U.S. Fish & Wildlife Service

Abundance and Run Timing of Adult Steelhead Trout in Crooked and Nikolai Creeks, Kenai Peninsula, Alaska, 2007

Alaska Fisheries Data Series Number 2008-2

Kenai Fish and Wildlife Field Office
Kenai, Alaska
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Kenneth S. Gates and Douglas E. Palmer

Abstract

Fish weirs with underwater video systems were installed and operated on Crooked and Nikolai creeks during 2007 to collect abundance and run timing information for immigrating steelhead trout. Each weir and video system was installed prior to the spring steelhead trout spawning migration. A combined total of 1,335 steelhead trout was counted past the Crooked (N=766) and Nikolai (N=569) creek weirs between 26 April and 28 May. The escapement into Nikolai Creek is considered a conservative estimate because of high water periodically submerging the weir during May. Peak weekly passage occurred between 13 and 19 May for both Crooked and Nikolai creeks. Sex of each passing steelhead trout was determined by examining video footage recorded from each weir. Females comprised 52% of the escapement at Crooked Creek and 60% of the escapement at Nikolai Creek. Water temperatures during the operational periods ranged from 1.1°C to 8.1°C at Crooked Creek and 0.6°C to 5.7°C at Nikolai Creek.

Introduction

Crooked and Nikolai creeks are the only two streams in the Kasilof River watershed known to support steelhead trout *Oncorhynchus mykiss* (Johnson et al. 2004). Crooked Creek historically supported a small wild run of steelhead trout estimated to consist of a maximum of several hundred fish (Gamblin et al. 2004). The Alaska Department of Fish and Game (Department) enhanced this run beginning in the 1980's to provide additional angling opportunity. Enhancement efforts created a fishery unique from other steelhead trout fisheries on the Kenai Peninsula because it provided anglers an opportunity to harvest fish. Sport catches of steelhead trout in the Kasilof River and Crooked Creek peaked during the mid-1990's and averaged 5,836 fish between 1993 and 1995 (Mills 1994; Howe et al. 1995, 1996). During the same period, harvest of steelhead trout averaged 1,397 fish annually. Higher catches during this period were a direct result of the enhancement program. The enhancement program was terminated in 1993 after concerns were raised about straying of hatchery steelhead trout into the Kenai River. Since termination of the enhancement program, catch has declined and has averaged 579 fish between 1997 and 2004 (Gamblin et al. 2004; Larry Marsh, Alaska Department of Fish and Game, personal communication). Anticipating a decline in the number of steelhead trout available to anglers, the Alaska Board of Fisheries restricted the fishery within Crooked Creek and the Kasilof River below the Sterling Highway Bridge to catch-and-release beginning in 1996.

Current fishery regulations limit fishing in Crooked Creek from 1 August through 31 December, and only unbaited, single hook, artificial lures may be used between 15 September and 31 December. In addition, no retention of rainbow or steelhead trout is allowed from Crooked

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Creek. Regulations pertaining to the Kasilof River from 1 September through 15 May allow fishing with one unbaited, single hook, artificial lure from the mouth to the Sterling Highway Bridge. In this same section of river from 16 May through 30 June, only one single hook may be used. Like Crooked Creek, no retention of rainbow or steelhead trout is allowed in the Kasilof River below the Sterling Highway Bridge. Fishing above the Sterling Highway Bridge and in Nikolai Creek is open year-round for rainbow and steelhead trout with a daily bag limit of 2 per day/2 in possession with only one fish exceeding 20 inches in length. The annual bag limit is 2 rainbow/steelhead trout greater than 20 inches taken from Kenai Peninsula waters. Harvest of steelhead trout above the Sterling Highway Bridge is typically fewer than 50 fish annually.

Information regarding the steelhead trout population in Nikolai Creek is limited to escapement estimates reported by Gates and Palmer (2006a and 2006b), visual observations made by U.S. Geological Survey (USGS) field technicians during the early 1990's (Carol Woody, U.S. Geological Survey, personal communication), and the presence of one steelhead trout captured in Tustumena Lake by Jones and Faurot (1991) which may have been returning to Nikolai Creek. Escapement estimates made by Gates and Palmer (2006a and 2006b) during 2005 and 2006 were 84 and 373 fish, respectively.

Steelhead trout returning to the Kasilof River watershed are considered fall-run fish, entering fresh water in the fall and over-wintering before spawning in tributaries in May and June. Larson and Balland (1989) documented similar behavior in steelhead trout returning to the Anchor River on the lower Kenai Peninsula. Begich (1997) has also described the Karluk River steelhead trout population, the largest steelhead population on Kodiak Island, as a fall run. More recently, USGS operated a weir on the Ninilchik River to enumerate emigrating steelhead trout (kelts). The timing of kelts passing downstream through the weir varied considerably between years, starting as early as 19 May in 2000 and as late as 12 June in 2001 (USGS, unpublished data). Median cumulative downstream passage dates have ranged from 9 to 18 June in the Ninilchik River. Kelt information is limited for Crooked and Nikolai creeks, but timing of their downstream migration is likely very similar to that observed for the Ninilchik River.

Harvest and catch information collected by the Department indicate that the steelhead trout over-wintering in the Kasilof River do not enter Crooked Creek until late April or early May (Gamblin et al. 2004). The spring spawning migration is thought to occur when water temperatures approach 2° C or when changes in discharges can be detected (Gates and Palmer 2006a; Gates and Palmer 2006b). The distribution of over-wintering steelhead trout in the Kasilof River is poorly understood, however the Kenai Fish and Wildlife Field Office (KFWFO) initiated a two-year radio telemetry study during the fall of 2007 to determine the over-wintering distribution and seasonal migration.

Preliminary investigations of steelhead trout were initiated by the Service in Crooked Creek during 2004. The project objective during 2004 was to develop an underwater video system for enumerating steelhead trout. Steelhead trout were enumerated during the month of May at the Crooked Creek Hatchery and concurrently at a weir equipped with an underwater video system 200 m upstream of the hatchery. Daily counts of steelhead trout from both locations were similar, indicating that the underwater video was an accurate and cost effective method to enumerate fish passage. A total of 206 steelhead trout was enumerated during 2004; however, this was likely a conservative estimate of abundance because weir and video counts were not initiated until 4 May (U.S. Fish and Wildlife Service, unpublished data). To gain more information pertaining to the run-size of spawning populations of steelhead trout in tributaries to the Kasilof River and Tustumena Lake, the Service installed and operated an underwater video system in Crooked and Nikolai creeks during 2005, 2006, and 2007. Specific objectives during 2007 were to: 1) enumerate adult steelhead trout entering Crooked and Nikolai creeks; and 2) determine the run-timing of adult steelhead trout entering Crooked and Nikolai creeks.

