STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-80-R-2

Study No.: 654

Title: Evaluation of brown trout and steelhead competitive interactions in Hunt Creek, Michigan.

Period Covered: October 1, 2000 to September 30, 2001

Study Objective: To determine if the introduction of steelhead into a stream where they presently do not exist will affect the abundance, survival, growth, or disease status of resident trout species.

Summary: Potential effects of competitive interactions between steelhead and resident brown trout in Hunt Creek are being evaluated by comparing population dynamics of resident trout in a treatment zone (TZ) before (1995-97) and after (1998-02) adult steelhead were stocked into the TZ. In addition, annual resident trout populations are being estimated in reference zones (RZ's) without steelhead. We have made seven consecutive annual fall estimates of brook and brown trout populations in the TZ of Hunt Creek, and in RZ's located on Hunt and Gilchrist Creeks. Adult steelhead were stocked in the TZ each spring from 1998-01. Brook and brown trout abundance, growth, and survival in the TZ were compared between the pre- and post-steelhead-stocking periods. Ratios of abundance, survival, and growth of resident trout populations in treatment and reference zones were compared between pre- and post-steelhead stocking periods to help distinguish between possible effects of interspecies interactions and environmental factors.

We are collecting information on stream discharge in all study zones because the magnitude and seasonal pattern of stream discharge is known to have strong effects on the reproductive success of salmonid species. Stream discharge at the upstream end of the Hunt Creek RZ is monitored hourly all year with an electronic river stage height recorder. Discharges in the TZ and Gilchrist Creek RZ are highly correlated with discharge at this site.

Hourly water temperatures were electronically recorded all year in both the TZ and RZ because water temperature differences between years can influence the outcome of certain species interactions. Warmer temperatures during the winters of 1998-99 and 1999-00 decreased the period between brown trout egg deposition to fry emergence such that it was less likely that steelhead spawning in 1999 or 2000 would have superimposed their redds upon partially developed brown trout alevins.

We counted and characterized both steelhead and resident trout redds in the TZ to determine both the spatial distribution of redds and the time period when most spawning occurred. The majority of brown trout spawning occurred during the last half of October and most steelhead spawned prior to 15-April every year of the study. The range of water depths and velocities measured immediately upstream of redd pockets by both species overlapped considerably. Steelhead superimposed their redds upon 7% of brown trout redds mapped the previous fall in 1998-99 and 1999-00, but in 2000-01 redd superimposition approached 50%.

Preliminary analyses indicated that fall abundance of YOY brown trout in the TZ did not change significantly relative to abundance in RZ's after steelhead were stocked. However, survival of brown trout YOY to the subsequent fall was significantly lower in 1999 as compared to years when age-1 steelhead were not present in the TZ. Hence, fall abundance of yearling brown trout in the TZ was significantly lower in 1999-00 than during 1995-97 and the TZ:RZ-ratio of yearling abundance was also significantly lower during 1999-00. Analysis of survival and abundance for 2000-01 can not be completed until scale samples collected in fall 2001 are aged. I detected no significant changes in growth of brown trout over the study period.

Job 2. Title: <u>Monitor water temperature in treatment and reference zones.</u>

Findings: I recorded water temperatures hourly using electronic thermometers at 5 sites. One thermometer was located near the upstream boundary of the Hunt Creek RZ, and the other four thermometers were located near the upstream and downstream boundaries of the Hunt Creek TZ and the Gilchrist Creek RZ. Monthly mean temperatures at the downstream boundaries of the Gilchrist Creek RZ and both the TZ and RZ of Hunt Creek are shown in Table 1.

Water temperatures in the Hunt Creek TZ and the Gilchrist RZ were very similar throughout the year. Water temperatures in the Hunt Creek RZ were slightly warmer in winter and cooler in summer than in other study areas.

I used water temperature data collected during the primary incubation period, 15-October through April to estimate whether brown trout fry were likely to emerge before steelhead spawned the following spring. The number of days between brown trout egg deposition and hatch predicted from incubation time models (Crisp 1981, 1988) ranged from 69 d for the 1999 year class up to 117 d for the 1996 year class (Table 2). Predicted dates for median swim-up were as early as 27-March for the 2000-year class and as late as 30-April for the 1996-year class. This analysis suggests that some brown trout alevins were still in their redds when steelhead spawning took place during each spring from 1998-01. Thus, steelhead redds that are superimposed upon brown trout redds dug the previous fall could cause mortality of brown trout fry.

