U.S. Fish and Wildlife Service

Appendices for the Report: Migration Patterns of Adult Bull Trout in the Wenatchee River, Washington 2000–2004

Barbara M. Kelly Ringel, Judy Neibauer, Kathleen Fulmer and

Mark C. Nelson

U.S. Fish and Wildlife Service
Leavenworth, Washington

***On the cover**: Two lacustrine-adfluvial adult male bull trout competing to spawn with an adult female (in the middle) in the White River drainage. USFWS photograph by Barbara M. Kelly Ringel.*

The correct citation of these appendices is:

Kelly Ringel, B. M., J. Neibauer, K. Fulmer, and M. C. Nelson. 2014. Appendices for the report: Migration patterns of adult bull trout in the Wenatchee River, Washington 2000-2004. U.S. Fish and Wildlife Service, Leavenworth, Washington. 21pp.

Disclaimers

Any findings and conclusions presented in this report are those of the authors and may not necessarily represent the views of the U.S. Fish and Wildlife Service.

Spatial information may not meet National Map Accuracy Standards. This information may be updated without notification. No warranty is made by the U.S. Fish and Wildlife Service as to accuracy, reliability, or completeness of these data for individual or aggregate use with other data. Original map data was compiled from various sources.

The mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use by the federal government.

Table of Contents

Appendix A: Tagging Information 1

Appendix B: Archival Temperature/Depth Tags and Attachment Methods 3

Appendix C: Angling in Lake Wenatchee and Icicle Creek 13

Appendix D: Pelvic Fin Ray Removal in Adult Bull Trout 19

Appendix E: Movement Summaries of Individual Bull Trout 22

Appendix A: Tagging Information

Table 1. Tagging information for bull trout captured in the Wenatchee River watershed during 2000-2003: radio transmitter code, capture location and date, length (mm), weight (g), and archival temperature/depth tag (yes or no).

Code	Capture location	Date	Length (mm)	Weight (g)	Archival Tag?
70	Lake Wenatchee	24-Jul-00	520	1,590	no
71	Lake Wenatchee	24-Jul-00	650	2,000	no
72	Lake Wenatchee	24-Jul-00	500	1,040	no
73	Lake Wenatchee	24-Jul-00	670	2,090	no
74	Lake Wenatchee	25-Jul-00	655	2,130	no
75	Lake Wenatchee	25-Jul-00	660	2,360	no
76	Lake Wenatchee	25-Jul-00	550	1,590	no
77	Lake Wenatchee	25-Jul-00	560	1,540	no
78	Lake Wenatchee	25-Jul-00	640	1,770	no
79	Lake Wenatchee	25-Jul-00	615	1,810	no
80	Lake Wenatchee	25-Jul-00	625	1,590	no
81	Lake Wenatchee	10-Aug-00	600	1,590	no
82	Lake Wenatchee	10-Aug-00	570	1,410	no
83	Lake Wenatchee	10-Aug-00	520	1,360	no
84	Chiwawa R. weir	14-Aug-00	580	1,590	no
85	Chiwawa R. weir	20-Jul-00	615	1,950	no
86	Chiwawa R. weir	20-Jul-00	605	2,130	no
87	Chiwawa R. weir	20-Jul-00	585	2,000	no
88	Chiwawa R. weir	26-Jul-00	600	1,770	no
89	Chiwawa R. weir	26-Jul-00	520	1,360	no
90	Chiwawa R. weir	26-Jul-00	520	1,320	no
91	Chiwawa R. weir	26-Jul-00	560	1,540	no
92	Chiwawa R. weir	01-Aug-00	650	2,220	no
93	Chiwawa R. weir	01-Aug-00	675	2,680	no
94	Chiwawa R. weir	01-Aug-00	555	1,540	no
95	Chiwawa R. weir	01-Aug-00	660	2,000	no
96	Chiwawa R. weir	08-Aug-00	540	1,410	no
97	Chiwawa R. weir	08-Aug-00	680	2,680	no
98	Chiwawa R. weir	10-Aug-00	535	1,270	yes
99	Chiwawa R. weir	14-Aug-00	530	1,180	no
100	Tumwater Dam	18-Jul-01	540	1,410	no
101	Lake Wenatchee	24-Jul-01	505	1,040	no
102	Lake Wenatchee	24-Jul-01	585	1,590	no
103	Lake Wenatchee	24-Jul-01	540	820	no
104	Lake Wenatchee	24-Jul-01	520	1,090	no
105	Icicle Creek	25-Sep-01	390	680	no
106	Icicle Creek	25-Sep-01	490	1,180	yes
107	Icicle Creek	26-Sep-01	530	1,540	yes
108	Lake Wenatchee	29-May-02	475	1,090	no
109	Lake Wenatchee	29-May-02	500	1,090	yes

Code	Capture location	Date	Length (mm)	Weight (g)	Archival Tag?
110	Lake Wenatchee	29-May-02	490	1,130	yes
111	Lake Wenatchee	29-May-02	492	1,220	yes
112	Lake Wenatchee	30-May-02	585	1,590	yes
113	Lake Wenatchee	30-May-02	530	1,040	yes
114	Lake Wenatchee	30-May-02	520	1,500	yes
115	Lake Wenatchee	30-May-02	500	1,180	yes
116	Lake Wenatchee	30-May-02	495	1,270	no
117	Chiwawa R. weir	30-Jul-02	640	2,590	no
118	Chiwawa R. weir	30-Jul-02	650	2,400	no
119	Chiwawa R. weir	30-Jul-02	560	1,500	no
120	Tumwater Dam	30-Jul-02	725	3,810	no
122	Tumwater Dam	30-Jul-02	470	1,000	no
123	Chiwawa R. weir	08-Aug-02	570	1,860	no
124	Chiwawa R. weir	08-Aug-02	560	1,660	no
127	Chiwawa R. weir	08-Aug-02	560	1,360	no
128	Icicle Creek	26-Aug-02	540	1,310	no
129	Chiwawa R. weir	10-Sep-02	556	1,360	no
130	Icicle Creek	12-Sep-02	490	1,130	no
131	Tumwater Dam	18-Jun-03	590	2,130	no
132	Tumwater Dam	23-Jun-03	635	2,860	no
140	Dryden Dam	06-Jul-01	-	-	no
141	Icicle Creek	25-Sep-01	400	1,540	no

