented in Washington, Oregon, Idaho, and

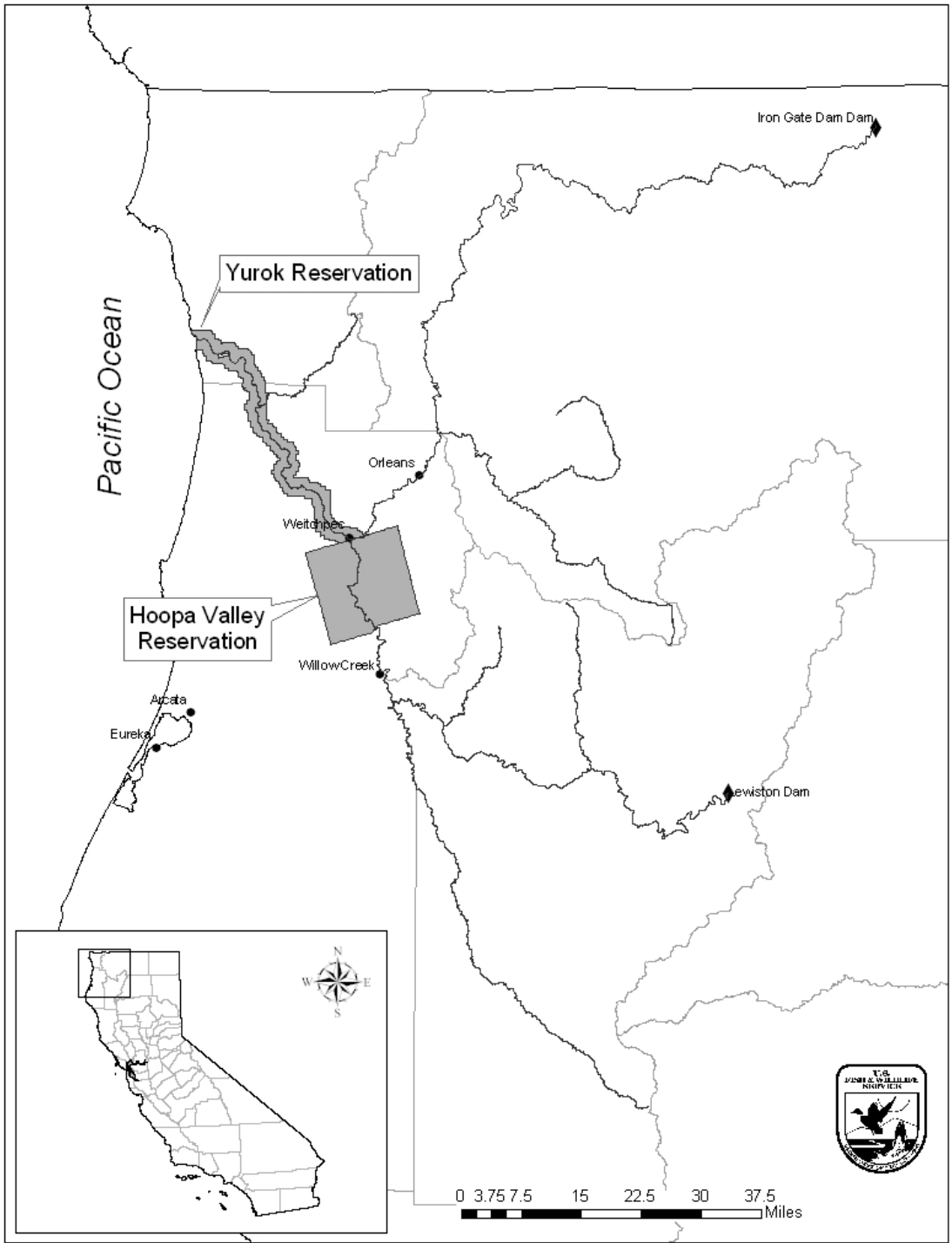


Figure 1. Overview of the Klamath River Basin that is accessible to anadromous salmonids.

California (Nehlsen et al. 1991, Frissell 1993, Brown et al. 1994). A status review of coho salmon populations from Washington, Oregon, and California (Weitkamp et al. 1995) prompted the National Marine Fisheries Service (NMFS) to list coho salmon populations within the Southern Oregon Northern California (SONC) Evolutionary Significant Unit (ESU) as threatened under the Endangered Species Act (ESA) on 6 May, 1997.

In consultation with the NMFS and the U.S. Fish and Wildlife Service (USFWS), the Bureau of Reclamation (BOR) developed a Ten Year Operations Plan that proposed to “divert, store and deliver (from storage) Klamath Project (Project) water consistent with applicable law” from the upper Klamath River Basin (NMFS 2002). In their 2002 Biological Opinion, NMFS determined that the Project was likely to jeopardize the continued existence of coho salmon and result in the adverse modification of designated critical habitat of coho salmon.

In their reasonable and prudent alternative (RPA) to BOR’s proposed action, NMFS required BOR to continue to refine RPA target flows by, in part, implementing various scientific studies to determine the effect of different IGD flow regimes have on coho salmon survival. In response to data uncertainties listed in the BO, BOR requested the USFWS to document the abundance and physical characteristics, and location of coho salmon redds within the mainstem Klamath River downstream of IGD. Surveys were performed for three consecutive weeks following the completion of fall Chinook salmon spawning surveys, with the goal of capturing the peak of coho salmon spawning activity. Due to incomplete coverage of the potential spawning period and periodic high flows experienced during surveys, redd counts presented in this report are minimum estimates.