Job 3. Title: <u>Monitor water stage and discharge.</u>

Findings: Stream discharge is monitored primarily because high stream discharge around the time that fry emerge from redds is known to have strong negative effects on the reproductive success of brown trout (Nuhfer et al. 1994). Because the timing of stochastic events such as floods can differentially affect recruitment of species with different life histories (Strange et al. 1992) stream discharge in Hunt Creek is monitored throughout the year at a site located 2 km upstream of the TZ.

An exceptionally high spring discharge of 95 cfs occurred on 31-March 1998. This flood did not appear to impair brown trout reproductive success in Hunt Creek but fall YOY abundance in the Gilchrist Creek RZ was substantially lower than normal in 1998. Spring discharge peaks during 1999-00 did not exceed 40 cfs. Stage height recorder malfunctions during late 1998 and early 1999 precluded daily estimates of discharge between 16-Oct 98 and 20-March 99. The mean and range of daily discharge for months with complete data is shown in Figure 1.

Job 5. Title: Locate and mark locations of trout redds and measure redd characteristics.

Findings: Brown trout redds were again counted in the 3,400-m Hunt Creek TZ during the primary spawning period in fall 2000. Three redd counts had been made in 2001 at the date this report was written. Spawning activity was greatest during the last half of October and actively spawning fish were frequently observed during late October redd counts. Figure 2 shows that the highest number of active brown trout redds were present near the end of October in 3 of 4 years from 1998 to 2001. Few brown trout were observed on redds after October in any year. Redds were not counted during Michigan's firearm deer season (November 15-30) to reduce conflicts with landowners along the creek. The number of active redds observed in all years during the first week of December ranged from 0 to 5 during 1998-00.

Habitat characteristics near brown trout redds such as water velocity, depth, and substrate type were collected and summarized for about 30 redds each year. These data were compared to spawning habitat used by steelhead under Job 9.

Job 6. Title: Collect population and biological data.

Findings: We again made mark-and-recapture estimates of brook and brown trout populations during late summer (August or September) in 2001 in a 3.4 km treatment zone on Hunt Creek, a 0.7 km reference zone on Hunt Creek, and a 2.3 km reference zone on Gilchrist Creek. Similar population estimates have been conducted each year from 1995 to 2000. Populations of juvenile steelhead were also estimated during years they were present — 1998-01. Scales collected in 2001 have not been aged, to date. Hence, data analyses reported for this segment do not include comparisons of abundance or growth for years more recent than 2000. Similarly, survival of fish during 2000 can not be reported until scales collected in 2001 are aged.

Abundance of steelhead YOY was approximately 2.3 times higher than abundance of brown trout in the TZ in all years when steelhead were stocked (1998-00) (Table 3). Brown trout YOY abundance in both the TZ and Gilchrist Creek RZ was significantly lower in 1998-00 than during the pre-steelhead stocking period of 1995-97 (ANOVA $P < 0.05$). Abundance of YOY brown trout in the Hunt Creek TZ averaged $976 \cdot ha^{-1}$ in 1998-00, after steelhead were stocked, compared to $1289 \cdot ha^{-1}$ during 1995-97. However, YOY brown trout in the Gilchrist Creek RZ were also less abundant during the later period, averaging $1487 \cdot ha^{-1}$ during 1998-00 compared to $1976 \cdot ha^{-1}$ during 1995-97 (Table 4). By contrast, abundance of YOY brown trout in the Hunt Creek RZ was significantly higher during 1998-00 than during 1995-97 (Table 5).

I used Bonferroni multiple t-tests (Miller 1981) to test for significant differences in the ratio of brown trout YOY abundance in the TZ to YOY abundance the Gilchrist Creek RZ. The TZ:RZ ratio before steelhead stocking was 0.65 compared to 0.70 after steelhead were stocked. These ratios were not significantly different, which suggests that temporal declines in YOY abundance in both the treatment and reference zones were caused by factors other than interspecies interactions. Effects of an intermittently active beaver dam located downstream that sometimes impounds water within the sampling area confound interpretation of data from the Hunt Creek RZ.