Appendix B: Archival Temperature/Depth Tags and Attachment Methods

Barbara M. Kelly Ringel

Introduction

Temperature is considered a limiting factor in the distribution of bull trout (Dunham et al. 2003). During migrations adult bull trout can experience a wide range of temperatures with daily fluctuations, seasonal variation, and differences dependent on location in the watershed. Limited data are available on the temperatures encountered by individual bull trout throughout the year. The development of miniature temperature loggers that are attached to the fish allows the continuous recording of data at high resolution (Rikardsen et al. 2007). When coupled with radio-telemetry data, information on the ambient water temperatures directly experienced by bull trout throughout a stream network can be collected.

During our bull trout movement study in the Wenatchee River watershed, we participated in a cooperative project conducted by the U.S. Forest Service Rocky Mountain Research Station to test the utility of archival temperature/depth tags to monitor the ambient water temperatures of radio-tagged bull trout. Two other bull trout telemetry studies also cooperated with the research station (Salow and Hostettler 2004; Howell et al. 2010). Because these devices had not previously been used on bull trout, the first objective was to develop and test methods of externally attaching the tag. Our primary objective was to monitor the ambient water temperature of individual telemetered bull trout and depths during movements in Lake Wenatchee.

Methods

Archival tags – Archival temperature and depth data loggers (model LTD1100; Lotek Wireless, Ontario, Canada) were externally attached to a subset of radio tagged fish. The tags measured 8 x 16 x 27 mm, weighed 5.0 g in air, and estimated battery life was three years. The archival tag recorded temperature (± 0.2°C) and pressure (mbar, ± 1%) every 30 minutes. Archival tags needed to be removed from the recaptured fish to retrieve data. Pressure data was converted to depth (m) below the surface of the lake.

Tag attachment – After surgical implantation of a radio transmitter was completed, an archival tag was externally attached to the body below the dorsal fin of the bull trout. Two hollow catheter needles were used to pierce through the musculature and nylon-coated stainless steel leader material was threaded through small holes on the tag and through the catheters before they were removed. Neoprene was used to cushion the side of the fish. A plastic disc was placed over the neoprene on the non-tag side and the leader ends were secured using crimped hollow metal tubes (see Figure 1).

Recapture and observation – Recapture of tagged fish occurred during WDFW trapping operations at the Chiwawa River weir. Radio-tagged bull trout were located during mobile tracking and snorkeling was used to assess the condition or behavior of the fish and observe if the archival tag was present.

Results

Surgery- A total of 62 bull trout were radio-tagged during our study and 10 of these also received archival tags. Radio transmitter implantation surgery for bull trout without archival tags took a mean of 6 min 7 s (SD = 1 min 16 s, n = 52). External attachment of archival tags added about 2 minutes to the implantation surgery time (mean total time = 8 min 3 s, SD = 1 min 40 s, n = 10).

Bull trout recaptured- Four of the ten bull trout that received archival tags were recaptured at the Chiwawa River weir. Two fish (codes 111 and 114) recaptured in the year they were tagged had the archival tags still present. Two fish (codes 110 and 115) recaptured the following year had lost their archival tags.

Code 111 was recaptured at the Chiwawa River weir 56 days after it was tagged in Lake Wenatchee and the archival tag was removed. The bull trout had open wounds with raw abrasions under the tag and around the piercings in the musculature (Figure 1). Because the weir was in the down position and would remain so for the following three days and nights, code 111 was released at the weir site. The bull trout moved downstream from the weir into the Wenatchee River where the radio transmitter was later recovered. It was assumed that the fish had died.

Code 114 was recaptured at the Chiwawa River weir 47 days after it was tagged in Lake Wenatchee. The condition of the fish was not noted and the archival tag was left on the fish so that it could collect temperature data during migration and spawning in the Chiwawa River. It was transported by WDFW upstream 13.3 km to the designated release site but 12 days later it had moved back downstream to the weir. It held upstream of the weir for four days then continued downstream when the weir was lowered. It moved downstream in the Wenatchee River and then upstream in Beaver Creek to rkm 0.1 where the radio transmitter was later recovered. The archival tag was not found and it was assumed the fish died.

Codes 110 and 115 were recaptured at the weir 392 to 398 days after tagging. Both had lost their archival tags at an unknown date but the piercing wounds were healed and light scarring was noted at the attachment site.

Figure 1. Bull trout code 111 recaptured on July 25, 2002 showing attachment method (left photo) and the abrasions caused by the tag, neoprene, and attachment wires (right photo).

Bull trout not recaptured- Two bull trout (codes 107 and 112) were observed by snorkelers about a year after tagging but had lost the archival tag at an unknown date (Table 1). Code 107 was observed 344 days after it was tagged and open abrasions or the piercing wounds were noted but it was judged to be in healthy condition. Code 112 was observed 476 days after it was tagged and scarring was noted at the tag attachment site. The other four bull trout were never observed and the fate of the tags or condition of the fish was unknown.

Tag loss- Loss of the archival tag was confirmed for four bull trout. The fate of the tag was unknown for four bull trout that were never observed (Table 1).

Movements- Five of the archival tagged bull trout were tracked for only short periods, ranging from 52 d to 119 d, but two of these appeared to have spawned (Table 1). Four bull trout were tracked for 2 to 3 years, and one made one spawning migration while three made two spawning migrations (Table 1). One fish (code 107) was tracked for three years and was not documented in a spawning area, but this may have been a hybrid brook *x* bull trout. Thus, 70% of the archival tagged fish appeared to make movements similar to the other tagged bull trout in the study.

Table 1. Summary information for bull trout with externally attached archival temperature and pressure sensor tags.