Study Area

The Kasilof River drains a watershed of 2,150 km^2, making it the second largest watershed on the Kenai National Wildlife Refuge (Refuge). The watershed consists of mountains, glaciers, forests, and the Kenai Peninsula's largest lake, Tustumena Lake. The Kasilof River is only 29 km long and drains Tustumena Lake, which has a surface area of 29,450 hectares, a maximum depth of 287 m, and a mean depth of 124 m. All tributary streams in the watershed which drain refuge lands enter Tustumena Lake except Crooked Creek (Figure 1).

Crooked Creek is a tannin-stained stream approximately 80 km long which intersects the Kasilof River at river-kilometer nine (60° 19.20'N and 151° 16.55'W; NAD83). The headwaters of Crooked Creek are on the Refuge and the watershed drains approximately 75.6 km^2 (Moser 1998). Crooked Creek has a highly sinuous channel and substrates ranging from sand to cobble.

Nikolai Creek enters the south shore of Tustumena Lake approximately 8 km SE of the lake outlet (60° 11.43'N and 151° 0.36'W; NAD83). Its watershed is approximately 95 km^2 and falls within the Refuge boundary and a designated wilderness area (Moser 1998). Nikolai Creek has a relatively steep gradient, low sinuosity, and predominately cobble substrate.

Methods

Weir and Video Operations and Design

The weir located at Crooked Creek Hatchery was installed to monitor the steelhead trout escapement in Crooked Creek. The hatchery weir is a permanent structure with a steel corrugated footer and bulkheads. Metal grates are placed onto the weir framework to divert fish migrating upstream into a hatchery raceway. An underwater video system was installed in the raceway to monitor fish passage. After passing the video system, fish exit the hatchery into Crooked Creek and continue their upstream migration. Fish moving downstream bypass the hatchery and pass over the weir unharmed.

The Nikolai Creek weir was located approximately 200 m upstream from the mouth of the creek. The weir was constructed using a combination of floating resistance board panels (Tobin 1994) and flexible pickets (Palmer 2003). Flexible pickets were used in low velocity sections of the stream near each bank and were constructed from 2.5-cm inside-diameter polyvinyl chloride (PVC) electrical conduit. Each flexible panel measured 3 m long by 1.5 m high with 1.9-cm spacing between pickets. Panels were held together by 3-mm stainless wire rope. Metal tripods were used to support the flexible picket panels. The floating portion of the weir was constructed using specifications outlined by Tobin (1994), with minor modifications to the panel width, picket spacing and resistance board material. The setup and design of the weir allowed upstream movement of fish through a counting chute. Downstream movement of fish occurred over a partially submerged floating weir panel. Except when weir maintenance was required, the Nikolai Creek weir was unmanned and outfitted with a video and microwave system to monitor upstream fish passage.

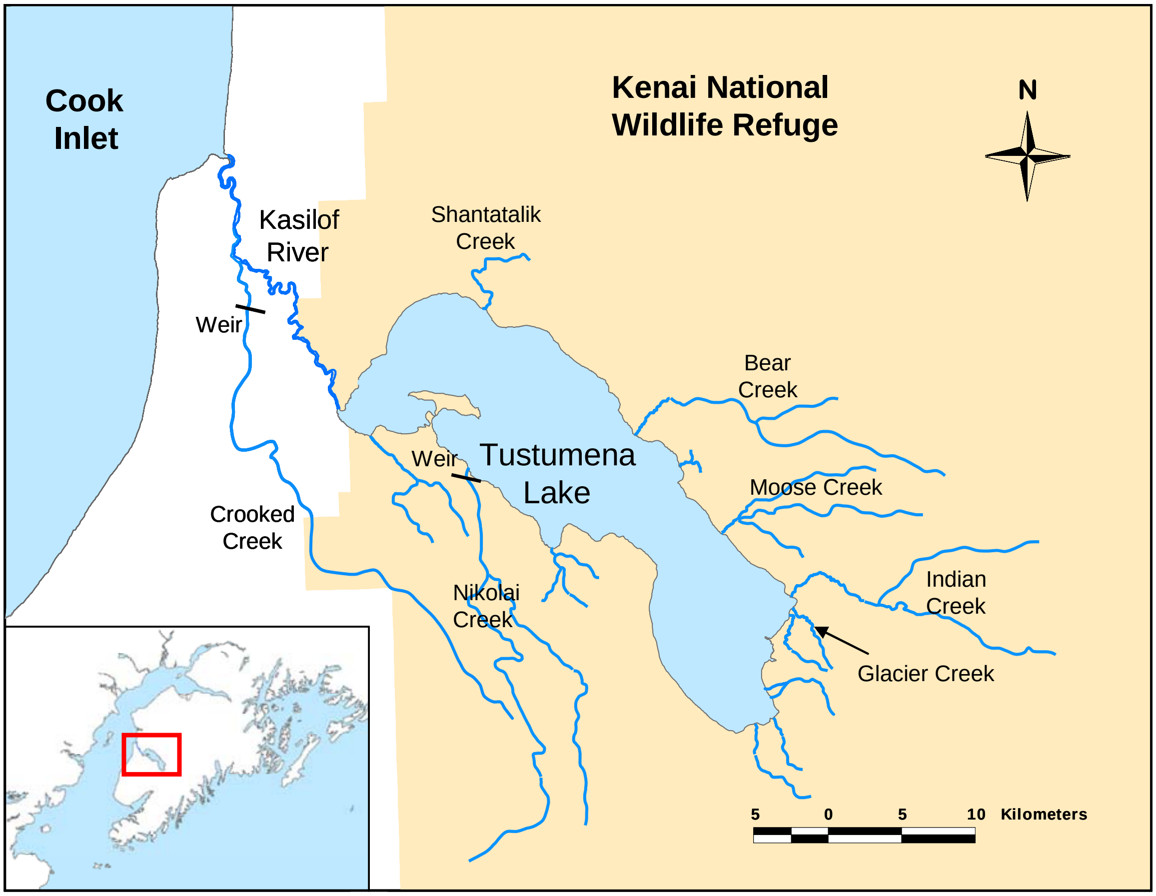

FIGURE 1. —Map of the Kasilof River watershed showing weir locations on Crooked and Nikolai creeks.