Materials and Methods

Survey Procedures

Employees of Arcata Fish and Wildlife Office (AFWO) of the USFWS, Karuk Tribe of California (KTOC), and Yurok Tribe conducted coho salmon redd surveys in November and December of 2001 through 2005. Survey crews floated on catarafts down the mainstem Klamath River, focusing on previously noted spawning areas. Choice areas within spawning grounds often include sites of groundwater seepage, side channels, stream margins, and tributary mouths (Groot and Margolis 1991). The river was split into six reaches from IGD (rkm 310.3) downstream to the confluence of Indian Creek (rkm 173.8), covering 136.5 rkm (Figure 2). In 2001, an additional 77.3 rkm was surveyed downstream of Indian Creek to the river access at the Highway 96 Bridge in Orleans (rkm 96.5). In 2004, surveys continued downstream to the Independence Creek river access (rkm 152.9), adding 20.9 rkm to the overall survey. While the Chinook salmon spawning run was still in progress, redds were identified as belonging to coho salmon if live coho salmon were observed at the redd site. Once the Chinook salmon spawning run ended, all new redds observed were assumed to have been constructed by coho salmon.

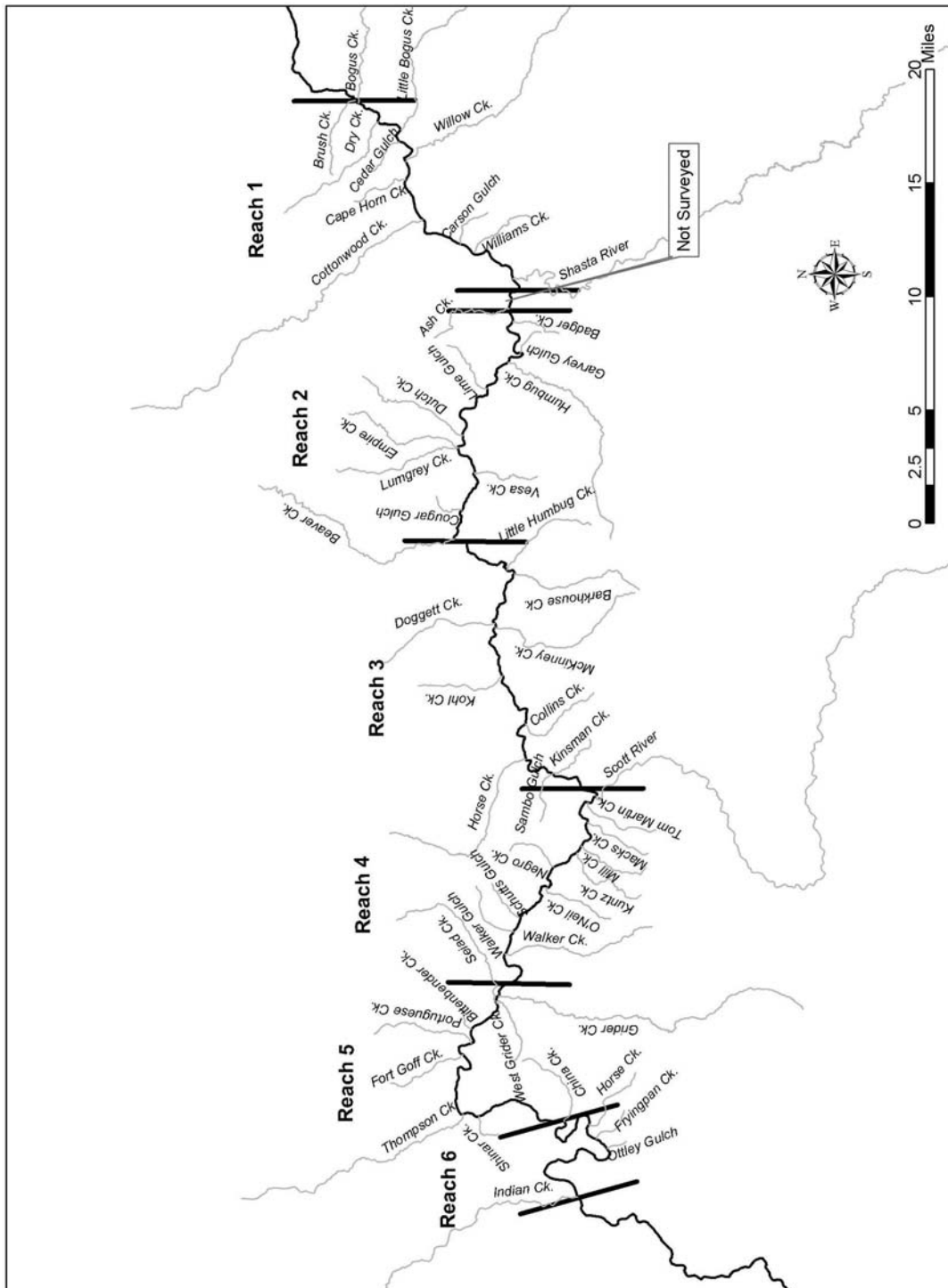


Figure 2. Mainstem Klamath River coho salmon spawning survey project location including individual study reaches 1 to 6.

