Experimental Bull Trout Hatchery

Progress Report Two
Experimental Broodstock Development

1995 - 1997

by

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August, 1998

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ACKNOWLEDGMENTS

The author would like to thank Montana Power Company, particularly Jon Jourdonnais, who provided the funding to develop and equip the bull trout isolation facility. The staff at Creston National Fish Hatchery spent countless hours caring for, feeding, and cleaning the tanks and were also invaluable in the success of this program. In particular I thank Dan Carty, Mark Maskill, Don Edsall, Jon Lane, Gar Holmes, John Scott, Jim Till and Dave Bermel. This program was partially supported by Bonneville Power Administration under the Hungry Horse Mitigation program.

EXECUTIVE SUMMARY

This report is a summary of research findings from experimental bull trout culture work conducted at Creston National Fish Hatchery during 1995 through 1997. Bull trout raised in the hatchery grew at rates considerably exceeding those of wild stocks. The accelerated rate of growth in the hatchery appeared to markedly affect age of maturation. Approximately one-third of males were sexually mature at age 2 (1996). Nearly all males and most females (80+ %) were sexually mature at age 3 (1997). Paired matings of experimental broodstock produced an average eyeup rate of 70.5% in 48 incubation test lots during 1997. Spawning in the hatchery peaked in late September, similar in timing to wild stocks. Thermal conditions in the spring-fed water supply at Creston National Fish Hatchery appear ideally suited to bull trout broodstock development, although further experimentation is needed to refine rearing and spawning techniques.

BACKGROUND

In 1993 a grant was obtained from the Montana Power Company to retrofit an existing building at the USFWS Creston National Fish Hatchery (CNFH) in Kalispell, Montana to allow for experimental work with bull trout to proceed. In August of that year, an isolation facility with a water chiller, Heath incubator, and rearing tanks was constructed.

A previous progress report (see Progress Report 1, Fredenberg et al. 1995) described the fish culture work conducted at the bull trout hatchery in calendar years 1993 and 1994. Included was a detailed discussion of the methods used to rear juvenile bull trout from eggs collected from wild parents in Lion Creek and Holland Creek in the Swan River drainage. The primary purposes of that study were:

1.) To evaluate thyroid hormone levels and the relationship to imprinting. The project was completed and the results summarized in a manuscript submitted to the North American Journal of Fisheries Management in August, 1998 (Fredenberg et al. 1998).

2.) To develop and improve fish culture techniques necessary to raise bull trout in a hatchery environment. This objective is continued in this report.

The Columbia River and Klamath River populations of bull trout were listed as "threatened" under the Endangered Species Act by the U.S. Fish and Wildlife Service on June 10, 1998 (USFWS 1998). Juvenile bull trout have been successfully raised in hatcheries in several states and Canada (Goetz 1989). However, a review of the literature did not indicate that other hatcheries have succeeded in rearing captive bull trout for broodstock purposes. In 1996 and 1997 we continued rearing juvenile bull trout from the 1993 egg collection in order to evaluate the feasibility and complications of a captive bull trout brood program. The potential exists for restoration stocking or supplementation of bull trout from hatcheries to be employed as a tool in bull trout recovery (Montana Bull Trout Scientific Group 1996).

This report discusses those experimental efforts to rear bull trout broodstock at Creston National Fish Hatchery from 1995-1997. Included are data on growth, maturation, and viability of gametes as well as insights on problems encountered and recommendations for future efforts. The material in this report is presented as a summary of study results, and has not been extensively peer-reviewed for publication. Opinions presented are mostly those of the author, and do not necessarily represent the position of the U.S. Fish and Wildlife Service.

METHODS

On September 19-21, 1993, about 20,800 eggs were collected from seven wild female bull trout taken off redds in two tributaries to the Swan River drainage of northwest Montana (Fredenberg et al. 1995). About 30% of the eggs collected were from Lion Creek, and the remainder (70%) from Holland Creek (see Fredenberg et al. 1995). These two stocks represent somewhat different life history types. Adults from the Lion Creek stock migrate at least 41 km upstream from Swan Lake to spawn in Lion Creek and the juveniles rear in the stream for up to four years before returning to Swan Lake. On the other hand, adult fish from the Holland Lake stock migrate only a few hundred meters upstream from Holland Lake to spawn in Holland Creek, and the juveniles are believed to rear primarily in the lake.

Each wild female spawned in 1993 was hand-stripped into a bowl and then sperm from one or two males captured in the vicinity was dripped into the bowl and mixed. After a few minutes, water from the stream was added and the eggs were rinsed and deposited in a bucket containing a solution of Betadyne. Eggs were water hardened in the iodophor solution for one hour, then transported to Creston National Fish Hatchery and placed in the incubator trays; generally within three hours of spawning.