Age-1 brown trout in both the TZ and Gilchrist Creek RZ were significantly less abundant in 1999-00 than in 1995-97. However, the decline in abundance was relatively greater in the zone where juvenile steelhead were present because the TZ:RZ ratio of yearling abundance was significantly lower during 1999-00 than during 1995-97 (Bonferroni t, $P < 0.05$). This decline in yearling abundance in the TZ was associated with significantly lower survival of the 1999 year class to age-1 in the TZ relative to the Gilchrist Creek RZ (Table 6).

Brown trout YOY and yearlings were larger than juvenile steelhead of the same age group. YOY steelhead in Hunt Creek averaged 72-mm total length from 1998-00. Yearling steelhead averaged 150 mm in 1999-00 while yearling brown trout averaged 171 mm (Table 7). Brown trout YOY averaged 89 mm in the TZ both before and after dense populations of YOY steelhead were established (Table 7). Brown trout growth was slightly slower in the Gilchrist Creek RZ (Table 7). However, there were no significant differences in mean length at age of brown trout either between years within a stream or between streams ($P < 0.05$).

Job 7. Title: <u>Test fish for BKD and other diseases</u>

Findings: Sixty brown trout were collected for disease screening from Hunt Creek each summer during 1996-01 and from Gilchrist Creek during 1990, 1994, and 1999. In 1999 and 2001, we also collected juvenile steelhead from the Hunt Creek TZ. Brown trout were screened for the presence of *Renibacterium salmoninarum*, *Yersinia ruckeri*, and *Aeromonas salmonica.* Five-fish pools of trout heads were examined for the presence of spores of the parasite *Myxosoma cerebralis.* Virological tests were performed to detect the presence of the hemorrhagic septicemia virus, the infectious pancreatic necrosis virus, and the *Oncorhynchus masou* virus. None of these diseases or parasites have been detected in any of the brown trout collected from Gilchrist Creek. No viral diseases or pathogenic bacterial diseases have been detected in brown trout from Hunt Creek. *M. cerebralis* spores were detected in brown trout collected in 1998 and 2000-01. The spores were not found in steelhead screened in 1999 but they were found in 8 of 12 pools of steelhead examined in 2001. Spore density was low, 11 or fewer per screening slide, and no clinical signs of whirling disease have been observed in either species.

Job 8. Title: <u>Monitor stocking of adult steelhead</u>

Findings: Adult steelhead were stocked at the downstream end of the Hunt Creek TZ each spring from 1998-01. Eighty steelhead of each sex were stocked each year. Size at planting and percent ripeness is summarized in Table 8.

Steelhead redds in the TZ were counted twice weekly beginning 2 d after stocking in 1998-99 and once a week in 2000-01. Steelhead began spawning within a day after being stocked in all years. A majority of spawning appeared to occur within a week after stocking during all years. Few steelhead were observed on redds two weeks after stocking.

Job 9. Title: <u>Characterize steelhead redds</u>

Findings: We measured water depth at the front of both brown and steelhead trout redd tail spills (Grost et al. 1991), and water velocity at 0.6 of water column depth at the same point. In addition, we characterized the dominant particle size and percentage of sand-embeddednes of redd gravel used by both species.

Brown trout and steelhead redds were located in similar water depths and the range of depths used overlapped (Table 9). Mean water velocity upstream of redd pockets was slightly higher for steelhead, but again, there was broad overlap between the range of water velocities measured just upstream of redd pockets (Table 9).

On average, steelhead spawned over larger gravel than brown trout. Gravel larger than 25-mm in diameter predominated at nearly 90 percent of steelhead redd sites. Brown trout redds were in gravel of this size 55 percent of the time. Steelhead and brown trout spawned over smaller gravel, ranging from 6-24 mm in diameter, 10 percent and 44 percent of the time, respectively.

Brown trout redds were more frequently embedded with sand than steelhead redds. All steelhead redds were less than 25 percent embedded with sand compared to 51 percent of brown trout redds. Forty percent of brown trout redds were 26-50 percent embedded and the remaining 5 percent were more than 50 percent embedded.

A subsample of from 30 to 40 brown trout redds were marked and mapped each fall from 1997-00. The percentage of steelhead redds dug the following spring that were superimposed upon brown trout redds was determined each spring after steelhead spawning had ceased. In 2001, steelhead completely excavated 33% of brown trout redds marked in fall 2000. Partial superimposition was observed for an additional 15% of marked brown trout redds. This contrasted sharply with observations from prior years. Steelhead superimposed their redds upon brown trout redds dug the previous fall only about 7 percent of the time during 1998-00. In spring 2000, steelhead superimposed redds upon 3 of 40 brown trout redds marked during fall 1999. During spring 1998, steelhead superimposed redds upon only 2 of 31 brown trout redds marked in fall 1997.