Individual Reaches

The six reaches in the survey area ranged in length from 20.7 to 27.6 rkm (Table 1) and typically took about seven or eight hours each to survey, depending on flow levels.

Rafting Equipment

Two 4.3 m inflatable catarafts were used for direct observation of coho salmon redds. These rafts are commonly used for whitewater navigation because of their stability and maneuverability in fast water. Catarafts were stacked on a flatbed trailer and deployed at selected access sites along the study area. Each raft was equipped with a rowing frame, a modified observation platform, and an anchoring system. Two personnel, a rower and an observer, operated each raft.

Collection of Redd Data

Upon observation, redd locations were marked on laminated aerial orthophotos and location information was recorded on data forms. Redds were marked with flags containing the following information: date, number of redds previously recorded for the site, number of new redds, total number of redds, redd location(s) in channel, and redd site number. Flags were tied to vegetation on the bank nearest to the redd(s). Different colored flagging was used each week to prevent redds from being double counted during the course of the survey.

Table 1. Individual reach distance, river access, and typical survey time.

Reach	Distance		Downstream River Access	Approximate Survey Time (hrs)
	(rkm)	Upstream River Access		
1 ^a	22.3	IGD (RKM 309.8)	Deliverance Camp (RKM 287.5) ^b	11
2	23.8	Ash Creek (RKM 285.7)	Beaver Creek riffle (RKM 261.9) ^c	7
3	27.6	Beaver Creek	Blue Heron (RKM 234.3) ^d	8
4	20.7	Blue Heron	Seiad Bar (RKM 213.6) ^e	8
5	21.2	Seiad Bar	China Point (RKM 192.4) ^f	7
6a ^g	7.4	China Point	Gordons Ferry (RKM 185) ^b	4
6b ^g	11.2	Gordons Ferry	Indian Creek confluence (RKM 173.8) ^b	4

^a due to the high percentage of redds two cataraft crews surveyed this reach, each covering the mid-channel to their resp

^b river access located directly off of Hwy 96

^c river access is located on the right bank on a large gravel bar downstream from Beaver Cr. Bridge of Hwy 96

^d river access is approximately 2 rkm upstream of the Scott R. confluence

^e river access is located on the right bank and is accessible by the road to the south of the California Department of Trans

^f river access is located on the right bank at the U.S. Forest Service river access off Hwy 96

^g due to the high concentration of redds in this area, Reach 6 was split into two sub-reaches, 6a and 6b

General information recorded on data forms included: date, weather, crew members, and Secchi disc depth. Redd information recorded on forms included: Universal Transverse Mercator (UTM) coordinates, rkm, mesohabitat number, mesohabitat type, number of complete redds, distance to nearest tributary, number of males, females, and/or jacks observed on the redd, length of redd, width of redd, pit depth, mound depth, adjacent depths and velocities at 0° and 45° to pit, dominant and subdominant substrate immediately adjacent to redd, distance from nearest shore, and stream width. Redd measurement data were not collected on redds occupied by live fish to avoid spawning disturbance.

Redd Location

Redd locations were recorded on laminated aerial orthophotos having overlays of UTM coordinates, 0.05 rkm increments (measured from Klamath River mouth to IGD), channel types, and mesohabitat types. Stream channel type, mesohabitat type and habitat unit number were recorded on data forms for each redd location. Mesohabitat habitat numbers were referenced from the orthophotos, which identify and sequentially number individual habitat units from IGD to the Klamath River mouth. Redd locations were categorized into three channel types: split channel (SPC), side channel (SC), and main channel (MC) and further segregated into four mesohabitat types: pool (P), low slope (LS, gradient < 0.3%), moderate slope (MS, gradient = 0.3 to 0.8%), and steep slope (SS, gradient > 0.8%). based on methods described by Hawkins et al. (1993) and later modified by USFWS, United States Geological Survey (USGS) and Utah State University (Hardy and Addley 2001).

Redd Area

Redd size measurements were taken with a measuring tape to the nearest 0.03 m. Redd length was measured as the distance from the upstream margin of the pit to the downstream end of the tail spill. Redd width was measured at the widest horizontal distance across the redd. Redd area was calculated as the product of the length and width measurements.

Depths of Pit, Mound, and Adjacent Area

Depths were measured using an incremented stream flow rod and recorded to the nearest 0.02 m. Pit depth was measured as the depth of the water column at the center of the redd pit. Mound depth was measured as the depth of the water column at the center of the redd mound. Adjacent water column depth was measured at the immediate undisturbed substrate at 45° upstream from the center of the pit on the right side of the redd center line.

Water Velocity

Water column velocity was measured immediately adjacent to each unoccupied redd using standard USGS protocol. Focal velocity was measured at 0.6 depth at the head of the redd pit. Velocities were also taken at 0.6 depth 45° upstream from the center of the pit on the right side of the redd center line. Velocities were measured with a Price AA

flow meter to the nearest 0.01 ft/sec.