It is well-established that bull trout eggs require very cold incubation temperatures for normal development (McPhail and Murray 1979). We incubated the eggs in 1993 at an average temperature of 3.1°C. Eggs were incubated in an 8-tray Heath stack and examined periodically (at least once every two weeks) during incubation. Dead eggs and/or alevins and severely crippled fry were picked off and enumerated. Egg survival in all lots averaged 97.4% from unfertilized egg to eyeup and 97.1% from unfertilized egg to hatch.

After the alevins neared swimup in March 1994, they were transferred to 283 liter rearing troughs (see Fredenberg et al. 1995). Throughout rearing, feed was delivered with a Ziegler automatic belt feeder placed at the head of the rearing tank. All fry were initially fed Biodiet Bio-trainer #1 (Bio-Products Inc., Warrenton Oregon). Rations were carefully weighed out and fish were fed 2.0-4.0 percent of body weight daily.

At the conclusion of phase one of the thyroid monitoring study (October 24, 1994) the fish were moved to a set of larger fiberglass tanks (approx. 2,000 liter). Care of the fish throughout phase two of the thyroid study (November 1994-May 1996) continued as described above with the exception that diet was switched to Silver Cup salmon feed (Nelson and Sons Inc., Murray, Utah) and fish were fed to satiation. Plasma thyroxin samples were collected every other week from 10 fish (occasionally only 5) sampled at random. Each fish was anaesthetized, measured to the nearest 0.1 mm, and weighed on an analytical balance (0.01g). Throughout the thyroxin study the two stocks (Holland and Lion) were maintained in separate tanks. These fish were the source of

some of the growth data included in this report, but they were depleted during the thyroxin study and a separate lot of fish became the experimental broodstock.

On August 26, 1994 an estimated 12,000 bull trout surplus to the thyroxin study were transferred from the isolation facility to tanks set up in a sheltered raceway. The two stocks (Lion and Holland) were combined and from that point on individuals were not distinguishable, although the original ratio of about 70% Holland stock and 30% Lion stock was probably maintained due to random sorting. Problems were encountered with fish jumping out of those tanks, so on December 15, 1994 the remaining (approximately 9,000) fish were moved from the covered fiberglass tanks to an outdoor raceway. After December 15, 1994 experimental broodstock were maintained in an outdoor raceway.

In March of 1995 it was noted that the bull trout in the raceway were easily frightened and repeatedly stressed by activity or movement and they tended to crowd up at the head of the raceway. Since being moved outside in December, 1994 the fish were being hand fed during the normal daytime hatchery schedule, but did not feed aggressively. Condition factor and fin quality of randomly selected individuals was noted to be poor at that time. To reduce stress, several surplus aluminum baffles (approximately 1 m X 2.5 m) were placed in the raceway, elevated approximately six inches off the bottom on cinder blocks to simulate natural overhead cover. Fish rapidly began using these for shelter during daylight hours. The feeding regimen was modified to return to the use of belt feeders, which were loaded in late afternoon (approximately 1400-1600 hours) and allowed to dispense feed for a six hour period into the evening.

In June, 1995 high mortality rates (up to 0.5% per day) were experienced in the bull trout stock maintained in the outdoor raceway and furunculosis (*Aeromonas salmonicida*) was determined to be the cause. Treatment of the bacterial disease with oxytetracycline was initiated and the infection subsided, only to recur in August, 1995. A treatment of Romet-30 was effective in reducing the outbreak. During 1996 and 1997 several more furunculosis outbreaks occurred in these fish, typically in March-April or in September associated with spawning, and all were successfully treated with Romet-30 although mortalities occurred with each outbreak.

On April 11, 1996 about 5,300 surplus fish from this lot were stocked into Duck lake on the Blackfeet Indian Reservation. The remaining 400 fish were kept at CNFH, forming the base for the experimental broodstock discussed in this report. Raceway conditions (with baffle shelters and belt feeding in the evening) were maintained throughout 1996 and 1997.

Throughout incubation and rearing, water temperatures were monitored with Hobo-Temp remote sensing devices placed in the water. Data from these devices was periodically downloaded and summarized on a computer file. Daily maximum

temperatures in raceway #1 (highest of six daily readings recorded for 1996 and 1997) were summarized in this report to illustrate the normal range of water temperatures bull trout broodstock were reared in.

Bull trout in the outdoor raceway were inventoried approximately quarterly, with a subsample of approximately 100 fish measured (0.1 mm), weighed on an electronic balance (2.0 g), and evaluated for obvious abnormalities, signs of disease, and reproductive condition. During 1996 and 1997 several evaluations were made during the prespawning and spawning periods.