Setup and design of the video system was similar to that used by Gates and Palmer (2006a and 2006b) in Crooked and Nikolai creeks during 2005 and 2006, and Anderson et al. (2004) in Big Creek during 2003. One underwater video camera was located inside a sealed video box attached to the fish passage chute. The video box was constructed of 3.2-mm aluminum sheeting and was filled with filtered water. Safety glass was installed on the front of the video box to allow for a scratch-free, clear surface through which images were captured. The passage chute was constructed from aluminum angle and was enclosed in plywood isolating it from exterior light. The video chute from which video images were captured was modified in 2007 so that the backdrop could be adjusted laterally to minimize the number of fish passing through the chute at one time. The backdrop could also be easily removed from the video chute when dirty and replaced with a new one. Video images from Nikolai Creek were transmitted via a 2.4 GHz microwave frequency to a digital video recorder (DVR) located at a private residence near the Sterling Highway. Microwave transmission of the video signal minimized power requirements needed at the remote site and allowed the crew to remotely monitor fish passage. The underwater camera, microwave transmitter, and underwater lights at Nikolai Creek were powered by three 80-watt solar panels. Two solar panels wired in parallel supplied power to two 360Ah 6-volt batteries wired in series which powered the underwater lights. The remaining solar panel maintained the charge on one 12-volt battery which powered the underwater camera and microwave transmitter. All video images from each project were recorded on a removable 120 gigabyte hard drive at 20 frames-per-second using a computer-based DVR. Fish passage was recorded 24 hours per day seven days each week. Stored video files were reviewed daily. The video box and fish passage chute at each weir were artificially lit using a pair of 12-volt underwater pond lights. Pond lights at Crooked Creek were equipped with 20-watt bulbs which provided a quality image. Lights used at Nikolai Creek were equipped with 10-watt bulbs to conserve battery power. The lights provided a consistent source of lighting during day and night hours. Each DVR was equipped with motion detection to minimize the amount of blank video footage and review time. Appendix 1 contains a complete list of video and microwave equipment.

Biological Sampling

Biological sampling during 2007 was limited to determining the sex of immigrating steelhead trout using video images recorded by the DVR. An observer assigned a sex to each fish based on their external characteristics as they swam through the video chute. Fish with no assigned sex were marked as unknown. No effort was made to collect scales for age determination during 2007 because of the uncertainty in accurately assigning ages to steelhead trout. Department biologists are currently conducting age validation work on steelhead trout and we have provided them with steelhead trout scale samples previously collected from Crooked Creek. Pending results from this work, we may resume age and length sampling during 2008.

Water temperatures were recorded at each weir location using an Optic StowAway Temp logger (ONSET Computer Corporation®). Temperatures were recorded every 30 minutes and averaged for the day. Temp loggers were operated between 18 April and 30 May in Crooked Creek and 15 April and 30 May in Nikolai Creek.

Results

Weir and Video Operations

The weir and video systems at Crooked and Nikolai creeks were operated between 25 April and 28 May. The weirs at each site were installed several days prior to the video being operational and the start of the spring spawning migration of steelhead trout. The Department assumed the operation of the Crooked Creek weir and video system after 28 May for Chinook salmon enumeration and reported no additional steelhead trout passing the video system. Each video system operated smoothly during the steelhead trout monitoring period. A helicopter was used to access the Nikolai Creek weir site during installation and periodically for two weeks thereafter to clean the weir because of ice conditions on Tustumena Lake. High water during May in Nikolai Creek periodically submerged parts of the weir and interrupted steelhead counts. Once Tustumena Lake was free of ice on 9 May, the weir site was visited nearly each day to clean and maintain the weir. The weir site was visited twice a day during times of peak passage and flow, once in the morning and late evening. Parts of the weir would sometimes become submerged between visits but times and duration were unknown therefore no attempt was made to estimate passage during these periods.

Biological Data

A total of 766 steelhead trout was counted passing the video system at Crooked Creek Hatchery between 26 April and 28 May (Figure 2; Appendix 2). Peak weekly passage (N=309) occurred between 13 and 19 May and median cumulative passage occurred on 13 May. The highest daily count (N=97) occurred on 16 May. The number of steelhead trout counted after 22 May only represented 3% (N=24) of the total escapement. Water temperatures ranged between 4.6°C and 7.0°C between 13 and 19 May, the week of peak steelhead trout passage (Figure 2; Appendix 4).

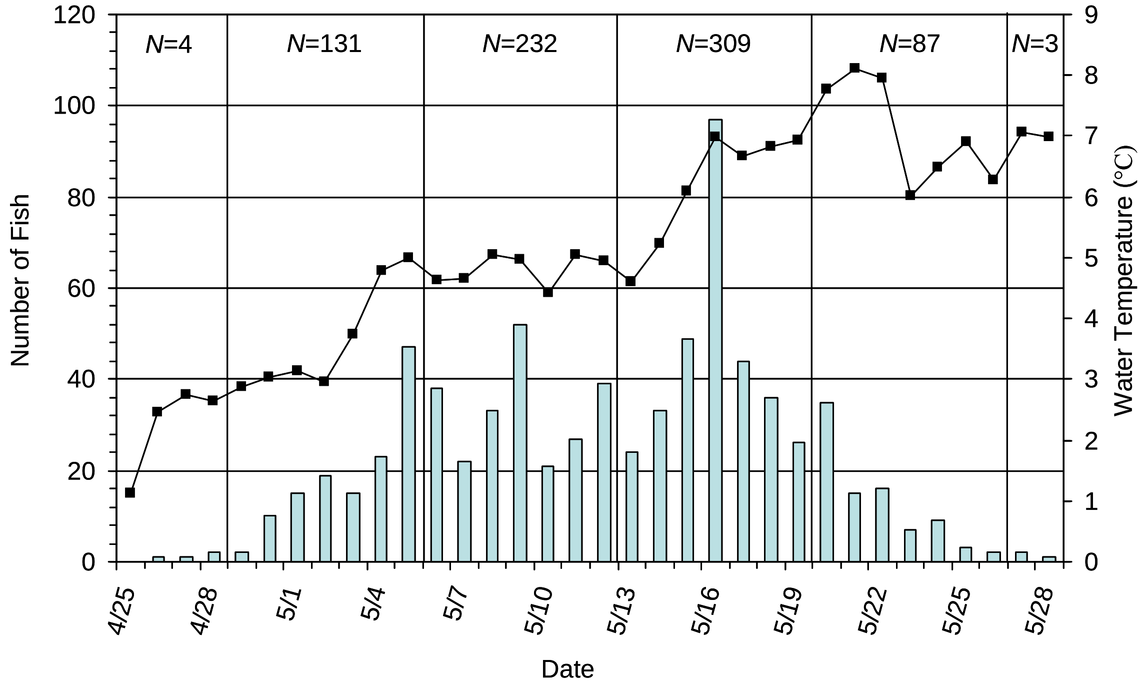

FIGURE 2. —Daily and weekly escapement of steelhead trout and water temperatures in Crooked Creek, Alaska, 2007. Counts did not begin until mid-day on 25 April.

Sex composition of steelhead trout returning to Crooked Creek was determined during the review of video records and was comprised of 52% females. Sex ratios favored males during the first half of the run but shifted to a dominant female component during the second half of the run (Figure 3). Sex could not be determined for three steelhead trout; these fish were omitted from the estimate.