Substrate Type

Substrate composition of redd locations was based on Wentworth's scale modified by USFWS, California Department of Fish and Game (CDFG), and USGS (Table 2). Dominant and subdominant substrate types were estimated visually in the area immediately adjacent to each redd on undisturbed substrate to determine initial redd building material.

Iron Gate Dam Discharge

Mean daily river flow was obtained from the USGS gauging station (Number 11516530; Latitude 41° 55' 41", Longitude 122°26'35" NAD 27; <http://waterdata.usgs.gov/ca/nwis>), located in the Klamath River just downstream of IGD. Mean daily river flow was recorded in cubic feet per second (cfs).

Table 2. Substrate types and size categories used for mainstem Klamath River coho salmon carcass surveys.

Code	Type	Size (cm)
18	Clay	-
19	Sand or silt/sand	< 0.3
20	Coarse sand	0.3 - 0.5
21	Small gravel	0.5 - 2.5
22	Medium gravel	2.5 - 5.1
23	Large gravel	5.1 - 7.6
24	Small cobble	7.6 - 15.2
25	Medium cobble	15.2 - 22.9
26	Large cobble	22.9 - 30.5
27	Small boulder	30.5 - 61.0
28	Medium boulder	61.0 - 121.9
29	Large boulder	> 121.9
30	Bedrock	-

Results

A combined total of 38 coho salmon redds were observed within the survey reach for all five years combined (Appendix A). A total of 13 redds were observed in 2001, seven in 2003, and six each in 2002, 2004, and 2005 between IGD and the Indian Creek confluence at rkm 172.5. In 2001, eight additional redds were observed in the mainstem Klamath River downstream of the lower boundary of the study reach at Indian Creek. These eight redds were excluded from comparisons between years. All newly constructed coho salmon redds were observed from November 15 to December 18 with

the majority of redds (63%, $n = 24$) observed during surveys on December 11 and 12 (Figure 3). Most redds (68%, $n = 26$) for combined survey years were observed within 20 rkm of IGD (Figure 4).

All redds were observed within 1.5 rkm of a tributary mouth, as follows: Willow Creek (rkm 303; $n = 14$), Cottonwood Creek (rkm 297.4; $n = 5$), Williams Creek (rkm 292.7; $n = 7$), Barkhouse Creek (rkm 256.6; $n = 8$), Kohl Creek (rkm 248; $n = 2$), and Horse Creek (rkm 240.2; $n = 2$) (Figure 5; Appendix C). Mean distance between all tributaries in the survey area is approximately 3 rkm and mean distance between major tributaries in the survey area is about 14 rkm. Fifteen of the observed redds were in low slope areas, 13 in pools, and 10 in moderate slope areas.

Redd measurement data were not collected for all observed redds due to occupation by live fish. Therefore, redd parameters reported below have sample sizes lower than the total number of redds observed. Redd area ranged from 2.8 to 4.8 m² (mean = 3.6 m², $n = 5$) (Appendix B). A removed outlier measured 12.3 m².

Pit depth measurements ranged from 0.37 to 0.76 m (mean = 0.61 m, $n = 8$) (Appendix B). Mound depth measurements ranged from 0.24 to 0.61 m (mean = 0.38 m, $n = 8$). Adjacent depth ranged from 0.37 to 0.76 m (mean = 0.55 m, $n = 9$).

Focal velocity, measured at the upstream edge of pit, ranged from 0.49 to 1.05 m/s (mean = 0.77 m/s, $n = 9$) (Appendix B). Depth at the head of the pit ranged from 0.26 to 0.76 m (mean = 0.52 m). The 0.6 depth velocity measurements at a 45° angle upstream to the right from the redd pit ranged from 0.55 to 1.62 m/s (mean = 0.95 m/s, $n = 9$). Depth at velocity measurements 45° upstream from the pit ranged from 0.24 to 0.73 m (mean = 0.53 m).

Of nine redds for which substrate was recorded, medium gravel was the dominant substrate ($n = 6$) (Appendix B). Medium cobble was the dominant substrate for two redds and large gravel was the dominant substrate for one redd.

Redd distance from the shore ranged from 1.0 to 10.7 m (mean = 2.4 m, $n = 21$) (Appendix C). Stream width at redd locations ranged from 4 to 70 m (mean = 27.7 m, $n = 14$), including side channels.