The potential for superimposition of steelhead redds upon developing brown trout alevins varies between years due to differences in winter incubation temperatures. I used temperature data collected from Hunt Creek and models developed by Crisp (1981, 1988) to make projections of median hatch and emergence dates for brown trout eggs deposited during mid-October. The predicted date of brown trout alevin emergence ranged from 27-March 1999 following a warm winter, to 30-April 1996 following a severe winter (Table 2). It is likely that brown trout alevins were present in the gravel each year that steelhead were stocked because the projected median swim-up dates for brown trout during 1998-01 occurred either later or at about the same time as steelhead were actively spawning.

Job 10: Title: <u>Analyze data and write progress report</u>

Findings: This progress report was prepared.

Job 11: Title: <u>Estimate populations of resident trout and steelhead in additional streams</u>

Findings: During July and August 2000-01 we made mark-and-recapture estimates of resident trout species, steelhead, and other potamodromous species in five additional streams. Streams sampled were the Baldwin River, Houghton Creek, the Little South Branch of the Pere Marquette River, the mainstem Pere Marquette River, and the Platte River. Resident trout species populations were likewise estimated in rivers inaccessible to Great Lakes fish. These streams were the North and South Branch Boardman Rivers, Hersey River, mainstem Manistee River, and the North, South, and mainstem Au Sable Rivers. After an additional year of field data is collected and summarized I will test hypotheses relating vital statistics of resident trout populations to the presence and abundance of potamodromous salmonids.

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Table 1.–Monthly mean water temperatures (ºC) in the Hunt Creek treatment and reference zones and in Gilchrist Creek 1996-00. Asterisks indicate months with missing or incomplete data.

Month	Year 1996	1997	1998	1999	2000
Hunt Creek Treatment Zone					
January	0.9	1.0	1.9	1.6	1.7
February	1.4	1.7	3.2	2.6	2.6
March	2.6	3.0	3.1	3.8	5.3
April	4.9	5.5	7.9	8.1	7.4
May	9.9	8.6	13.2	12.5	12.6
June	13.9	14.9	14.2	15.5	14.9
July	14.9	15.5	16.2	16.7	16.0
August	15.0	13.8	15.3	14.7	15.7
September	12.3	12.2	13.2	12.3	13.0
October	8.7	7.8	9.4	8.3	9.9
November	3.8	4.3	5.9	6.1	5.4
December	2.5	3.0	3.7	3.1	1.4
Hunt Creek Reference Zone					
January	2.1	2.5	3.6	3.2	3.0
February	2.5	3.1	4.5	4.0	3.3
March	3.5	3.9	4.3	4.1	5.1
April	*	6.0	8.4	7.7	6.9
May	*	9.0	13.0	11.1	11.1
June	*	14.3	14.1	13.9	13.0
July	*	15.1	15.6	15.1	13.8
August	*	13.9	15.0	13.6	13.7
September	*	12.5	13.4	11.8	11.7
October	*	8.7	10.0	8.3	9.2
November	*	5.4	6.7	6.7	*
December	*	4.5	5.0	4.3	*
Gilchrist Creek Reference Zone					
January	1.2	1.5	2.5	1.5	1.5
February	1.7	2.1	3.5	2.5	2.3
March	2.8	3.1	3.4	3.6	5.2
April	5.2	5.5	8.2	8.0	7.3
May	10.4	9.1	13.9	12.7	12.5
June	14.7	15.6	14.8	16.1	14.8
July	15.7	16.4	16.4	17.5	16.1
August	15.9	14.7	15.9	15.4	15.7
September	13.2	13.0	13.7	12.9	12.9
October	9.1	8.9	9.6	8.5	9.5
November	4.3	4.7	5.8	6.0	5.3
December	2.9	3.6	3.7	2.9	1.4

Table 2.–Projected dates for median hatch and swim up for brown trout spawning in the Hunt Creek TZ on 15-October. Projections based on mean daily temperature during incubation (Crisp 1988).