A total of 569 steelhead trout was counted passing Nikolai Creek weir between 27 April and 28 May 2007 (Figure 4; Appendix 3). Peak weekly passage (*N*=352) occurred between 13 and 19 May. Passage observed during this week accounted for 62% of the total escapement. Median cumulative passage occurred on 15 May. Nearly all of the steelhead trout passage occurred at water temperatures less than 5°C with the peak weekly passage occurring between 3.1°C and 4.3°C (Figure 4; Appendix 4). Females comprised 60% of the total sexed escapement based on review of the video records. Sex composition was skewed towards males early in the run but quickly changed to predominately females throughout the remainder of the run (Figure 5). Sex could not be determined for four steelhead trout; these fish were omitted from the estimate.

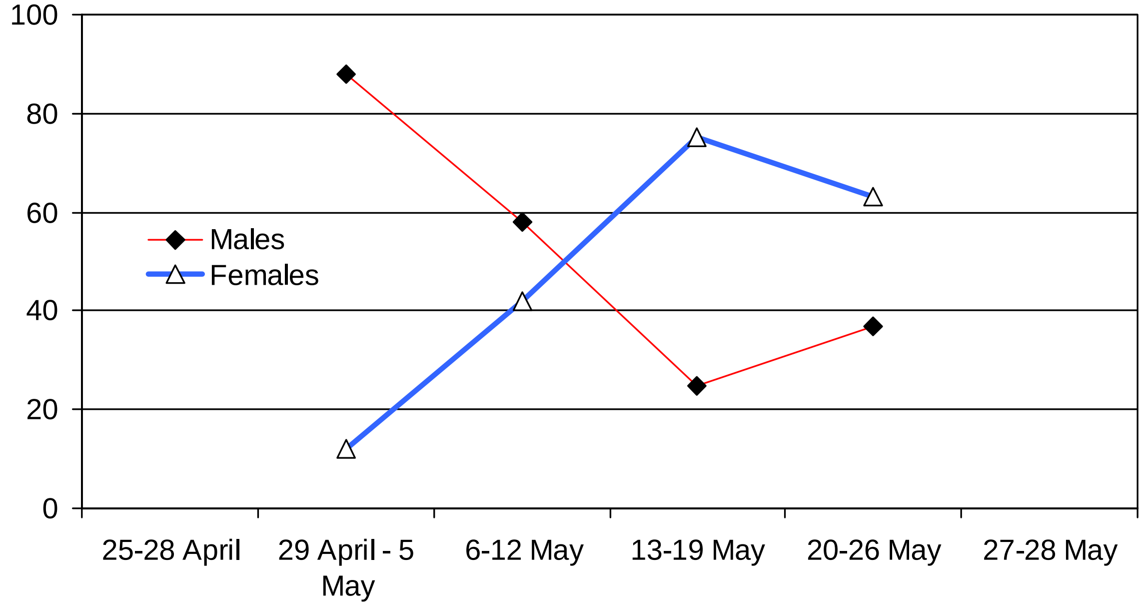

FIGURE 3. —Weekly percent of male and female of steelhead trout observed at Crooked Creek, Alaska, 2007. Steelhead trout observed prior to 29 April (*N*=3 males) and after 26 May (*N*=4 females) were omitted from this figure.

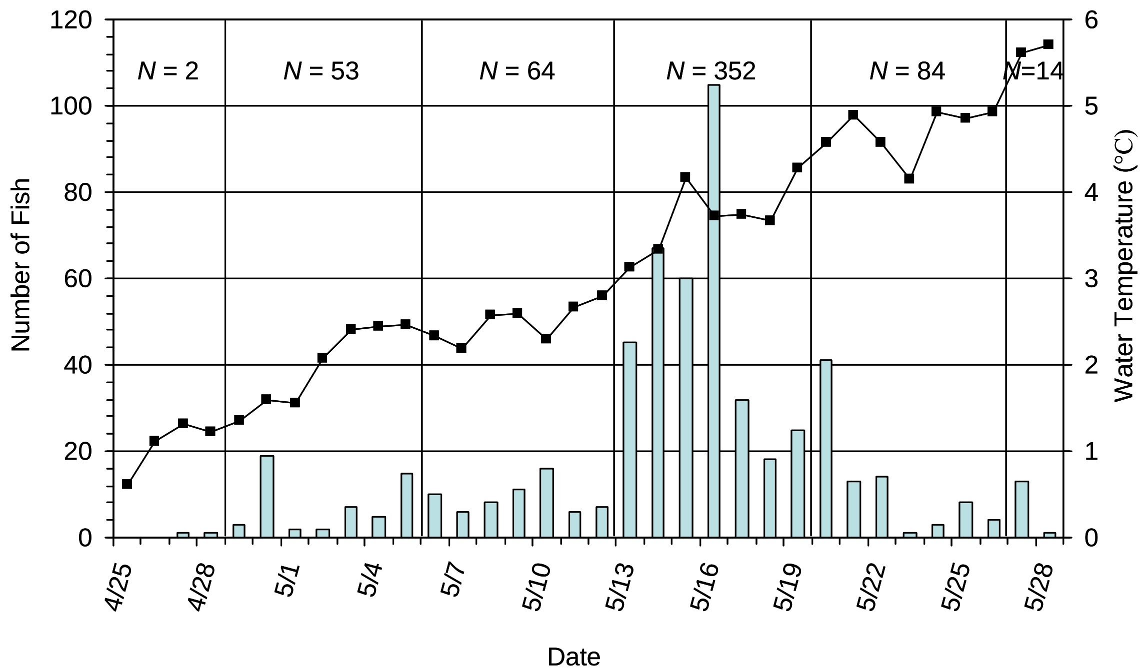

FIGURE 4. —Daily and weekly escapement of steelhead trout and water temperatures in Nikolai Creek, Alaska, 2007. Counts did not begin until mid-day on 25 April.

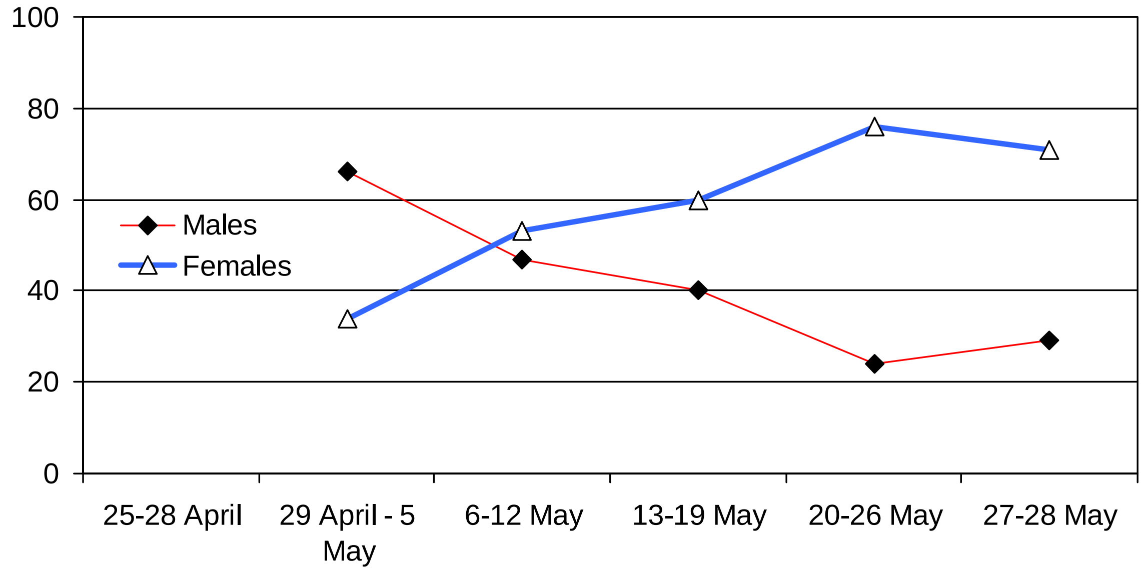

FIGURE 5. —Weekly percent of male and female steelhead trout observed at Nikolai Creek, Alaska, 2007. Two steelhead trout observed prior to 29 April were omitted from this figure.