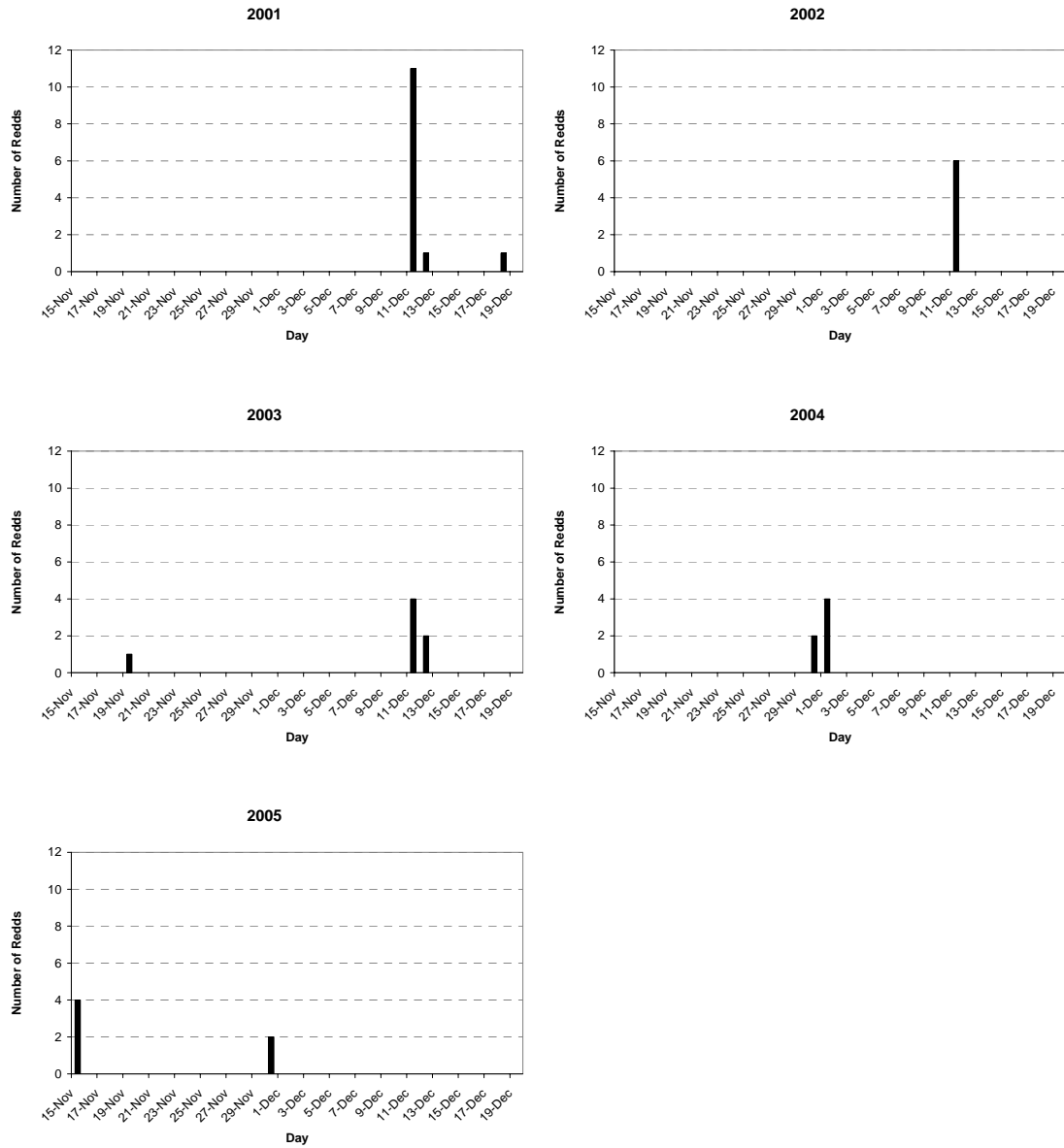


Figure 3. Total number of coho salmon redds observed by date on the mainstem Klamath River between Iron Gate Dam and the Indian Creek confluence for each survey year.