Code	Location tagged	Date tagged	Time tracked	Spawn frequency and movements	Behavior or fate	Tag loss
98	Chiwawa	10-Aug-01	52 d	1 spawn, then to lake	normal	unknown
109	Lake Wen	29-May-02	119 d	1 spawn, then to lake	normal	unknown
110	Lake Wen	29-May-02	2 years	2x spawn, then to lake	normal	< 398 d
111	Lake Wen	29-May-02	58 d	tag removed at weir	died	removed
112	Lake Wen	30-May-02	2 years	2x spawn, then to lake	normal	< 476 d
113	Lake Wen	30-May-02	2 years	1 spawn (2nd y), to lake	normal	unknown
114	Lake Wen	30-May-02	63 d	weir trap, transported	died	No
115	Lake Wen	30-May-02	3 years	2x spawn, then to lake	normal	< 392 d
106	Icicle	25-Sep-01	53 d	Downstream of DRY	unknown	unknown
107	Icicle	26-Sep-01	3 years	Icicle, Wen R, Col R	normal	< 344 d

Temperatures and depths recorded by bull trout code 111

Temperatures- Bull trout code 111 was in Lake Wenatchee from May 29 to July 20 and recorded water temperatures ranged from 3.7 to 14.7^{o}C (Figure 2). The ambient temperature of the fish while in Lake Wenatchee varied 4.0ºC or more on 8 days, with the biggest temperature change from 4.2ºC to 12.0ºC during 8.5 hours on June 13. The bull trout was rarely in water warmer than 12ºC, and 95% of the recorded temperatures were 11.1ºC or less. The maximum water temperature recorded was 14.7ºC at 3.3 m depth on July 20 at 2145 as it migrated out of Lake Wenatchee, and when it passed the WLK station in the Wenatchee River (1.0 km downstream of the lake) at 2350, the temperature was recorded as 13.4ºC.

Code 111 arrived at the Chiwawa weir on July 21 at 2155 when the river temperature was 11.3ºC. It held downstream of the weir for four nights until trapped the morning of July 25 when the archival tag was removed. The fish was likely in the Wenatchee River during July 21 and then in the Chiwawa River during July 22 to 25. Water temperatures recorded by the archival tag during this period ranged from 10.2 to 14.0^{o}C, with the coolest temperatures in the morning (0715–0945) and warmest in the late afternoon (1515–1715). The daily water temperatures recorded in the Chiwawa River by the archival tag and by a temperature logger at the weir were within 0.2^{o}C, which is the range of error for each recording device (Table 2).

Vertical Movements in Lake Wenatchee- Bull trout code 111's archival tag recorded depth pressure in Lake Wenatchee from May 29 to July 20, 2002. Code 111 initially moved to its deepest location at 35.9 m soon after release and within a few hours moved to a depth of 2.3 m (Figure 2). This movement was likely a tagging effect, so excluding that initial depth, code 111 used depths ranging from 0.4 m to 27.9 m. Ninety percent of the time code 111 was between 0.7 m and 16.7 m and median depth was 3.6 m.

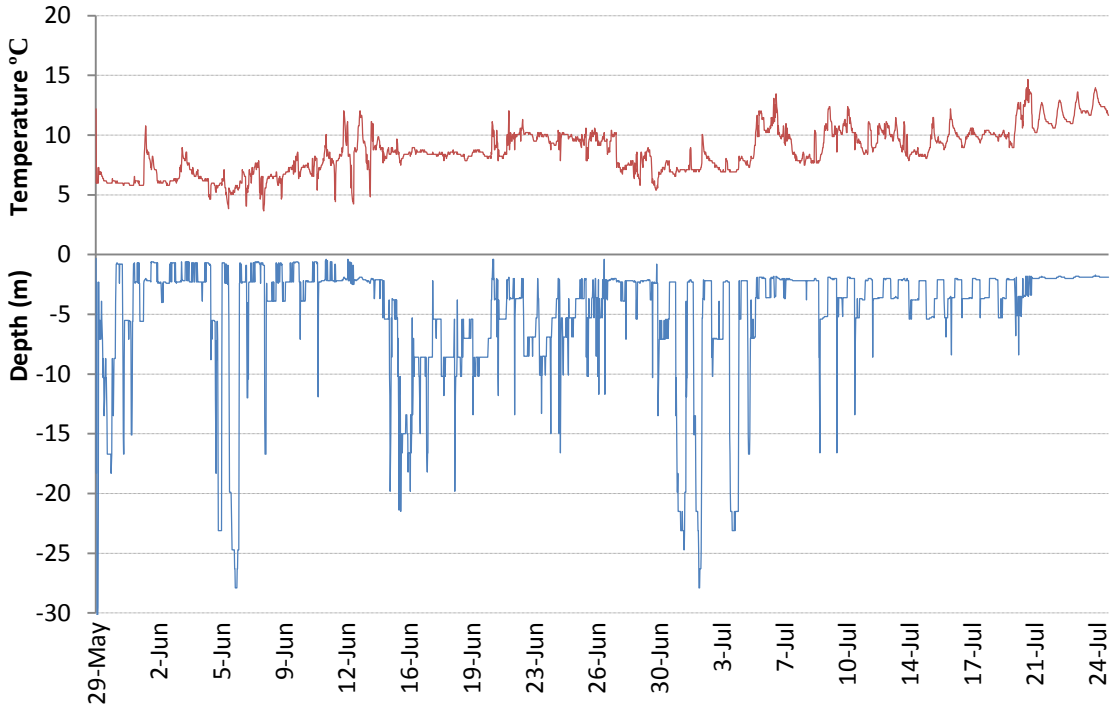

Figure 2. Archival tag temperature (°C) and depth (m) recordings for bull trout code 111 while in Lake Wenatchee May 29 to July 20, the Wenatchee River July 20-21, and the Chiwawa River July 21 to 25, 2002.

Table 2. Comparison of temperatures recorded by externally attached archival tag on bull trout code 111 and by a data logger in the Chiwawa River at the weir (rkm 0.8), July 21-25, 2002.