Year spawned	Median Hatch Date	Median Swim-up Date
1995	2/09/96	4/30/96
1996	1/27/97	4/24/97
1997	2/01/98	4/15/98
1998	12/23/98	3/29/99
1999	1/04/01	3/27/00
2000	1/07/01	4/05/01

Table 3.–Fall numbers of brown, brook, and rainbow trout per hectare, by age, in 3.4-km treatment zone of Hunt Creek MI where adult steelhead were stocked in 1998-00.

	Age					
Year	0	1	2	3	4	5+
			Brown trout			
1995	1616	509	199	130	20	10
1996	970	428	161	74	15	6
1997	1283	414	145	64	15	2
1998	1048	490	120	92	18	3
1999	947	297	163	70	26	1
2000	933	165	98	68	24	3
			Rainbow trout			
1998	2541	0	0	0	0	0
1999	2241	340	0	0	0	0
2000	2097	245	0	0	0	0
			Brook trout			
1995	22	8	0.7	0.5	0	0
1996	80	49	5	0	0	0
1997	102	51	6	0.4	0	0
1998	67	35	8	0	0	0
1999	41	10	2	1	0	0
2000	41	14	1	0	0	0

Table 4.–Fall numbers of brown and brook trout per hectare, by age, in a 2.3 km section of Gilchrist Creek MI used as a reference zone, 1995-00.

Year	Age 0	1	2	3	4	5+
Brown trout						
1995	2173	731	278	113	12	1
1996	1867	403	173	57	16	4
1997	1887	537	129	43	15	4
1998	1032	694	133	62	23	8
1999	1689	435	199	80	7	3
2000	1741	461	140	70	15	0
Brook trout						
1995	14	27	6	0	0	0
1996	21	30	5	0.5	0	0
1997	30	22	6	0	0	0
1998	23	12	8	0	0	0
1999	17	33	0	0	0	0
2000	2	9	1	0.5	0	0

Table 5.–Fall numbers of brown and brook trout per hectare, by age, in a 0.7 km section of Hunt Creek MI used as a reference zone, 1995-00.

Year	Age 0	1	2	3	4	5+
Brown trout						
1995	374	300	172	91	16	14
1996	236	66	102	129	28	23
1997	1038	116	84	64	30	6
1998	1442	419	90	86	39	13
1999	541	252	166	67	16	10
2000	524	144	87	53	10	0
Brook trout						
1995	2843	395	40	0	0	0
1996	2303	200	12	0	0	0
1997	3453	360	7	0	0	0
1998	3752	1306	32	0	0	0
1999	1896	177	21	0	0	0
2000	2137	108	6	0	0	0

Table 6.–Percent survival of brown trout in Hunt and Gilchrist Creeks, by age, from the year listed to the following year.

	Age			
Year	0	1	2	3
Hunt Creek Treatment Zone				
1995	27	32	37	12
1996	43	34	40	20
1997	38	29	63	28
1998	28	33	59	28
1999	17	33	42	34
Hunt Creek Reference Zone				
1995	18	34	75	31
1996	49	127	62	23
1997	40	77	104	60
1998	17	40	74	18
1999	27	34	32	15
Gilchrist Creek Reference Zone				
1995	19	24	21	14
1996	29	32	25	27
1997	37	25	48	53
1998	42	29	60	11
1999	27	32	35	19

Table 7.–Mean length at age (mm) of brown trout in Hunt and Gilchrist Creeks during September 1995-00.

	Age				
Year	0	1	2	3	4
		Hunt Creek			
1995	90	163	210	265	361
1996	90	164	212	270	334
1997	88	171	229	270	372
1998	92	173	224	271	323
1999	85	174	230	279	336
2000	91	168	230	274	338
		Gilchrist Creek			
1995	81	153	198	263	338
1996	78	148	197	266	329
1997	80	150	214	272	334
1998	85	148	213	264	323
1999	86	166	217	276	355
2000	85	159	224	269	337

Table 8.–Mean total length (mm), weight (kg), and ripeness of adult steelhead stocked in Hunt Creek during 1998-2001.

	Year			
Parameter	1998	1999	2000	2001
Mean total length of males	701	686	788	745
Mean total length of females	694	688	732	727
Mean weight of males	3.2	3.2	4.7	4.0
Mean weight of females	3.2	3.3	3.9	3.9
Percent ripe males	38	34	60	61
Percent ripe females	34	25	36	44

Table 9.–Mean water depths (cm) at the upstream end of redd pocket and mean water velocity (cm/s) at 0.6 of depth at the same point, for redd sites used by brown trout and steelhead in Hunt Creek, Michigan.