In 1997 mature fish from the experimental broodstock at Creston National Fish Hatchery were spawned for the first time (age 3). Spawning procedure was similar to that successfully used in the wild in 1993 and 1994 (Fredenberg et al. 1995). Fish were sorted on August 13, sexed, and tagged with individually numbered visual implant tags in the right ocular postorbital region. At this time, approximately 30 males were already ripe, expelling milt when stripped. No ripe females were encountered. Beginning September 10, 1997, the fish were sorted weekly, with males placed in a separate raceway, ripe females spawned, and nonripe females and immature fish placed above a screen for weekly follow-up examination.

Each ripe female was anaesthetized in a solution of MS 222, wiped dry to reduce chances of transferring mucus or bacteria, and air-spawned (using injected bottled oxygen) with eggs deposited into a plastic container in a solution of 0.5% saline. An effort was made, using shaking and gentle pressure, to remove all eggs. Ripe males were retrieved at random from a pool of previously unused fish, anaesthetized and wiped dry, and their milt expressed directly into the egg container. Fertilized eggs were thoroughly mixed and left undisturbed for five minutes. All fish were mated 1:1, and all procedures were conducted under a shade tarp to reduce direct sunlight on sunny days. After five minutes fertilized eggs were rinsed in clean spring water, placed in individually numbered containers, and water hardened for 30 minutes in a closed cooler in 50 ppm iodophor solution. Water hardened eggs were then sampled for size, volumetrically enumerated, and transferred into a Heath incubator set up with six individually numbered isolation compartments per drawer in the bull trout isolation facility. Length and tag number of each spawned pair was recorded on a data sheet corresponding to individual incubator compartment. Fish that had shed their original tag were retagged at the time of spawning.

Eggs collected from the broodstock in 1997 were incubated in chilled well water at an average temperature of 5.8°C (5.0 °C minimum, 6.6°C maximum). Temperature fluctuated rhythmically up to 1°C as the chiller cycled on and off. Eggs were monitored weekly and dead eggs picked off and enumerated from each compartment as needed (but at least every other week to prevent fungal growth). Because the Heath incubator drawers were compartmentalized there may have been some interruption of the optimal

water circulation pattern. It was felt this might have reduced egg viability in certain compartments that were more heavily stocked with eggs.

At this incubation temperature (5.8°C) eggs eyed in about 54-56 days (313-325 °C temperature units) and were completely hatched in about 88-90 days (510-522 °C temperature units).

Fry that were produced from these experiments were reared at CNFH through the end of June, 1998. Most were distributed to research facilities and/or preserved for specimens. No growth or survival data were collected, but development was monitored and appeared to be normal.

RESULTS

Water supplied to outdoor raceways at Creston National Fish Hatchery is from groundwater springs that flow into 20-acre Jessup Mill Pond. Air temperature and solar heating influences the temperature of water in the pond that flows downstream to the hatchery. Maximum annual variation is about 8°C. A thermograph installed in raceway #1 (at the top of the hatchery, nearest the source) where the bull trout were held for a two-year period (1996-1997), illustrates the normal range and variability of seasonal and annual water temperatures (Figure 1). Normal daily maximums were 1°C or less above the daily minimum. In general, maximum daily temperatures increased slowly from February through April, stabilized near peak values of 7-9°C in May through August, then declined in September through November to minimum values of 2-3°C in December and January. Within this general pattern ambient weather conditions and or/ice may moderate the norm by up to 2°C.

In general, bull trout are a slow-growing, late-maturing salmonid that is adapted to cold water conditions (Pratt 1992). Under natural conditions most fish of the migratory form spend up to four years in natal tributaries before emigrating to larger streams or lakes to mature. They do not begin reproducing until age 4 at the earliest, but commonly do not reach sexual maturity until age 5 or older (Pratt 1992, Fraley and Shepard 1989, USFWS 1998). Growth rates of bull trout held at Creston Hatchery (Figure 2) greatly exceed those of their wild counterparts (Table 1). In general, 3½ year old hatchery fish (August 1997) achieved lengths equivalent to those normally seen at about age six in wild fish.

In hatchery bull trout, weight increase during 1995 (age 1) paralleled length increase. Weight gain began to dramatically exceed length gain at about mid age 2, after fish exceeded approximately 300 mm in length (Figure 2). Condition factor (K) of age 1 and 2 fish sampled for thyroxin analysis (1995 through April 1996) ranged between 0.82 and 0.95, showing little evidence of seasonal variation or trend prior to sexual maturity.