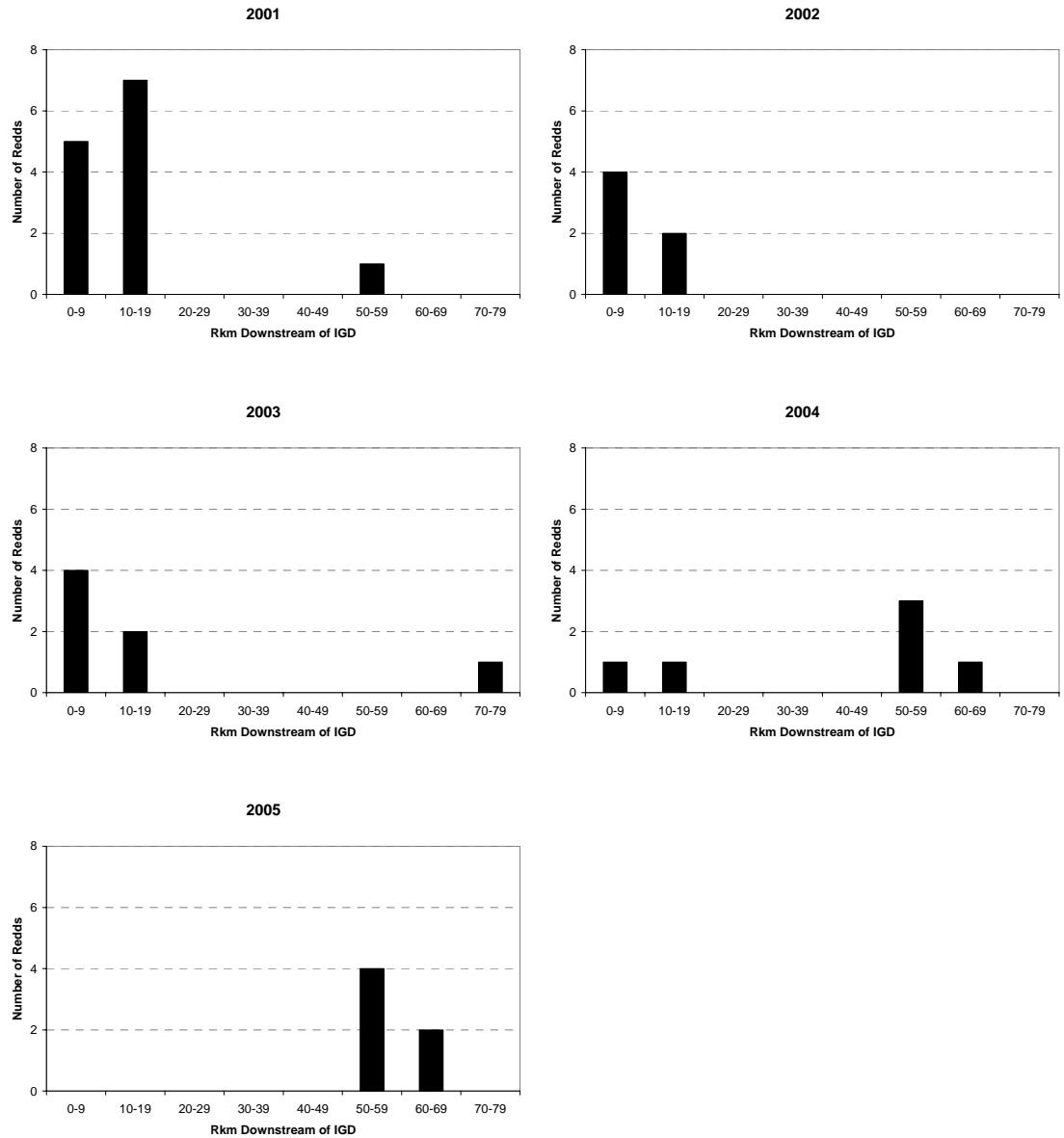


Figure 4. Numbers of coho salmon redds observed on the mainstem Klamath River between Iron Gate Dam and the Indian Creek confluence in relation to distance downstream of Iron Gate Dam for each survey year.

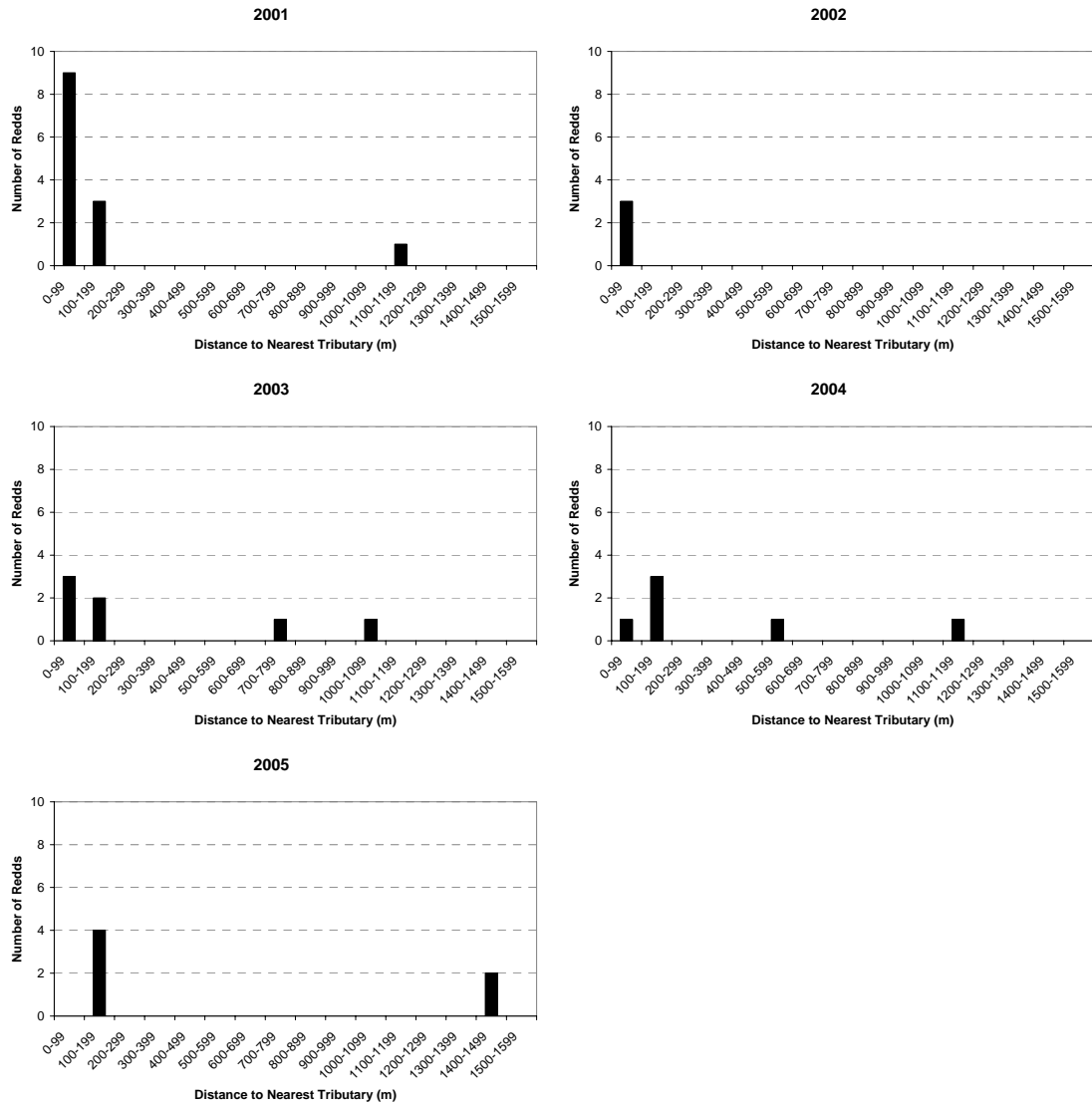


Figure 5. Numbers of coho salmon redds observed on the mainstem Klamath River between Iron Gate Dam and the Indian Creek confluence in relation to distance to the nearest tributary.