Discussion

A combined total of 1,335 steelhead trout was counted past the Crooked (*N*=766) and Nikolai (*N*=569) creek weirs between 26 April and 28 May. We feel that these estimates of abundance accurately represent the relative strength of the steelhead trout return to each of these streams; however, estimates from Nikolai Creek are likely conservative because high water periodically submerged the weir throughout the run. Steelhead trout were not immediately observed passing either weir following installation, suggesting that the steelhead trout migration started after the weirs were installed.

The return of steelhead trout to Crooked Creek during 2007 was greater than that observed during 2004 (*N*=206), 2005 (*N*=379), and 2006 (*N*=604) (Figure 6). Similarly, steelhead trout returning to Nikolai Creek were observed in greater numbers during 2007 than in 2005 (*N*=84) and 2006 (*N*=373) (Figure 7). The larger escapement observed at Nikolai Creek in 2007 is thought to be attributed to more frequent maintenance of the weir and estimating the early component of the steelhead trout return and not a result of a larger return. The 2006 escapement may have been similar to the 2007 escapement if the weir had not been flooded on three occasions during times of peak passage. Estimating the early component of each run is made possible by either one or a combination of the following: earlier weir installation dates and a later return of steelhead trout during 2007. Peak weekly passage at Crooked and Nikolai creeks occurred one week later in 2007 than in 2006 suggesting a delayed steelhead trout migration compared to observations made in 2006. Delayed spring weather conditions could have been the cause for a later return of steelhead trout during 2007.

Sex ratios of steelhead trout in Crooked and Nikolai creeks have favored females for all years of observation. Female to male sex ratios were nearly identical between 2006 (1.3:1) and 2007 (1.1:1) for Crooked Creek and were the same between years for Nikolai Creek (1.5:1). These sex ratios are considered representative for steelhead trout returning to Crooked and Nikolai creeks and much different from the highly skewed female to male sex ratios (3:1) observed during 2005. Sex ratios during 2005 were likely biased heavily toward females because both weirs were installed late and females tend to dominate the later part of the return. Sex ratios observed at Crooked and Nikolai creeks during 2007 are similar to those observed for spring run steelhead trout populations currently being monitored by the Department in Southeast, Alaska (David Love, Alaska Department of Fish and Game, personal communication). Determining the age composition and spawning histories of steelhead trout through scale analysis may provide some additional knowledge regarding the sex ratios observed in Crooked and Nikolai creeks.

Water temperature and flow regime remain the two factors which likely have the most influence on run-timing of steelhead trout in Crooked and Nikolai creeks. The mean water temperature recorded in Crooked Creek (4.6°C) between 18 April and 30 May, 2007 was nearly the same as what was recorded between 15 April and 31 May during 2006 (4.5°C). The mean water temperature recorded in Nikolai Creek (2.6°C) between 15 April and 30 May, 2007 was the coldest recorded since 2004. During 2007, water temperatures in Crooked Creek remained cooler earlier in the steelhead trout run before gradually increasing to 8.1°C on 21 May (Appendix 2; Appendix 4). Water temperatures in Nikolai Creek remained even colder never exceeding 5.7°C during the operational period (Appendix 3; Appendix 4). Passage at Crooked Creek began on 26 April, the first day that average daily water temperatures exceeded 2°C. Although the run-timing of steelhead trout in Nikolai Creek was similar to Crooked Creek, the average daily water temperatures did not reach 2°C until 2 May (Appendix 3). In this instance, increases in discharge may have had a greater influence than water temperature in triggering the immigration of steelhead trout in Nikolai Creek. Other studies have also noted that water temperature and discharge are important environmental factors influencing the upstream movement of steelhead trout (Shapovalov and Taft 1954; Kesner and Barnhart 1972; Jones 1972). We will be coordinating with the Water Resources Division of the Service to determine the feasibility of establishing water discharge stations in Crooked and Nikolai creeks during 2008.

In conclusion, installing Crooked and Nikolai creek weirs during the third week of April has enabled us to monitor fish passage during the beginning of each run and provide better estimates of run timing and abundance. The use of underwater video on both streams and microwave transmission for Nikolai Creek video have proven to be a relatively inexpensive and reliable tools to monitor the abundance and run-timing of these two steelhead trout populations. We plan to monitor steelhead escapement in both streams during 2008. The Nikolai Creek weir and video operations during 2008 will be funded by the Office of Subsistence Management, Fisheries Resource Monitoring Program. During 2008, genetic tissue samples will be collected from 50 steelhead trout returning to Nikolai Creek. Genetic samples from Crooked Creek have already been collected from previous years. All genetic samples will be processed by the Conservation Genetics Laboratory to determine if the two populations are distinct from one another and to what level. Weather conditions permitting, both weirs will be installed and operational by 20 April to provide an accurate assessment of run-timing, abundance, and composition of the return. This assessment information will be useful in formulating future management strategies for steelhead trout in the Kasilof River watershed.