The accelerated rate of growth in the hatchery appeared to lead to early maturation in hatchery fish as well. Fraley and Shepard (1989) noted that most bull trout spawners in wild runs of the North and Middle Forks Flathead were age 6 or 7 (73-83%) with the youngest at age 5 (10-24%). Age 5 was also the youngest age of spawners in the Swan system (Fraley and Shepard 1989), but there younger fish comprised a higher percentage of the total (33-43%).

<u>1996 Maturation and Spawning</u>

All age 2 bull trout held for the broodstock experiment were individually examined on July 31, 1996 (n = 359). At that time approximately 18% were judged to be sexually maturing males, with characteristic darkening of pigmentation and development of a sharply pointed lower jaw (kype). Average length of mature males (309 mm) and size

Table 1. Back-calculated range of length (mm) at age for wild bull trout from Montana river basins, compared to mean (and approximate range) of known age hatchery fish reared at Creston National Fish Hatchery. Flathead data from Fraley and Shepard (1989); Swan data from Leathe et al. (1985); Saint Mary data from Mogen (1998).

Age	Flathead (Wild)	Swan (Wild)	Saint Mary (Wild)	Creston Hatchery
1	52 - 75	48 - 76	64 - 77	95 (80 - 110)
2	98 - 129	92 - 120	117 - 147	230 (176 - 283)
3	139 - 204	126 - 179	187 - 233	323 (293 - 375)
4	228 - 360		298 - 328	439 (393 - 487)
5	384 - 440		388 - 412	
6	472 - 538		450 - 474	
7	566 - 574		510 -539	
8	655 - 658		558 - 578	
9	731		630	

Table 2. Weekly progression of female bull trout maturity, number spawned, and number incubated in test series during 1997.

Date	# Ripe	# Spawned	# Incubated
9/10	4	4	4
9/17	8	8	7
9/24	53	32	20
10/1	Not Checked	21 (Held from previous week)	11
10/8	36	36	6
10/15	Not Checked	0	0
10/22	9	9	0
Total	**110**	**110**	**48**

range was consistent with the population mean (295 mm) and size range.

A follow-up inventory on September 27, 1996 (n=343) found 62 fish (18.1%) were ripe males, freely expelling milt when stripped. No sexually mature females were found. The mean length (319 mm) and size range (283-367 mm) of sexually mature males was again consistent with the population as a whole (mean length = 323 mm; range = 271-375 mm). Assuming a 1:1 sex ratio, approximately one-third of age 2 male bull trout in the experimental broodstock were sexually mature. This is two or three years earlier than sexual maturity normally occurs in the wild, although the size of mature fish is consistent with many wild populations. A final 1996 evaluation of the broodstock on October 24 found 59 fish that were mature males, with most still producing milt when stripped. There were no mature females at age 2.

1997 Maturation and Spawning

In 1997, the experimental broodstock (age 3) were first evaluated for sexual maturity on August 12 (n = 315). At that time the average length was 439 mm (range = 336-522 mm). On August 12, we segregated 138 fish (44% of the total) that were identified as males; 32 of these (23% of the males) were classified as ripe. Males exhibited characteristic dark pigmentation, a well-developed kype, and a prominent premaxillary notch on the tip of the snout. Another 98 fish (31% of the total) were classified as adult females (based on body and head shape), and the rest (25% of the total) could not be classified.

On August 12, 1997 all fish in the population were tagged with individually numbered visible implant (VI) tags. At the time, it was noted that tagging was difficult. Due to the dark pigmentation in the postorbital tissue, tags had to be applied very close to the surface to maintain readability, and we were concerned about retention. In fact, only 142 fish (45% of those that survived) retained their tags until October 22 (10 weeks). Twenty-three tagged fish died during the 10-week period due to stress associated with spawning and/or furunculosis.

These 142 tagged fish were useful in assessing the progression of maturity. Sixty-six tagged fish (46%) were originally classified as males on August 12, and sixteen of those were ripe at that time. On September 10 (4 weeks later) 61 of the original 66 males were ripe, one previously ripe male was spent (no milt), and five fish were reclassified as either female or immature. Thus, we concluded that sexing of males a month prior to spawning was 92% accurate. None of sixteen males originally classified as ripe on August 12 were still ripe ten weeks later, but many of those first classified as ripe on September 10 were still producing milt six weeks later on October 22.

Of 42 fish originally classified as female on August 12, 1997 a total of 34 eventually produced eggs (81%) and the remainder did not mature in 1997. None were later found to be males. Some females originally classified on August 12 were not ripe until

October 22, ten weeks later.