Discussion

Mainstem Klamath River coho salmon spawn timing was similar to that observed in tributaries between Independence Creek and the Scott River (D. Quigley, Scott River RCD, personal communication; T. Soto, KTOC, personal communication). The peak of spawning activity typically occurred around mid December, coinciding with the typical rise in river flows from storm events. Based on 2004 weir operations by CDFG, peak Shasta River spawn timing occurs after the second week in December (Hampton 2005). Most spawning activity for coho salmon normally occurs earlier at IGH, peaking during the third week of November (K. Rushton, CDFG, personal communication).

The large proportion of redds in close proximity to IGD suggest that coho salmon in this system are attempting to utilize historic spawning grounds that are now blocked by barriers to upstream migration. The close proximity of redds to tributaries suggest that coho salmon utilize tributaries as spawning grounds. The number of coho salmon that spawn in tributaries compared to the mainstem requires further investigation.

Sample sizes of redd habitat measurements were low (range = 5-10), which did not allow for meaningful statistical analyses. Based on the limited data we did collect, however, coho salmon observed spawning in the mainstem Klamath River built larger redds in deeper water than coho salmon found in other rivers (Table 3). Water velocity over these redds was near or above the upper end of the preferred range reported in the literature (Table 3). Hardin et al. (2005) found that Chinook salmon spawning in the mainstem Klamath River downstream of IGD also construct redds in deeper water compared to populations in other rivers.

Dominant substrates for all redds observed were medium gravel, medium cobble, and large gravel. These results are similar range found by Briggs (1953; 3.9-13.7 cm) in Groot and Margolis (1991).

Many improvements should be implemented on the study design if this annual monitoring is to be continued, including inclusion of the entire coho salmon spawning season.

Table 3. Comparison of redd parameters from this report to previous reports.

Parameter	Mainstem Klamath		Other Systems		Source
	n	Value	Value		
Mean Redd Area (m ²)	5	3.6	2.8	Burner (1951)	
			1.5	Gribanov (1948) and Groot and Margolis (1991)	
			2.6	Crone and Bond (1976)	
Mean Pit Depth (m)	8	0.61			
Mean Mound Depth (m)	8	0.38	0.16 ^a	Briggs (1953)	
Mean Adjacent Depth (m)	9	0.55			
Focal Velocity Range (m/s)	9	0.49-1.05	0.30-0.91 ^b	Thompson (1972)	
			0.30-0.55 ^c	Girbanov (1948)	

^a depth of water over redd

^b velocity criteria range

^c preferred stream flow

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Appendix A. Coho redd observation dates, locations, mesohabitat information, redd numbers, and spawner numbers.

Year	ID	Date	RKM	Location Description	Mesohabitat Number	Mesohabitat Type	GPS Coordinates		Number of Redds	Number of Coho Salmon Observed on Redds				
							Easting	Northing		Male	Female	Jacks	Unknown	Total
2001	1	11-Dec	303.2	50 m below KRCE bridge	44.0	LS	542900	4638100	1	1				2
	2	11-Dec	302.0	25 m below Willow Cr.	49.0	LS	542050	4638500	3	2	2			4
	3	11-Dec	297.4	In Cottonwood Cr.	69.0	P	538100	4637300	5	2	3	1		6
	4	11-Dec	292.8	120 m upstream of I-5 Bridge	98.0	MS	535689	4634070	2	1	2			3
	5	12-Dec	256.8	Barkhouse SC	342.6	P	513000	4630850	1					0
	6	12-Dec	172.5	Curly Jack Camp Ground	854.0	P	467400	4625800	6					0
	7	12-Dec	172.5	upstream of Elk Cr.	854.0	P	467400	4625800	1					0
	8	12-Dec	172.5	upstream of Elk Cr.	854.0	P	467400	4625800	1					0
	9	18-Dec	302.0	Willow Cr. mouth	49.0	LS	541957	4638664	1		1			1
2002	10	11-Dec	303.1	Klamath River Country Estates (KRCE)	44.0	LS	542771	4638297	1	1	1			2
	11	11-Dec	302.0	just downstream of Willow Cr.	49.0	LS	541957	463866	3	2	2			4
	12	11-Dec	292.8	just upstream of I-5 Bridge	98.0	MS	535689	4634070	2	1	2			3
2003	13	19-Nov	239.5	downstream of Horse Cr.	453.0	P	501500	4630600	1				1	1
	14	11-Dec	303.1	KRCE, 50 m below bridge	44.0	LS	542771	4638297	1					0
	15	11-Dec	302.0	Willow Cr., 20 m below confluence	49.0	LS	542771	4638297	3					0
	16	12-Dec	292.8	120 m upstream of I-5 Bridge	98.0	MS	535689	4634070	2					0
2004	17	30-Nov	303.1	near KRCE	44.0	LS	542771	4638297	1				2	2
	18	30-Nov	292.8	above I-5 Bridge	98.0	MS	535689	4634070	1		1			1
	19	1-Dec	256.7	Barkhouse SC	342.6	P	513000	4630850	1					0
	20	1-Dec	256.7	Barkhouse SC	342.6	P	513000	4630850	1					0
	21	1-Dec	256.7	Barkhouse SC	342.6	P	513000	4630850	1					0
	22	1-Dec	240.8	1/4 mile upstream of Horse Cr.	444.0	P	500200	4630100	1					0
2005	23	15-Nov	256.7	Barkhouse SPC	342.6	P	513000	4630850	1	1	1			2
	24	15-Nov	256.7	Barkhouse SPC	342.7	MS/P/LS	513000	4630850	3	3	3	1		7
	25	30-Nov	247.5	SC below Kohl Cr. near mansion	397.1	MS	505232	4631556	1	1	1			2
	26	30-Nov	247.5	SC below Kohl Cr. near mansion	397.1	MS	505231	4631556	1	1	1			2
TOTAL								46	16	21	2	3	42	