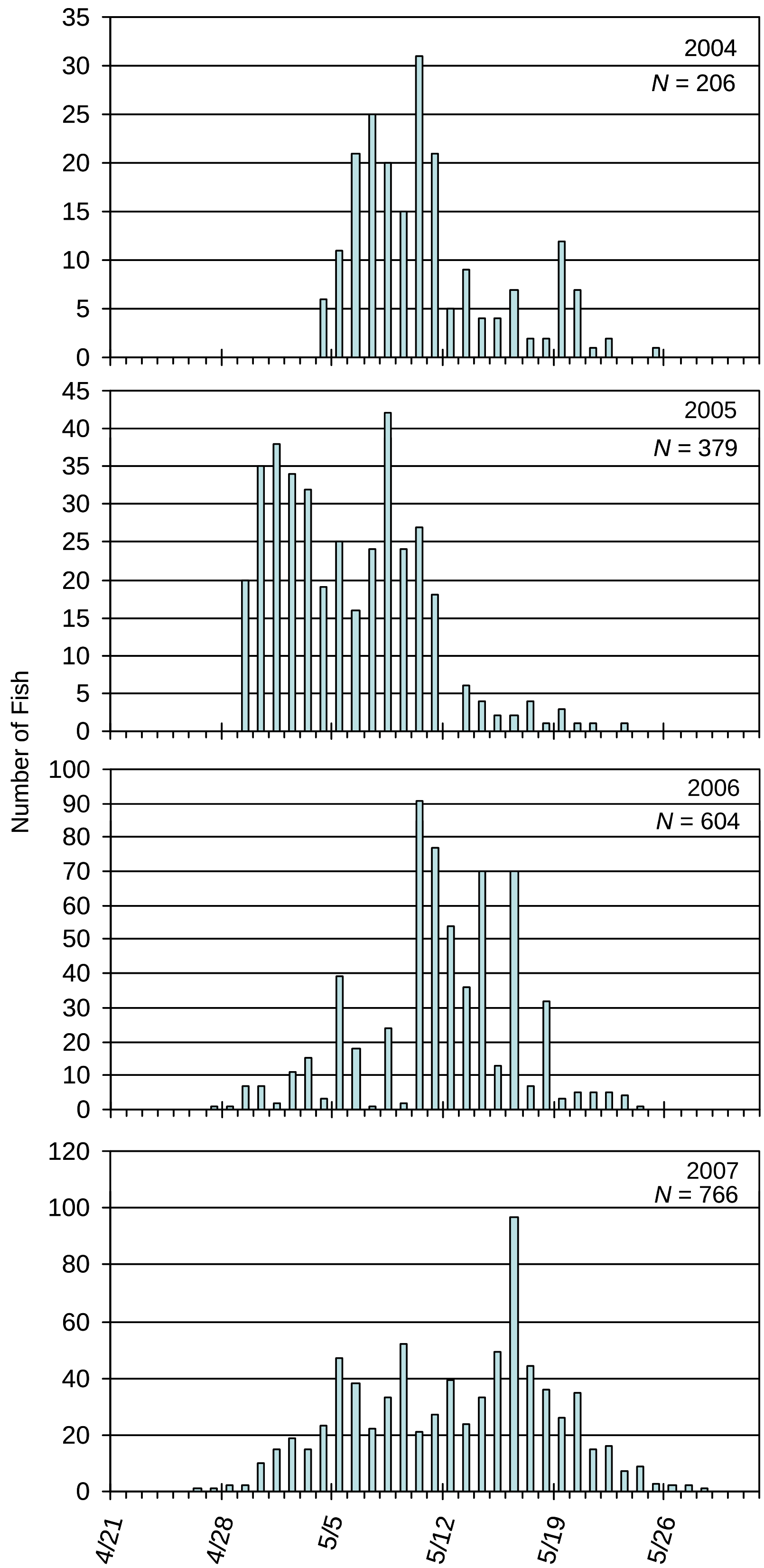

FIGURE 6. —Daily escapement of steelhead trout in Crooked Creek, Alaska, 2004 - 2007.

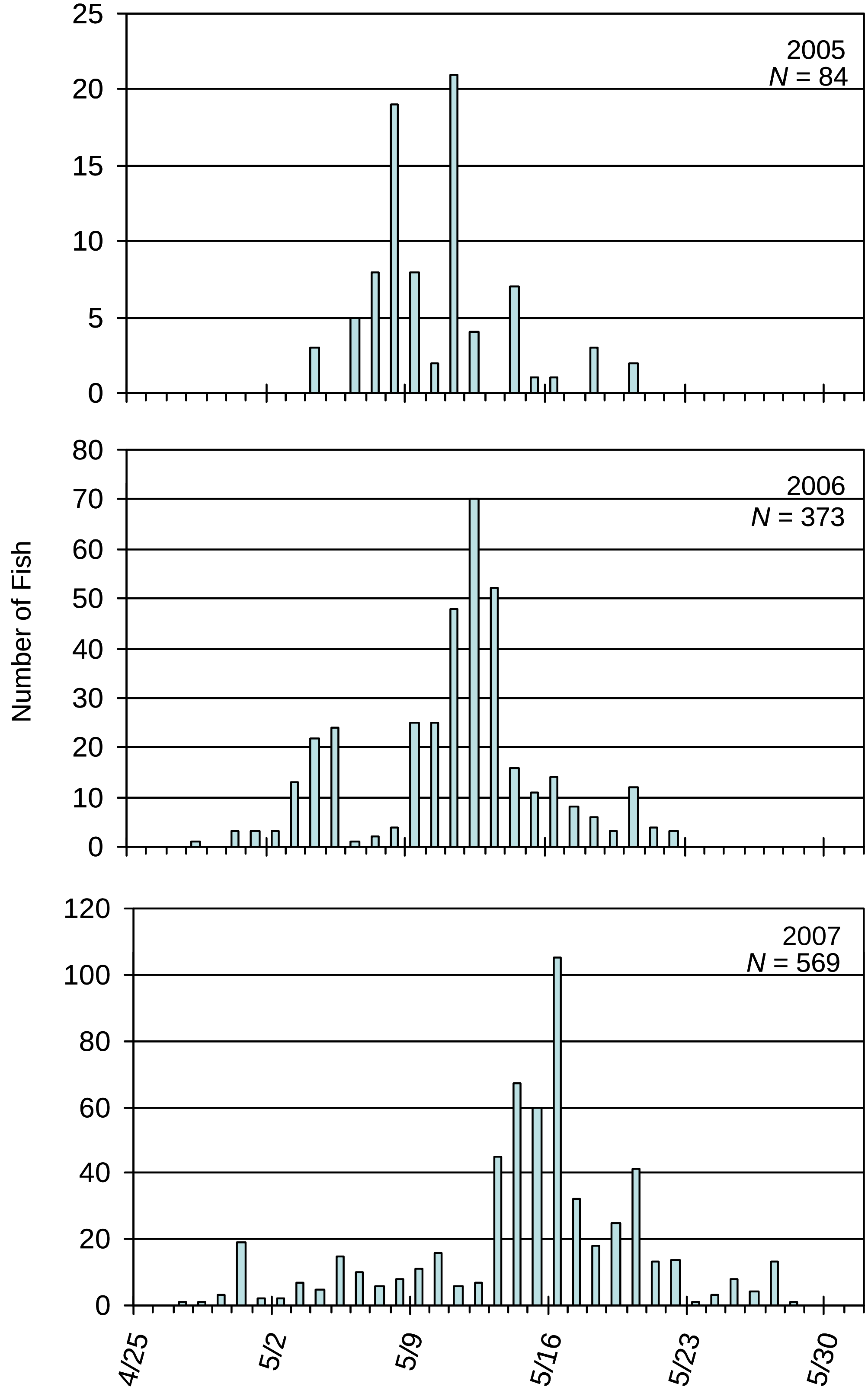

FIGURE 7. —Daily escapement of steelhead trout in Nikolai Creek, Alaska, 2005, 2006, and 2007.