In the final analysis, during the fall of 1997, the sex of 273 fish was accounted for. Sex was not accounted for of another 17 that died. A total of 134 of the 273 fish (49.1%) were males, 110 (40.3%) were females, and 29 (10.6%) did not mature in 1997. Thus the sex ratio of reproductive age 3 bull trout was 1.2:1 male to female. If the majority of the immature fish were female (as is likely), then the sex ratio was very near 1:1.

The first ripe females (four fish) were mated on September 10, 1997, with subsequent takes at weekly intervals for the next four weeks (Table 2). The eggs from the final take on October 22 were not kept. Nearly half of the total female spawners were ripe in the third week of spawning; represented by a peak date on September 24. Due to mortality and concerns about handling stress, the fish were not checked every week. Twenty-one of the females determined to be ripe on September 24 were held an extra week and spawned on October 1 (Table 2).

Of the 110 females that produced eggs in 1997, forty-eight individuals across the first five weekly takes were selected and mated for incubation trials (Table 3). The rest were either incubated collectively and used for other research, or the eggs were discarded without incubating. Mated males ranged from 395-520 mm in length, averaging 453 mm. The 48 females they were paired with ranged from 382-512 mm in length, averaging 443 mm.

Egg sizes of the 48 females in the incubation test, as determined by Von Bayer trough, were between 318-423 per ounce with a mean of 360 eggs per ounce (Table 3). These eggs were smaller than those taken from wild fish in 1993 and 1994, which averaged 253/oz. Fecundity ranged from 201-2,851 with an average of 1,493 eggs per female and a total of 71,641 eggs from the 48 females.

In the incubation trials, 70.5% of the eggs eyed up (Table 3). Eyeup was highest in the second and third takes (September 17 and 24) averaging 86%, then declined dramatically to 45% for the October 1 take and 41% for the October 8 take. Variation in eyeup among the 48 individual lots ranged from 1-99%. Attrition from eyeup to hatch was 4-6% during the September takes, but increased to 9-14% during October. The overall hatch rate (55%) was somewhat skewed downward by the fact that 12 lots from the peak take (September 24) were shipped out as eyeup eggs for a research project. Of the remaining 36 individual lots, survival from green egg to hatch ranged from 0-97%. Collective survival from green egg to hatch was highest in the second and third takes, at about 80%.

Table 3. Spawning and egg incubation statistics from Creston National Fish Hatchery experimental bull trout broodstock during 1997 (subtotals and totals in bold, means in parentheses).

SPAWN DATE	MALE LENGTH (mm)	FEMALE LENGTH (mm)	EGG SIZE (#/oz)	# GREEN EGGS	# EYEUP	# HATCHED	% EYEUP	% HATCH
9/10	431	?	-	396	89	65	22.5	16.4
"	457	445	369	1,773	1,447	1,426	81.6	80.4
"	497	457	401	1,833	1,690	1,643	92.2	89.6
"	479	447	373	1,163	240	129	20.6	11.1
SUB TOTAL 9/10 (n=4)				**5,165** (1,291)	**3,466** (866)	**3,263** (816)	**67.1**	**63.2**
9/17	467	512	369	2,851	2,770	2,569	97.2	90.1
"	455	417	369	1,830	1,772	1,763	96.8	96.3
"	421	382	351	755	522	491	69.1	65.0
"	448	447	360	1,396	925	757	66.3	54.2
"	466	440	360	1,571	1,436	1,394	91.4	88.7
"	520	410	369	201	105	79	52.2	39.3
"	417	427	351	1,121	878	857	78.3	76.4
SUB TOTAL 9/17 (n=7)				**9,725** (1,389)	**8,408** (1,201)	**7,910** (1,130)	**86.5**	**81.4**
9/24	503	433	423	1,233	787	661	63.8	53.6
"	469	412	351	1,811	1,745	-	96.4	-
"	411	442	401	2,633	2,522	-	95.8	-
"	467	410	369	1,314	848	-	64.5	-
"	462	475	381	2,417	2,293	-	94.9	-
"	457	488	318	1,685	1,559	-	92.5	-
"	482	495	381	2,430	2,164	-	89.1	-
"	425	427	369	1,849	1,822	-	98.5	-