Appendix B. Water velocity, depth, and dimensions of coho salmon redds.

ID	WATER VELOCITY ADJACENT TO REDD				REDD MEASUREMENTS						SUBSTRATE Adjacent to Redd (Code)	
	Upstream of Pit Center		45° Right of Pit		Redd Depths			Redd Size				
	Depth (m)	0.6 Velocity (m/s)	Depth (m)	0.6 Velocity (m/s)	Adjacent (m)	Pit (m)	Mound (m)	Length (m)	Width (m)	Area (m ²)		
9	0.26	0.78	0.24	0.55	0.56							23
17	0.30	0.94	0.43	0.90	0.37	0.37	0.24	0.34	0.9	2.79	21	21
18	0.76	0.60	0.58	0.55	0.58	0.76	0.40	0.02	2.2	12.31	21	21
19	0.61	1.05	0.64	1.05	0.67	0.76	0.61	0.03	1.2	4.46	21	21
20	0.55	0.75	0.73	0.73	0.76	0.73	0.46	0.03	1.6	4.77	21	21
21	0.61	0.51	0.49	1.62	0.40	0.61	0.34	0.03	0.6	2.77	21	21
22	0.55	0.84	0.67	1.22	0.55	0.55	0.43	0.17	1.3	3.08	21	21
25	0.58	0.49	0.49	1.15	0.47	0.55	0.30				25	25
26	0.46	1.02	0.49	0.78	0.55	0.55	0.30				25	25
COUNT	9	9	9	9	9	8	8	6	6	6	9	9
AVG	0.52	0.77	0.53	0.95	0.55	0.61	0.38	0.10	1.31	5.03	-	-
MAX	0.76	1.05	0.73	1.62	0.76	0.76	0.61	0.34	2.19	12.31	25	25
MIN	0.26	0.49	0.24	0.55	0.37	0.37	0.24	0.02	0.58	2.77	21	21

Appendix C. Coho salmon redd proximity to tributaries and shore, stream width, IGD flow, and comments.

ID	Distance to Nearest Tributary (m)	Distance to Nearest Shore (m)	Mean Stream Width (m)	IGD Flow (cfs)	Comments
1	1120	2.0	50	400	
2	25	1.5	40	400	
3	0	1.0	4	400	
4	120	2.5	70	400	
5	100			400	
6	60	5.5	35	400	downstream of Indian Cr. confluence; redds observed 6 weeks prior
7	60	5.0	45	400	downstream of Indian Cr. confluence
8	60	8.0	50	400	downstream of Indian Cr. confluence
9	30	1.8	40	400	
10	1	2.0		400	fish identified by I. Sanders
11	20			400	fish identified by I. Sanders
12	50			400	fish identified by I. Sanders
13	750			270	
14	1070			270	
15	20			270	
16	120			270	
17	1120	2.1		930	measured on Dec. 10, 2004; flow was 550 cfs at IGD
18	50	10.7		930	measured on Dec. 10, 2004; flow was 550 cfs at IGD
19	100	4.4		930	measured on Dec. 15, 2004; flow was 420 cfs at IGD and 197 cfs from Shasta R.
20	100	1.4		930	measured on Dec. 15, 2004; flow was 420 cfs at IGD and 197 cfs from Shasta R.
21	100	1.3		930	measured on Dec. 15, 2004; flow was 420 cfs at IGD and 197 cfs from Shasta R.
22	550	1.6		930	measured on Dec. 15, 2004; flow was 420 cfs at IGD and 197 cfs from Shasta R.
23	100			410	fish identified by I. Sanders
24	100			410	fish identified by I. Sanders
25	1470	5.9	9	410	data collected during chinook salmon surveys by M. Magnuson and J. Ogawa
26	1470	1.7	9	410	data collected during chinook salmon surveys by M. Magnuson and J. Ogawa
AVG	211	3	32	504	
MAX	1470	10.7	70	930	
MIN	0	1.0	4	270	