	Code 111 archival tag		Chiwawa River data logger	
Date	Minimum (°C)	Maximum (°C)	Minimum (°C)	Maximum (°C)
Jul 21	10.2	12.7	10.0	12.8
Jul 22	10.6	12.9	10.5	12.8
Jul 23	11.0	13.6	11.0	13.8
Jul 24	11.8	14.0	11.5	13.8
Jul 25	11.7	12.4	11.5	14.4 [a]

[a] Temperature was recorded in Chiwawa River after archival tag was removed from code 111.

Code 111 frequently moved to deeper than 6 m with most movements usually short in duration and during daytime hours. During 68% of the 53 days code 111 was detected in Lake Wenatchee, it moved to ≥ 6 m and then back up to shallower depths (Table 3), including during 73% of the days in June and 55% of the days in July. Forty-six percent of the 52 movements to ≥ 6 m depths were for less than 1 hour (thus had only one recording) and 83% of these (20 of 24) were during daytime. Fifty percent (14 of 28) of the movements to ≥ 6 m that lasted more than 1 hour were during the daytime, 43% occurred during both day and night, and 7% were entirely during the night (Table 3).

Table 3. Bull trout code 111 archival tag vertical movement to depths of 6 m or deeper in Lake Wenatchee during May 29-July 20, 2002. (In movement duration column- regular font indicates vertical movement occurred during daylight, bold font indicates movement occurred entirely at night, and *bold italic* font indicates movement occurred during both day and night).

Date	Time vertical movement began	Time vertical movement ended	Movement duration (hr:mm)	Depth (m)
29-May	2245	2315	**0:30**	7.1
30-May	1245	0115	0:30	7.1
30-May	0315	0845	***5:30***	18.3
31-May	0645	0845	2:00	16.7
31-May	1445	1515	0:30	7.1
31-May	1745	1915	1:30	15.1
5-Jun	0615	0645	0:30	7.1
5-Jun	1115	1245	1:00	18.3
5-Jun	1415	1945	5:30	23.1
6-Jun	0545	1845	***13:00***	27.9
7-Jun	0515	0715	***2:00***	12
8-Jun	0515	0645	***1:30***	16.7
10-Jun	0445	0515	**0:30**	7.1
11-Jun	0445	0515	**0:30**	11.9
15-Jun	0445	0745	3:00	19.8
15 to 17-Jun	1545	1415	***46:30***	21.5
17-Jun	1915	1945	0:30	7
18-Jun	0215	2315	***21:00***	19.8
19-Jun	0015	1745	***17:30***	10.2
19 to 20-Jun	2045	2045	24:00	10.2
21-Jun	0615	0645	0:30	11.8
22-Jun	0445	0515	**0:30**	13.4
22 to 23-Jun	1715	0845	***15:30***	8.5
23 to 24-Jun	1345	0615	18:30	13.3
24-Jun	1615	1645	0:30	15
24-Jun	1745	1845	1:00	16.6
24 to 25-Jun	2115	0445	**7:30**	10.1
25-Jun	0945	1015	0:30	6.9
25-Jun	1115	1145	0:30	6.9
26-Jun	0445	0515	**0:30**	8.6
26-Jun	0615	0645	0:30	10.2
26-Jun	0715	0745	0:30	10.2

Date	Time vertical movement began	Time vertical movement ended	Movement duration (hr:mm)	Depth (m)
26-Jun	1815	1845	0:30	8.5
26-Jun	2015	2045	0:30	10.2
26-Jun	2145	2215	0:30	11.7
27-Jun	0545	0615	0:30	11.7
28-Jun	1015	1045	0:30	7.1
29-Jun	2145	2215	0:30	10.3
30-Jun	0515	1245	7:30	13.5
30-Jun	1415	1845	4:30	7.1
1-Jul	0515	2015	15:00	24.7
2-Jul	0445	1545	***11:00***	27.9
3-Jul	0515	2015	15:00	10.2
4-Jul	0515	1715	12:00	23.1
5-Jul	0545	1545	10:00	16.7
9-Jul	0515	0615	***1:00***	16.6
10-Jul	0515	0545	0:30	16.6
11-Jul	0515	0615	***1:00***	13.4
12-Jul	0515	0545	0:30	8.6
16-Jul	1445	1515	0:30	8.4
20-Jul	0915	0945	0:30	8.4

Discussion

The archival tag project provided information about the temperature and depth regime of a bull trout in a lake and river environment. Although this information may be unique to the one fish, it is currently the only detailed data collected for bull trout in Lake Wenatchee and warrants discussion. The project also demonstrated some of the difficulties encountered while attempting to monitor temperatures at a fine scale during individual bull trout movements. These included potential effects of the archival tag or the external attachment method, interpretation of the data gathered in the lake, correlating archival data with the bull trout's location, and the limitations of the type of tag used.

Tag attachment–The neoprene pads caused excessive skin abrasions with open wounds and were not used in subsequent tagging after code 111 was recaptured. The crimping tubes we attached to the stainless steel leader did not adequately secure the tag and at least 40% of the tags were lost before the bull trout were recaptured or re-sighted. An alternate method of knotting the stainless steel leader was used in the Boise River project, but 100% of those bull trout lost the archival tag

(Salow and Hostettler 2004). The third method tested in the Boise River and the Lostine River project used nickel pins attached to Petersen discs and successfully secured the tags (Salow and Hostettler 2004; Howell et al. 2010).

Potential tag effects- Two bull trout with archival tags in this study died, including the only one whose archival tag was retrieved, and this mortality appeared related to the tag. Most of the other bull trout movements were similar to radio-tagged fish without archival tags and included migrations to spawning and overwintering areas. However, at least four bull trout lost the archival tag at unknown date and whether the others lost their tag is not known. Thus it is possible that the tags were attached for only a short time period and any effects on behavior or migration may not have been detectable. External tags place additional burdens on fish, including abrasion and infection, increased drag and physiological burden, and increased visibility to predators. Another concern with this method is that for the data to be recovered the bull trout must be recaptured, anesthetized, handled, and the tag removed- exposing the fish to additional stress and potential injury. Therefore this type of tag needs to be used with caution.