SPAWN DATE	MALE LENGTH (mm)	FEMALE LENGTH (mm)	EGG SIZE (#/oz)	# GREEN EGGS	# EYEUP	# HATCHED	% EYEUP	% HATCH
9/24	452	411	401	758	380	-	50.1	-
"	448	458	381	1,823	1,752	-	96.1	-
"	419	444	351	1,895	1,638	-	86.4	-
"	483	469	381	1,540	1,469	-	95.4	-
"	520	475	381	1,256	502	-	40.0	-
"	457	482	381	1,633	1,417	1,407	86.8	86.2
"	503	410	369	1,014	886	839	87.4	82.7
"	464	413	351	1,296	1,258	1,251	97.1	96.5
"	447	397	351	919	546	508	59.4	55.3
"	456	489	423	2,457	1,974	1,960	80.3	79.8
"	460	436	369	1,372	1,348	1,333	98.3	97.2
"	445	412	401	1,464	1,207	1,109	82.4	75.8
SUB TOTAL 9/24 (n=20)				**32,799** (1,640)	**28,117** (1,406)	**9,068** (1,134) n = 8	**85.7**	**79.6** n = 8
10/1	472	439	-	1,272	30	9	2.4	0.7
"	423	455	369	1,352	250	158	18.5	11.7
"	420	460	369	1,827	649	252	35.5	13.8
"	395	448	369	1,557	1,447	1,266	92.9	81.3
"	420	429	318	1,398	559	423	40.0	30.3
"	470	423	-	745	65	33	8.7	4.4
"	422	420	334	895	294	123	32.8	13.7
"	443	449	369	987	324	226	32.8	22.9
"	406	456	351	2,420	1,923	1,275	79.5	52.7
"	460	396	-	847	7	4	0.8	0.5
"	440	483	318	2,064	1,398	1,066	67.7	51.6
SUB TOTAL 10/1 (n=11)				**15,364** (1,397)	**6,946** (631)	**4,835** (440)	**45.2**	**31.5**

SPAWN DATE	MALE LENGTH (mm)	FEMALE LENGTH (mm)	EGG SIZE (#/oz)	# GREEN EGGS	# EYEUP	# HATCHED	% EYEUP	% HATCH
10/8	439	487	381	2,546	361	140	14.2	5.5
"	421	425	351	1,203	427	209	35.5	17.4
"	428	447	-	1,391	8	0	0.6	0
"	483	427	369	1,091	1,023	990	93.8	90.7
"	481	427	334	779	497	323	63.8	41.5
"	450	466	423	1,578	1,230	1,097	77.9	69.5
SUB TOTAL 10/8 (n=8)				**8,588** (1,431)	**3,546** (591)	**2,759** (460)	**41.3**	**32.1**
TOTAL 9/10-10/8 (n=48)				**71,641**	**50,483**	**27,835** n=35	**70.5**	**55.4**
RANGE 9/10-10/8 (n=48)	395-520	382-512	318-423	201-2,851	8-2,770		0.6-98.5	0.0-97.2
OVER-ALL MEAN	453	443	360	1,493	1,052	795	70.5	55.4

DISCUSSION

The overall mean rate of eyeup (70.5%) from eggs produced by the experimental bull trout broodstock was considerably lower than the results reported (Fredenberg et al. 1995) from wild stocks in 1993 (97.4%) and 1994 (96.6%) These results are not surprising, given that the experimental fish were all first-time spawners, mature females and males were younger than normally found in the wild (age 3), eggs were smaller, and the fish were subjected to several external stress factors including captivity and the recurring problems with furunculosis. In addition, we continue to learn and develop techniques to efficiently feed and shelter these fish in a fashion as similar as possible to the natural environment. We also noted a high rate of crippled fry in a few of the incubation lots, which could be an indication of the narrow genetic profile used to establish this experimental brood. Many of these factors may be mitigated in continuing 1998 trials and egg survival will likely increase, though we will not be able to ascertain which of these limiting factors are the most critical due to limited study design. Nonetheless, an eyeup rate of 70% for wild strains of fish is considered acceptable in many existing hatchery programs with other salmonid species.

One of our objectives in conducting only paired matings (rather than pooling) in 1997 was to evaluate the frequency of infertility and examine whether pooling of sperm and/or eggs might improve viability in the future. In general, the incubation tests indicate eyeup of many individual lots were relatively high. In 22 of 48 lots (46%) survival was 80+ % with eight lots (17%) dropping below 30% and most of those occurring in the last two takes. None of the lots were completely infertile, although a couple were very close.

The sharp decline in egg viability between the peak take (September 24) and the October 1 take that followed it is somewhat puzzling. It is noted that fish spawned October 1 were determined to be ripe on September 24, but were held for another week due to logistic constraints. Similarly, the fish spawned October 8 may have been ripe for up to two weeks prior to the egg take (Table 2). In addition, the males used in the later takes had probably been ripe for a month or more. While this is speculative, the eyeup rate of individual lots of the October egg takes is almost uniformly low, which suggests reduced viability of the gametes in either or both parents. In the future, females should be spawned promptly as they become ripe and consideration should be given to pooling or freezing sperm, especially for later takes.