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The Service would also like to thank the Department for allowing us to use their facilities at the Crooked Creek Hatchery. Utilizing the hatchery as a platform to operate the video system was instrumental in creating a smooth operating project. In addition, special appreciation is extended to Michael and Linda Sipes for providing us access to their property to operate the microwave equipment and DVR for Nikolai Creek.

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APPENDIX 1. —List of video and microwave equipment used to monitor steelhead trout abundance at Crooked and Nikolai creeks, Alaska, 2007.

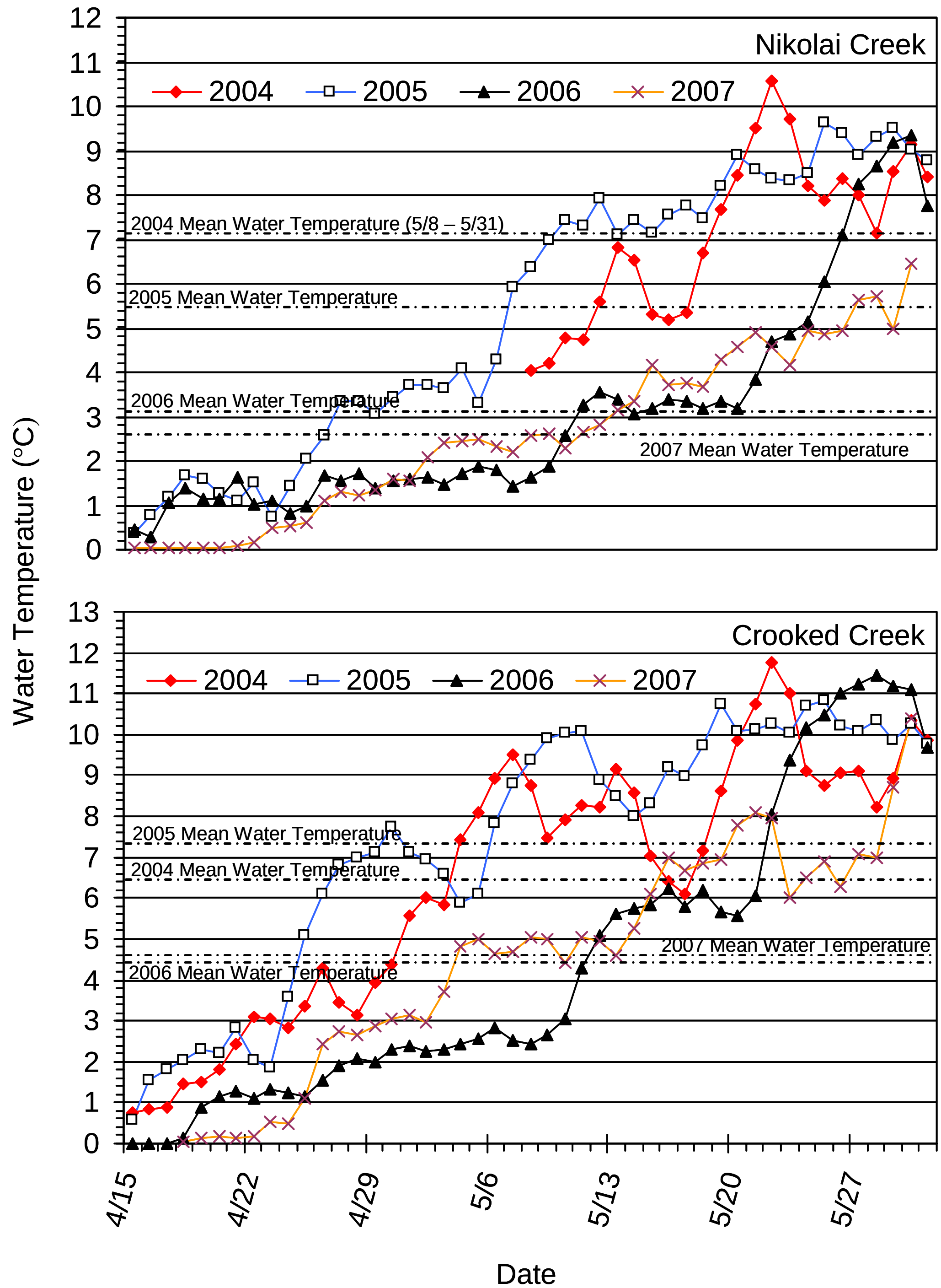
Item	Model #	Manufacturer	Contact
Digital Video Recorder	DVSM 4-120	Veltek International, Inc.	http://www.veltekcctv.com/
Underwater Camera	Model 10	Applied Micro Video	http://www.appliedmicrovideo.com/
Underwater Lights	Lunaqua 2 12-v	OASE	http://www.pondusa.com
External Harddrive	One Touch 250 GB	Maxtor.com	http://www.maxstore.com
Microwave Transmitter	BE-530T	Premier Wireless, Inc	http://www.premierwirelessinc.com/
Microwave Recievers	BE-322R	Premier Wireless, Inc	http://www.premierwirelessinc.com/
Parabolic Antennas	130135	California Amplifier	http://www.calamp.com

APPENDIX 2. —Daily counts and cumulative proportion of steelhead trout and water temperatures from Crooked Creek between 2004 and 2007. Boxed areas represent the second and third quartile and median passage dates.