Water temperatures–While in Lake Wenatchee, code 111 was usually in water cooler than 11ºC and in areas deeper than 2 m. Since the lake does not normally undergo stratification, only the water very near the surface or shore warms up, and the fish migrated out of the lake before the hottest part of the summer. Therefore, in combination with the lack of lake temperature monitoring stations and no exact radio-telemetry positions, it was not possible to evaluate whether code 111 selected or avoided areas and depths of the lake based on water temperatures. However, frequent movements to depth and variations in daily ambient temperature indicate that at least during the period tracked, the fish moved freely within the water column. When code 111 was in the Chiwawa River just downstream of the weir the water temperatures recorded by the tag were essentially the same as recorded by the data logger in the river, indicating those moderate temperatures were adequate for the bull trout and it apparently did not need to seek out cold water refuges.

Vertical movements in Lake Wenatchee- Code 111 made frequent vertical movements to depths ≥ 6 m and many were short duration, usually 1 hour or less. Because only one archival tag was recovered, however, the uniqueness of the vertical movement patterns for a pre-spawning adult bull trout is unknown. Without radio locations, the depth profile recorded by the archival tag cannot be used to determine whether the bull trout was moving along the profile of the lake bottom or diving in the pelagic zone. Interestingly, Thompson and Tufts (1967) set sinking gill nets in Lake Wenatchee and found many bull trout traveled perpendicular to the shore along the lake bottom moving between shallow and deep water. They also found that in uniformly deeper water bull trout moved along the lake bottom parallel to the shore. This suggests that some of the changes in depth recorded by bull trout code 111 were likely due to movements from shallow

near-shore areas to deeper off-shore areas as it traveled near the bottom of the lake, perhaps cruising along the bottom to greater depths and lower light levels to prey on fish.

Predators and prey need to utilize feeding and hiding habitat to maximize growth and reduce the risk of starvation and predation (Railsback et al. 2005). Light penetrates deeply in oligotrophic Lake Wenatchee (secchi disk readings = 6.3 m, Mullan 1986) but greater depths can provide some cover for bull trout. Light intensity influences the outcome of predator-prey interactions with lower light levels favoring the predator (Cerri 1983; Howick and O'Brien 1983). Coincidentally, the majority of code 111's movements to water depths ≥ 6 m were during the day (87%), where light levels would be low. Most movements to depth were quick, one hour or less, and were perhaps attempts to find prey. However, hydroacoustic surveys in Lake Wenatchee (Dawson et al. 1973; Dawson and Thorne 1974 and 1975; Stables 2002 and 2003) indicate that bull trout prey such as juvenile sockeye salmon make daytime movements to even deeper water, with most at depths ≥ 45 m- beyond the maximum recorded depth of code 111- and thus in a temporal sanctuary from predation by bull trout. At night, juvenile sockeye salmon must move up to shallower depths or to near shore areas to feed on plankton in Lake Wenatchee (Stables 2003), and as indicated by the depth profile of code 111, bull trout make similar movements. These movements between deeper and shallower areas and use of the littoral and pelagic zones may allow the native fish assemblage in Lake Wenatchee to partition habitat and balance the risk of predation with the necessity of foraging.

Additional information about predator-prey interactions in Lake Wenatchee is needed, particularly between bull trout and sockeye salmon. Lake Wenatchee contains one of the few remaining sockeye salmon populations in the Columbia River basin and they provide a valuable sport fishery as well as forage for threatened bull trout. One technique to learn more about bull trout in the Lake Wenatchee system is use of combined acoustic and radio transmitters (CART tags) that provide three dimensional acoustic tracking in the lake and radio-tracking during migrations in the spawning tributaries. Sensor options that transmit motion, temperature and depth would eliminate the need to recapture the fish in order to recover that data. Information from these internally implanted tags, combined with limnological, bioenergetic, and hydroacoustic surveys in Lake Wenatchee, would provide a holistic and detailed ecological study of the interactions of bull trout, forage fish, and the lake environment.

Literature Cited

Cerri, R. D. 1983. The effect of light intensity on predator and prey behavior in cyprinid fish: factors that influence prey risk. Animal Behavior 31:736-742.

Dawson, J. D., R. E. Thorne, and J. J. Traynor. 1973. Acoustic surveys of Lake Wenatchee and Lake Osoyoos in 1973. 18 p.

Dawson, J. D., R. E. Thorne. 1974. Acoustic surveys of Lake Wenatchee and Lake Osoyoos in 1974. 7 p.

Dawson, J. D., R. E. Thorne. 1975. Acoustic surveys of Lake Wenatchee 1975. 5 p.

Dunham, J., B. Rieman, and G. Chandler. 2003. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management 23:894-904.

Howell, P. J., Dunham J. B., Sankovich P. M. 2010. Relationships between water temperatures and upstream migration, cold water refuge use, and spawning of adult bull trout from the Lostine River, Oregon, USA. Ecology of Freshwater Fish 2010: 19: 96–106.

Howick, G. L. and W. J. O'Brien. 1983. Piscivorous feeding behavior of largemouth bass: an experimental analysis. Transactions of the American Fisheries Society 112:508-516.

Mullan, J. W. 1986. Determinants of sockeye salmon abundance in the Columbia River, 1880's-1982: a review and synthesis.

Railsback, S. F., B. C. Harvey, J. W. Hayse, and K. E. LaGory. 2005. Tests of theory for diel variation in salmonid feeding activity and habitat use. Ecology 86(4): 947-959.

Rikardsen, A. H., O. H. Diserud, J. M. Elliott, J. B. Dempson, J. Sturlaugsson, and A. J. Jensen. 2007. The marine temperature and depth preferences of Arctic charr (*Salvelinus alpinus*) and sea trout (*Salmo trutta*), as recorded by data storage tags. Fisheries Oceanography 16(5):436-447.

Salow, T. and L. Hostettler. 2004. Movement and mortality patters of adult adfluvial bull trout (*Salvelinus confluentus*) in the Boise River Basin Idaho. U.S. Bureau of Reclamation. Boise, Idaho. 40 p.