The timing of bull trout spawning in the experimental broodstock at Creston National Fish Hatchery appears to coincide with that of their parental stocks in the wild. In 1993 and 1994, eggs from wild fish in Lion Creek and Holland Lake were collected between September 16 and September 21. In the hatchery, the spawning peak was the week of September 24. The literature indicates that bull trout spawn during periods of decreasing fall water temperatures, preferring water temperatures of 5-9°C (USFWS

1998). Water temperatures at Creston National Fish Hatchery peaked in 1996 and 1997 at just over 9°C and began declining in early September, to the range of 5-8°C during September and early October.

These results indicate that hatchery production of viable bull trout eggs from captive broodstock is a potential option for recovery purposes. Continued research needs to be conducted to develop techniques for reducing stress (e.g. overhead cover, visual isolation, feeding techniques), improving egg survival (incubation and rearing temperatures, diet, etc.), and controlling external variables such as disease. We concur with the Montana Bull Trout Scientific Group (1996) that any projects involving stocking of hatchery bull trout must be appropriate in scope, judiciously applied, rigorously designed, and thoroughly monitored. That is, in part, our purpose in conducting this experimental program to develop appropriate techniques for the hatchery culture of bull trout. Initial investigations indicate that the water supply at Creston National Fish Hatchery is ideally suited for bull trout broodstock research and development.

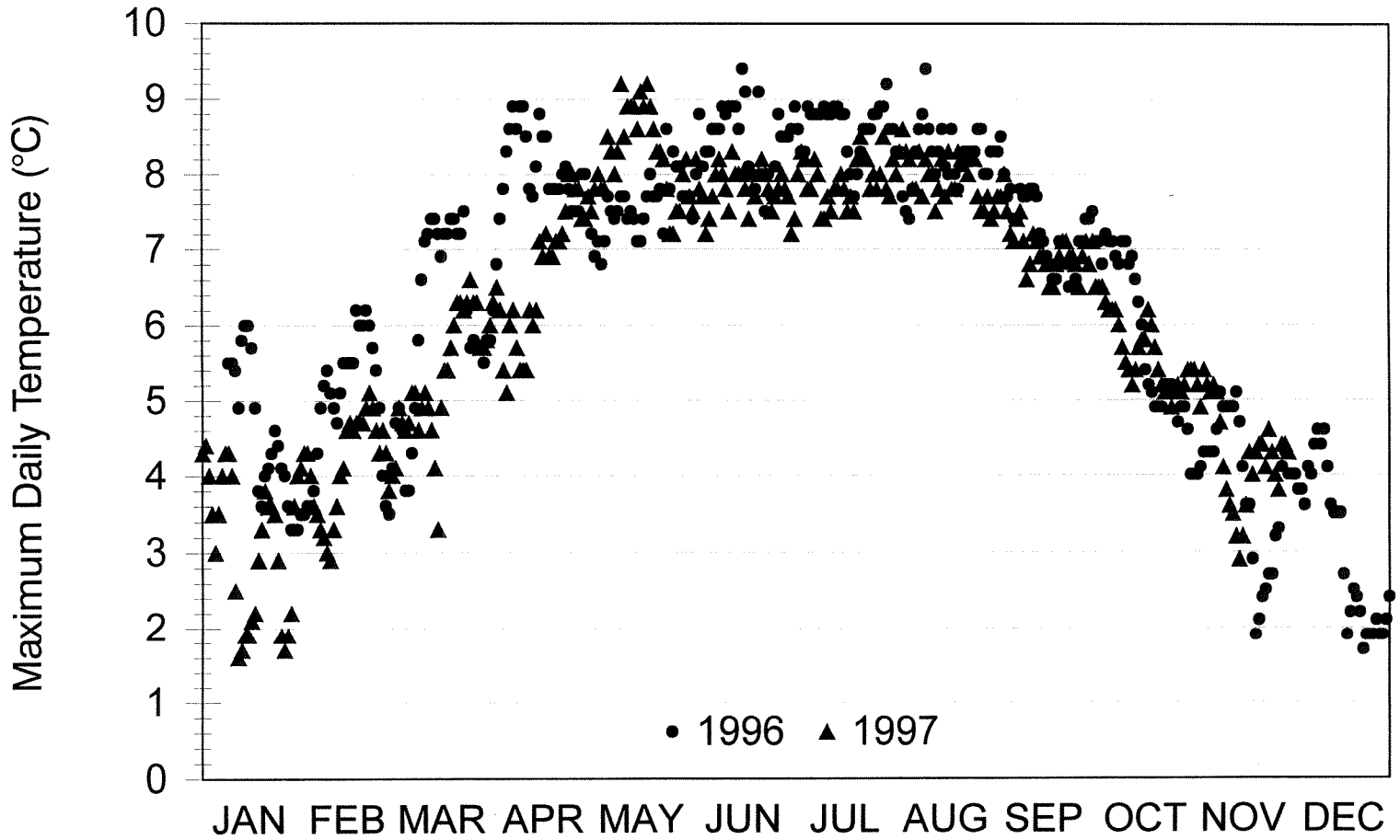

Figure 1. Maximum daily water temperature recorded in raceway #1 at Creston National Fish Hatchery during the period January 10, 1996 through November 30, 1997.