	2004			2005			2006			2007		
Date	Daily	Cumulative Proportion	Water Temperature	Daily	Cumulative Proportion	Water Temperature	Daily	Cumulative Proportion	Water Temperature	Daily	Cumulative Proportion	Water Temperature
4/15			0.76			0.57			0.00			
4/16			0.86			1.55			0.00			
4/17			0.89			1.82			0.00			
4/18			1.44			2.02			0.14			0.05
4/19			1.51			2.29			0.88			0.14
4/20			1.80			2.19			1.15			0.17
4/21			2.41			2.85	0	0.0000	1.29			0.15
4/22			3.10			2.05	0	0.0000	1.09			0.16
4/23			3.06			1.87	0	0.0000	1.31			0.53
4/24			2.83			3.60	0	0.0000	1.25			0.49
4/25			3.37			5.08	0	0.0000	1.17	0	0.0000	1.12
4/26			4.30			6.09	0	0.0000	1.54	1	0.0013	2.45
4/27			3.46			6.83	1	0.0017	1.92	1	0.0026	2.76
4/28			3.16			7.00	1	0.0033	2.09	2	0.0052	2.65
4/29			3.94	20	0.0528	7.10	7	0.0149	2.00	2	0.0078	2.87
4/30			4.39	35	0.1451	7.73	7	0.0265	2.32	10	0.0209	3.04
5/1			5.56	38	0.2454	7.11	2	0.0298	2.39	15	0.0405	3.13
5/2			6.01	34	0.3351	6.95	11	0.0480	2.24	19	0.0653	2.95
5/3			5.85	32	0.4195	6.59	15	0.0728	2.31	15	0.0849	3.73
5/4	6	0.0291	7.43	19	0.4697	5.90	3	0.0778	2.45	23	0.1149	4.80
5/5	11	0.0825	8.09	25	0.5356	6.10	39	0.1424	2.57	47	0.1762	5.00
5/6	21	0.1845	8.93	16	0.5778	7.81	18	0.1722	2.83	38	0.2258	4.63
5/7	25	0.3058	9.51	24	0.6412	8.80	1	0.1738	2.53	22	0.2546	4.67
5/8	20	0.4029	8.75	42	0.7520	9.39	24	0.2136	2.44	33	0.2977	5.06
5/9	15	0.4757	7.46	24	0.8153	9.92	2	0.2169	2.66	52	0.3655	4.98
5/10	31	0.6262	7.90	27	0.8865	10.04	91	0.3675	3.06	21	0.3930	4.41
5/11	21	0.7282	8.29	18	0.9340	10.10	77	0.4950	4.27	27	0.4282	5.06
5/12	5	0.7524	8.24	0	0.9340	8.89	54	0.5844	5.07	39	0.4791	4.95
5/13	9	0.7961	9.14	6	0.9499	8.47	36	0.6440	5.63	24	0.5104	4.61
5/14	4	0.8155	8.58	4	0.9604	7.99	70	0.7599	5.73	33	0.5535	5.24
5/15	4	0.8350	7.02	2	0.9657	8.33	13	0.7815	5.85	49	0.6175	6.10
5/16	7	0.8689	6.41	2	0.9710	9.18	70	0.8974	6.22	97	0.7441	6.98
5/17	2	0.8786	6.11	4	0.9815	8.97	7	0.9089	5.79	44	0.8016	6.66
5/18	2	0.8883	7.18	1	0.9842	9.71	32	0.9619	6.18	36	0.8486	6.84
5/19	12	0.9466	8.61	3	0.9921	10.75	3	0.9669	5.64	26	0.8825	6.94
5/20	7	0.9806	9.86	1	0.9947	10.08	5	0.9752	5.58	35	0.9282	7.78
5/21	1	0.9854	10.74	1	0.9974	10.13	5	0.9834	6.05	15	0.9478	8.11
5/22	2	0.9951	11.78	0	0.9974	10.28	5	0.9917	8.06	16	0.9687	7.96
5/23	0	0.9951	11.00	1	1.0000	10.05	4	0.9983	9.39	7	0.9778	6.03
5/24	0	0.9951	9.11			10.71	1	1.0000	10.16	9	0.9896	6.50
5/25	1	1.0000	8.78			10.85			10.46	3	0.9935	6.92
5/26			9.05			10.22			11.00	2	0.9961	6.29
5/27			9.10			10.07			11.24	2	0.9987	7.06
5/28			8.21			10.33			11.47	1	1.0000	6.98
5/29			8.93			9.86			11.17			8.72
5/30			10.37			10.26			11.09			10.41
5/31			9.86			9.76			9.69			

APPENDIX 3. —Daily counts and cumulative proportion of steelhead trout and water temperatures from Nikolai Creek during 2005, 2006, and 2007. Boxed areas represent the second and third quartile and median passage dates. Shaded areas are periods when the weir had been breached by high water.

	2005			2006			2007		
Date	Daily	Cumulative Proportion	Water Temperature	Daily	Cumulative Proportion	Water Temperature	Daily	Cumulative Proportion	Water Temperature
4/15			0.38			0.45			0.06
4/16			0.78			0.29			0.06
4/17			1.18			1.07			0.06
4/18			1.67			1.38			0.06
4/19			1.61			1.15			0.06
4/20			1.25			1.14			0.06
4/21			1.12			1.63			0.07
4/22			1.51			1.03			0.16
4/23			0.74			1.10			0.49
4/24			1.42			0.81			0.53
4/25			2.04			0.96	0	0.0000	0.62
4/26			2.58	0	0.0000	1.68	0	0.0000	1.12
4/27			3.35	0	0.0000	1.55	1	0.0018	1.32
4/28			3.35	1	0.0027	1.70	1	0.0035	1.22
4/29			3.05	0	0.0027	1.40	3	0.0088	1.35
4/30			3.43	3	0.0107	1.56	19	0.0422	1.60
5/1			3.73	3	0.0188	1.58	2	0.0457	1.56
5/2			3.71	3	0.0268	1.63	2	0.0492	2.08
5/3			3.62	13	0.0617	1.45	7	0.0615	2.40
5/4	3	0.0357	4.10	22	0.1206	1.72	5	0.0703	2.44
5/5	0	0.0357	3.29	24	0.1850	1.88	15	0.0967	2.47
5/6	5	0.0952	4.27	1	0.1877	1.81	10	0.1142	2.34
5/7	8	0.1905	5.90	2	0.1930	1.42	6	0.1248	2.19
5/8	19	0.4167	6.38	4	0.2038	1.63	8	0.1388	2.58
5/9	8	0.5119	6.99	25	0.2708	1.88	11	0.1582	2.60
5/10	2	0.5357	7.41	25	0.3378	2.58	16	0.1863	2.30
5/11	21	0.7857	7.30	48	0.4665	3.26	6	0.1968	2.67
5/12	4	0.8333	7.92	70	0.6542	3.56	7	0.2091	2.80
5/13	0	0.8333	7.09	52	0.7936	3.38	45	0.2882	3.13
5/14	7	0.9167	7.43	16	0.8365	3.05	67	0.4060	3.34
5/15	1	0.9286	7.14	11	0.8660	3.17	60	0.5114	4.17
5/16	1	0.9405	7.55	14	0.9035	3.40	105	0.6960	3.72
5/17	0	0.9405	7.76	8	0.9249	3.35	32	0.7522	3.75
5/18	3	0.9762	7.45	6	0.9410	3.17	18	0.7838	3.67
5/19	0	0.9762	8.20	3	0.9491	3.36	25	0.8278	4.28
5/20	2	1.0000	8.91	12	0.9812	3.17	41	0.8998	4.58
5/21			8.59	4	0.9920	3.82	13	0.9227	4.89
5/22			8.37	3	1.0000	4.69	14	0.9473	4.58
5/23			8.32			4.85	1	0.9490	4.15
5/24			8.47			5.16	3	0.9543	4.93
5/25			9.63			6.05	8	0.9684	4.86
5/26			9.40			7.10	4	0.9754	4.93
5/27			8.91			8.24	13	0.9982	5.62
5/28			9.29			8.67	1	1.0000	5.70
5/29			9.51			9.20			5.00
5/30			9.03			9.33			6.45
5/31			8.77			7.74			



APPENDIX 4. —Daily and mean water temperatures for Crooked and Nikolai creeks from 2004 to 2007.