Stables, B. 2002. Hydroacoustic survey of Lake Wenatchee, Washington May 16-17, 2002 with emphasis on sockeye fry spatial distribution. Report to Yakama Indian Nation, Toppenish, Washington.16 p.

Stables, B. 2003. Abundance, spatial distribution, and crepuscular migrations of sockeye salmon fry in Lake Wenatchee, Washington April and May 2003. Report to Yakama Indian Nation, Toppenish, Washington. 33 p.

Thompson, R. B., and D. F. Tufts. 1967. Predation by the Dolly Varden and northern squawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. Transactions of the American Fisheries Society 96(4):424-427.

Appendix C: Angling in Lake Wenatchee and Icicle Creek

Judy Neibauer

Methods

Angling was used in Lake Wenatchee and Icicle Creek to capture and tag adult migratory bull trout *Salvelinus confluentus* during our telemetry study (Kelly Ringel et al. 2013). Artificial lures with single barbless hooks and knotless nets were used as required under ESA Section 10 scientific collection permit CWFO-0. Fishing locations in the west end of Lake Wenatchee included from the WDFW sockeye salmon net pens floating near the mouth of the White River and from boats near the mouths of the Little Wenatchee and White rivers. A backpack water filter was modified as a gastric lavage pump to force water into the stomachs of untagged bull trout and discharge the contents for analysis. Stomach samples were preserved in glass jars (4 fl. oz.) containing isopropyl alcohol. Bull trout estimated to weigh less than 800 g or visually judged not in healthy condition were released without tagging.

Results and Discussion

Lake Wenatchee Angling

Locations and dates of angling- Fishing took place in Lake Wenatchee from the net pens on July 24, 25, and August 10, 2000, July 24 and September 1, 2001, and May 29 and 30, 2002 (Table 1). Boat fishing occurred on May 29 and 30, 2002 during snowmelt runoff, and the water levels in the lake and rivers were high and turbid.

Capture rates- Only two species of fish were encountered during 130 hours of angling in the west end of Lake Wenatchee. A total 48 bull trout and 23 northern pikeminnow *Ptychocheilus oregonensis* were captured for an overall catch per unit effort (cpue) of 0.37 bull trout per hour and 0.18 northern pikeminnow per hour (Table 1). The numbers and species of fish caught varied by date. No bull trout were caught on September 6, 2001. No northern pikeminnow were caught during July 2000 or May 2002. Twenty seven of the 48 bull trout captured in Lake Wenatchee were tagged, 16 were released due to their small size, 4 were released due to hooking injuries, and 1 died during removal of the hook from its gills (Table 2).

Table 1. Numbers and catch per unit effort (cpue) of bull trout and northern pikeminnow angled in Lake Wenatchee, 2000-2002.

Angling Date	Effort (hours)	n Bull trout	Bull trout cpue	n Northern pikeminnow	Northern pikeminnow cpue
May 29, 2002	10	8	0.8	0	0
May 30, 2002	15	9	0.6	0	0
July 24, 2000	15	6	0.4	0	0
July 25, 2000	15	13	0.9	0	0
July 24, 2001	13	6	0.5	5	0.4
Aug 10, 2000	8	6	0.8	3	0.4
Sept 6, 2001	54	0	0	15	0.3
Overall Totals	***130***	***48***	***0.37***	***23***	***0.18***

Stomach contents- Stomach samples were collected from three bull trout that were caught but not tagged on May 29 and 30, 2002 (Table 2). Two of these bull trout (480 and 590 g) had empty stomachs but the largest (730 g) contained enough worms (Oligochaeta) to fill three sample jars. Several other adult migratory bull trout caught at the same time near the mouths of the Little Wenatchee and White Rivers also appeared to have very full stomachs, but because they were selected for radio-tagging, stomach contents were not collected.

Table 2. Data for all bull trout (tagged and untagged) captured during angling in Lake Wenatchee, 2000-2002.

Date	Code	Length (mm)	Weight (g)	Notes
Jul 24, 2000	70	520	1,590	tagged
Jul 24, 2000	71	650	2,000	tagged
Jul 24, 2000	72	500	1,040	tagged
Jul 24, 2000	-	unk	955	too small
Jul 24, 2000	-	unk	550	too small
Jul 24, 2000	-	unk	unk	too small
Jul 25, 2000	73	670	2,090	tagged
Jul 25, 2000	74	655	2,130	tagged
Jul 25, 2000	75	660	2,360	tagged
Jul 25, 2000	76	550	1,590	tagged
Jul 25, 2000	77	560	1,540	tagged
Jul 25, 2000	78	640	1,770	tagged
Jul 25, 2000	79	615	1,810	tagged
Jul 25, 2000	80	625	1,590	tagged
Jul 25, 2000	-	510	1,090	mortality (hooked in gills)
Jul 25, 2000	-	unk	unk	too small
Jul 25, 2000	-	unk	unk	too small
Jul 25, 2000	-	unk	unk	too small
Jul 25, 2000	-	unk	unk	too small
Aug 10, 2000	81	600	1,590	tagged
Aug 10, 2000	82	570	1,410	tagged

Aug 10, 2000	83	520	1,360	tagged
Aug 10, 2000	-	unk	unk	too small
Aug 10, 2000	-	unk	unk	too small
Aug 10, 2000	-	unk	unk	too small
Jul 24, 2001	101	505	1,040	tagged
Jul 24, 2001	102	585	1,590	tagged
Jul 24, 2001	103	540	820	tagged
Jul 24, 2001	104	520	1,090	tagged
Jul 24, 2001	-	400	unk	too small
Jul 24, 2001	-	300	unk	too small
May 29, 2002	108	475	1,090	tagged
May 29, 2002	109	500	1,090	tagged
May 29, 2002	110	490	1,130	tagged
May 29, 2002	111	492	1,220	tagged
May 29, 2002	-	390	590	stomach empty
May 29, 2002	-	380	770	hooked in eye socket
May 29, 2002	-	unk	unk	hooked in eye socket
May 29, 2002	-	unk	unk	hooked in eye socket
May 30, 2002	112	585	1,590	tagged
May 30, 2002	113	530	1,040	tagged
May 30, 2002	114	520	1,500	tagged
May 30, 2002	115	500	1,180	tagged
May 30, 2002	116	495	1,270	tagged
May 30, 2002	-	unk	unk	hooked in gills
May 30, 2002	-	405	730	stomach full of worms
May 30, 2002	-	370	480	stomach empty
May 30, 2002	-	unk	unk	too small

Fish condition- During angling, some of the larger bull trout were caught in July, and the smallest were caught in May (Figure 1). Bull trout captured in May were noticeably thinner with less abdominal muscle mass compared to those captured in July. These skinnier fish were caught off the mouths of the White and Little Wenatchee rivers and seemed to be located strategically to forage on worms or other prey being flushed out of the tributaries during higher spring flows.