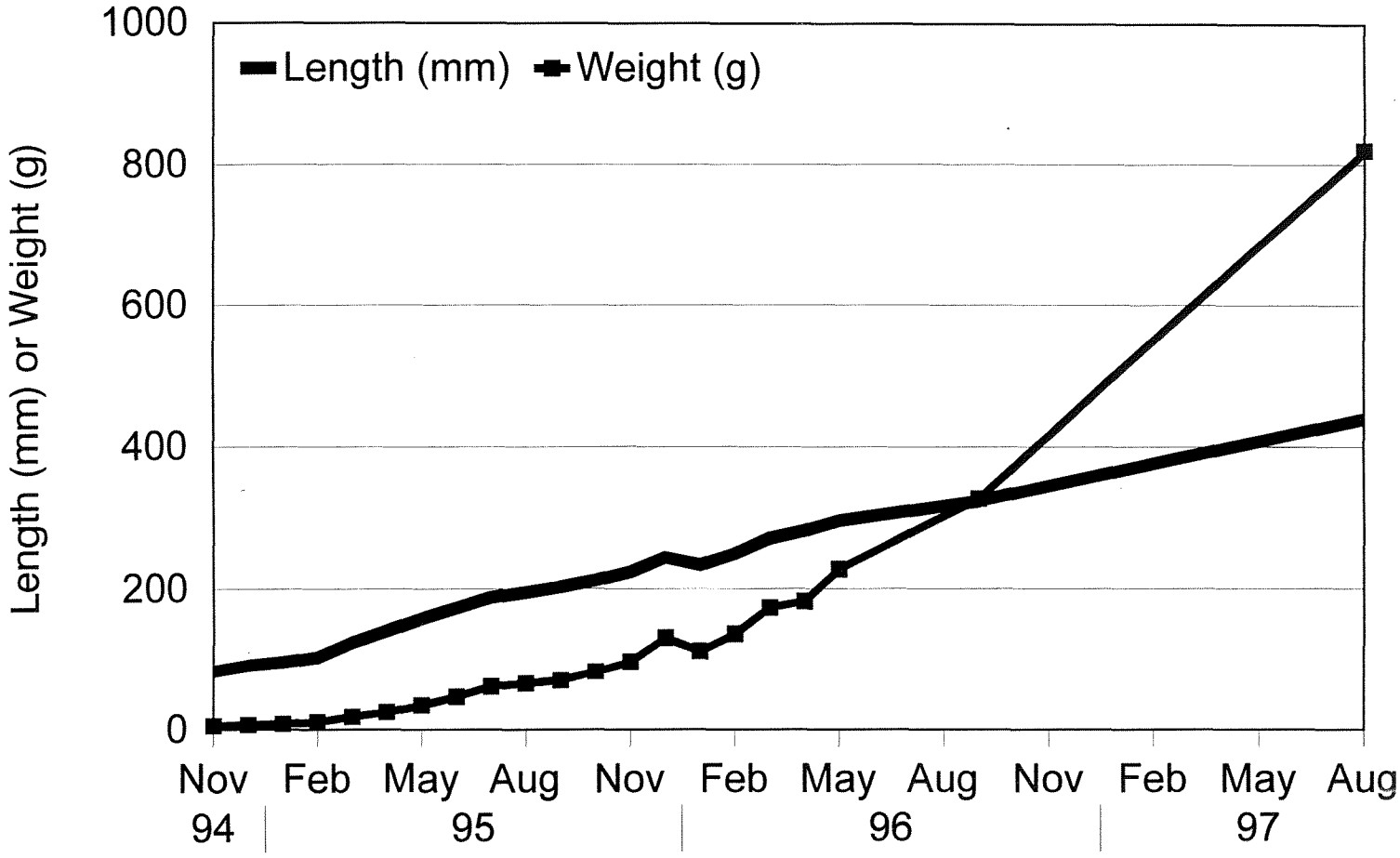

Figure 2. Mean length and weight of bull trout reared at Creston National Fish Hatchery. Samples collected every two weeks between November 2, 1994 (late age 0) and May 29, 1996 (early age 2); then annually in August, 1996 and August 1997(age 3).

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