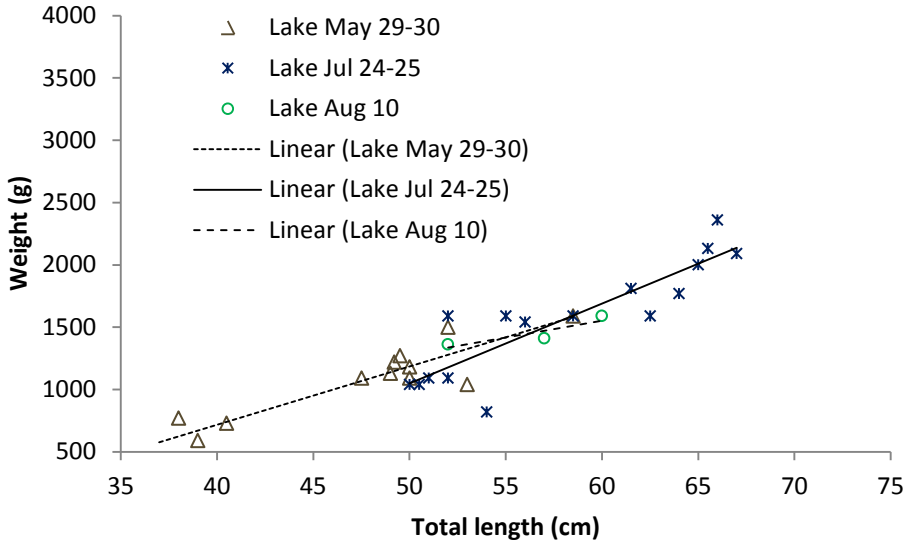

Figure 1. Scatter plot of lengths and weights of bull trout captured and measured in Lake Wenatchee (n = 32, including 27 tagged and 5 untagged fish) during three seasonal capture periods, 2000-2002.

Hooking injuries- During angling in Lake Wenatchee in 2000 and 2001, a total of 31 bull trout were caught and one died when hooked in the gills. In 2002, during the last period of angling in Lake Wenatchee on May 29-30, 4 of the 17 captured bull trout were injured by the hook puncturing the eye (3 fish) or the gills (1 fish) (Table 2). All swam away when released, including three with the hook still in the fish to prevent further damage during attempts to remove the hook. The injuries were thought to be caused by the hooking action of the straight shank J-style hooks that were being used on the lures. These were replaced with hooks with a smaller gape and curved point ("circle" style) and no further injuries were noted during angling in Icicle Creek that was conducted later in 2002.

Icicle Creek Angling

Capture location and dates- Fishing occurred on several dates during September 2001 and August and September 2002 at the Leavenworth National Fish Hatchery spillway pool on Icicle Creek (rkm 4.3).

Capture rates: In Icicle Creek, during 22.5 hours of angling a total of 8 bull trout were captured for an overall cpue of 0.36 bull trout per hour (Table 3). The number of bull trout caught varied by date with the majority caught on September 25, 2001. No bull trout were caught on August 29, 2002. One hatchery spring Chinook salmon was caught and released.

Table 3. Numbers and catch per unit effort (cpue) of bull trout angled in Icicle Creek, 2001-2002.

Angling Date	Effort (hours)	n Bull trout	n Tagged	cpue
Sep 25, 2001	6	4	3	0.67
Sep 26, 2001	4.5	1	1	0.22
Aug 26, 2002	3	1	1	0.33
Aug 29, 2002	3	0	0	0.00
Sep 03, 2002	3	1	0	0.33
Sep 12, 2002	3	1	1	0.33
Overall Totals	***22.5***	***8***	***6***	***0.36***

Stomach contents and fish condition- No stomach contents were sampled from bull trout captured in Icicle Creek. Untagged fish were not measured. See the results section in our final study report for information on the condition of bull trout tagged in Icicle Creek (Kelly Ringel et al. 2013).

Hooking injuries- In Icicle Creek during 2001, artificial lures with barbless straight shank J-style hooks were used but no hooking injuries to the five captured bull trout were observed. In 2002, after injuries were noted in Lake Wenatchee, only hooks with the curved point were used in Icicle Creek. No hooking injuries occurred to the three captured bull trout.

Washington Department of Fish and Wildlife adopted our proposal that selective gear rules (barbless hooks and artificial lures) be applied to Lake Wenatchee for the 2004/2005 fishing regulations. Circle hooks with a straight eye and an inline point curving 270° toward the shank are also effective at reducing deep hooking injuries (Prince et al. 2002; Cook and Suski 2004; Sullivan et al. 2013) and is the hook style we recommend for angling where bull trout may be incidentally caught.

Literature Cited

Cooke, S. J. and Suski C. D. 2004. Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? Aquatic Conservation: Marine and Freshwater Ecosystems 14:299-326.

Kelly Ringel, B. M., J. Neibauer, K. Fulmer, and M. C. Nelson. 2014. Migration patterns of adult bull trout in the Wenatchee River, Washington 2000-2004. U.S. Fish and Wildlife Service, Leavenworth, WA. 81pp with separate appendices.

Prince, E. D., M. Ortiz, and A. Venizelos. 2002. A comparison of circle hook and "j" hook performance in recreational catch-and-release fisheries for billfish. American Fisheries Society Symposium 30: 66-79.

Sullivan, C. L., K. A. Meyer, and D. J. Schill. 2013. Deep hooking and angling success when passively and actively fishing for stream-dwelling trout with baited J and circle hooks. North American Journal of Fisheries Management 33:1-6.

Appendix D: Pelvic Fin Ray Removal in Adult Bull Trout

Mark C. Nelson

Growth rates and age are largely unknown for bull trout *Salvelinus confluentus* in the wild. Techniques for estimating age and growth in captured fishes usually involve the analysis of calcified anatomical structures such as otoliths or scales. However, use of either of these structures is not generally feasible for bull trout. Obtaining otoliths requires the death of the fish, but in order to obtain meaningful population information, the high number of individuals needed to be sacrificed renders the technique inappropriate for threatened bull trout. Scales of bull trout are small and frequently regenerate, with the annuli of older individuals difficult to discern or accurately measure (Mullan et al. 1992). Thus, fin rays may be more suitable for ageing bull trout (Zymonas and McMahon 2009).

During our telemetry study of migratory adult bull trout in the Wenatchee River we collected pelvic fin rays from a subset of bull trout that were radio-tagged (Kelly Ringel et al. 2014). After an adult bull trout was anesthetized and lost equilibrium during preparations for transmitter implantation surgery, the leading one or two rays from the left pelvic fin were excised near the base with surgical scissors and placed in an envelope to dry.

Eight adult bull trout had pelvic fin ray excision during transmitter implantation surgery in 2002. All were captured during the summer months and water temperatures ranged from 10 to 15.5°C (Table 1). Three of the bull trout (38%) were tracked over 2 or 3 years and made at least one migration to a spawning area. Five of the eight (62%) made unexpected downstream movements within 4 to 23 days after tagging and fin ray removal. Four of these bull trout likely died: three transmitters (codes 123, 128, 129) were recovered and one transmitter (code 119) was located beneath rocks on the shore. The fifth bull trout (code 120) was tagged at Tumwater Dam but was last detected moving downstream past the Dryden Dam telemetry station four days later and that signal was never located again so it was suspected the fish had died.

Code 129 was tagged at the Chiwawa River weir late in the pre-spawning migration and moved upstream where it was detected by the fixed telemetry station near Rock Creek. It moved back downstream within a few hours but may have spent a brief period in a spawning area before it died.

Table 1. Tagging and movement histories of eight radio-tagged bull trout that also had pelvic fin ray excision in 2002.

Code	Length (mm)	Tagging T°C	Tagging date	1st Downstream movement date	Tracked to spawn area?	Days tracked	Tag recovered?
118	650	13	7/30/02	9/20/02	yes	3 yr	-
119	560	13	7/30/02	8/21/02	no	22 d	no
120	725	15.5	7/30/02	8/03/02	no	4 d	no
123	570	10	8/08/02	8/17/02	no	8 d	yes
124	560	10	8/08/02	10/01/02	yes	3 yr	-
127	560	10	8/08/02	10/07/02	yes	2 yr	-
128	540	15	8/26/02	8/31/02	no	23 d	yes
129	556	10.5	9/10/02	9/22/02	maybe	17 d	yes

In total, 5 of the 8 bull trout (62%) that had pelvic fin ray excision died or were assumed dead less than a month after tagging. This was a much larger percentage of presumed mortality shortly after surgery than occurred for the other tagged bull trout in the overall telemetry study (10 of 54 bull trout; 19%) and circumstantial evidence suggests fin ray removal may have been a causative factor. Other stresses including tag implantation surgery and resultant infections, relatively warm water temperatures during tagging (two surgeries were at 15 and 15.5°C), warm stream temperatures in the days after release, and tagging too close to the spawning season may have also contributed to their deaths.

A laboratory study conducted on captive subadult bull trout suggested that removal of pelvic fin rays was probably not deleterious to age 3 (209-298 mm) and age 4 (294-362 mm) fish but cautioned those results may not be applicable to large adults (Zymonas and McMahon 2006). They recommended field evaluations of the technique and noted that pelvic fin ray removal could reduce growth or survival of bull trout in the wild by affecting their ability to elude predators, capture prey, maneuver, or withstand pathogens.

We are not aware of any specific studies on large wild bull trout, but our observations of the unusual behavior and high mortality of the fish in our small sample indicate the technique may have deleterious effects on adult bull trout. Furthermore, we suspect that the visually striking white leading edge of the pelvic fin in adult bull trout may be a secondary sexual characteristic important in courtship or competition for mates (see cover photo of spawning adults) and its removal could potentially reduce individual reproductive success. Although pelvic fin rays may regenerate, the process takes over a year (Zymonas and McMahon 2006), and ray removal could potentially affect a mature adult over more than one spawning season. Therefore, based on our observations, we recommend that further studies be conducted on adults before the technique is warranted for use on wild populations of bull trout.

Literature Cited

Kelly Ringel, B. M., J. Neibauer, K. Fulmer, and M. C. Nelson. 2014. Migration patterns of adult bull trout in the Wenatchee River, Washington 2000-2004. U.S. Fish and Wildlife Service, Leavenworth, Washington. 81pp with separate appendices.

Mullan, J. W., K. R. Williams, G. Rhodus, T. W. Hillman and J. D. McIntyre 1992. Appendix K *in* Production and habitat of salmonids in Mid-Columbia River tributary streams. U.S. Fish and Wildlife Service, Leavenworth, Washington.

Zymonas, N. D. and T. E. McMahon. 2006. Effect of pelvic fin ray removal on survival and growth of bull trout. North American Journal of Fisheries Management 26:953-959.

Zymonas, N. D. and T. E. McMahon. 2009. Comparison of pelvic fin rays, scales, and otoliths for estimating age and growth of bull trout, *Salvelinus confluentus*. Fisheries Management and Ecology 16:155-164.

Appendix E: Movement Summaries of Individual Bull Trout

Available on request- contact USFWS Mid-Columbia River Fishery Resource Office