	Species	
Habitat Variable	Brown Trout	Steelhead
Mean water depth	29	27
Range of water depths used	10-70	11-62
Mean water velocity	65	70
Range of water velocities used	20-101	30-120

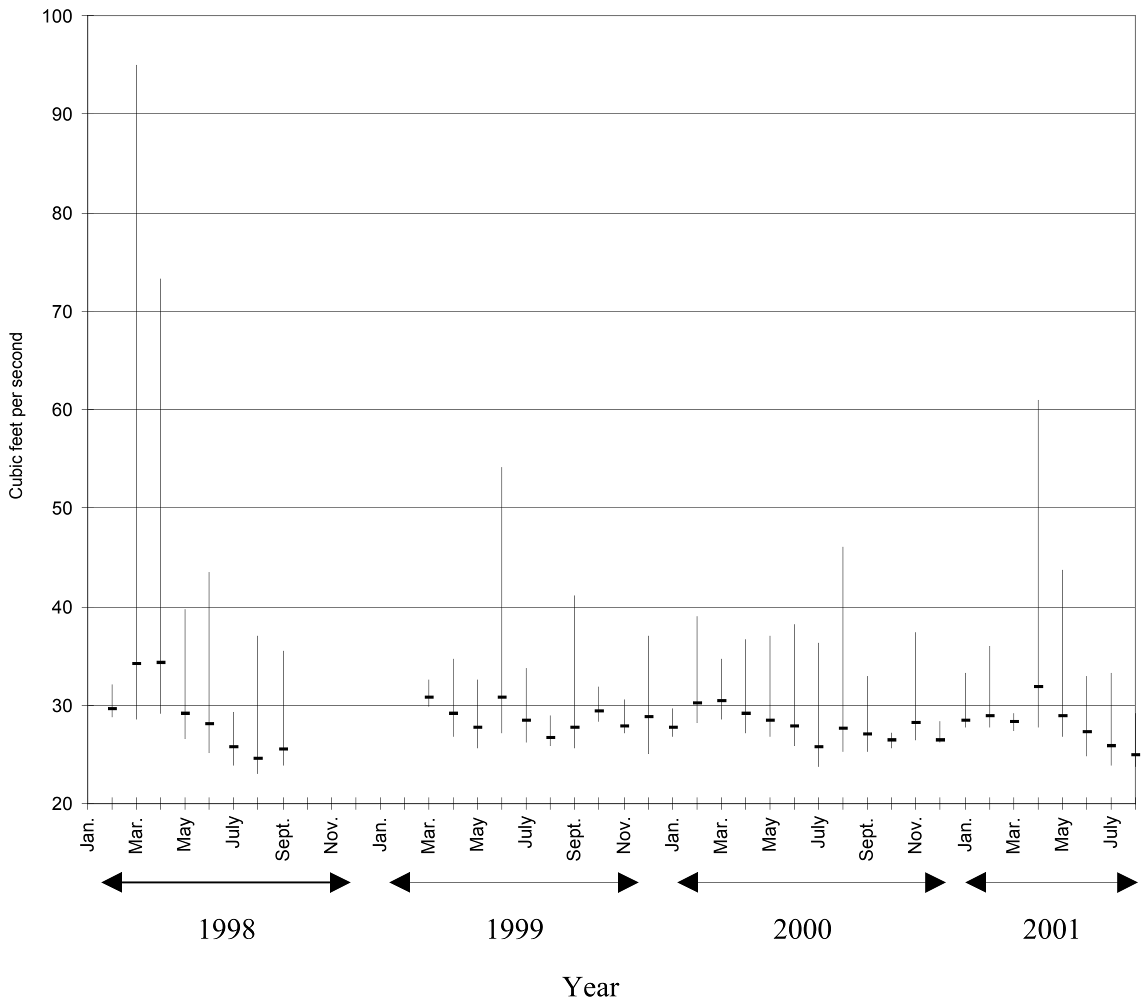

Figure 1.–Monthly mean, maximum, and minimum discharge in cfs of Hunt Creek upstream of the treatment zone from February 1998 through August 2001. Horizontal bars represent mean monthly discharge and the ends of the vertical bars depict maximum and minimum discharge. No data are presented for months with any missing daily discharge data.

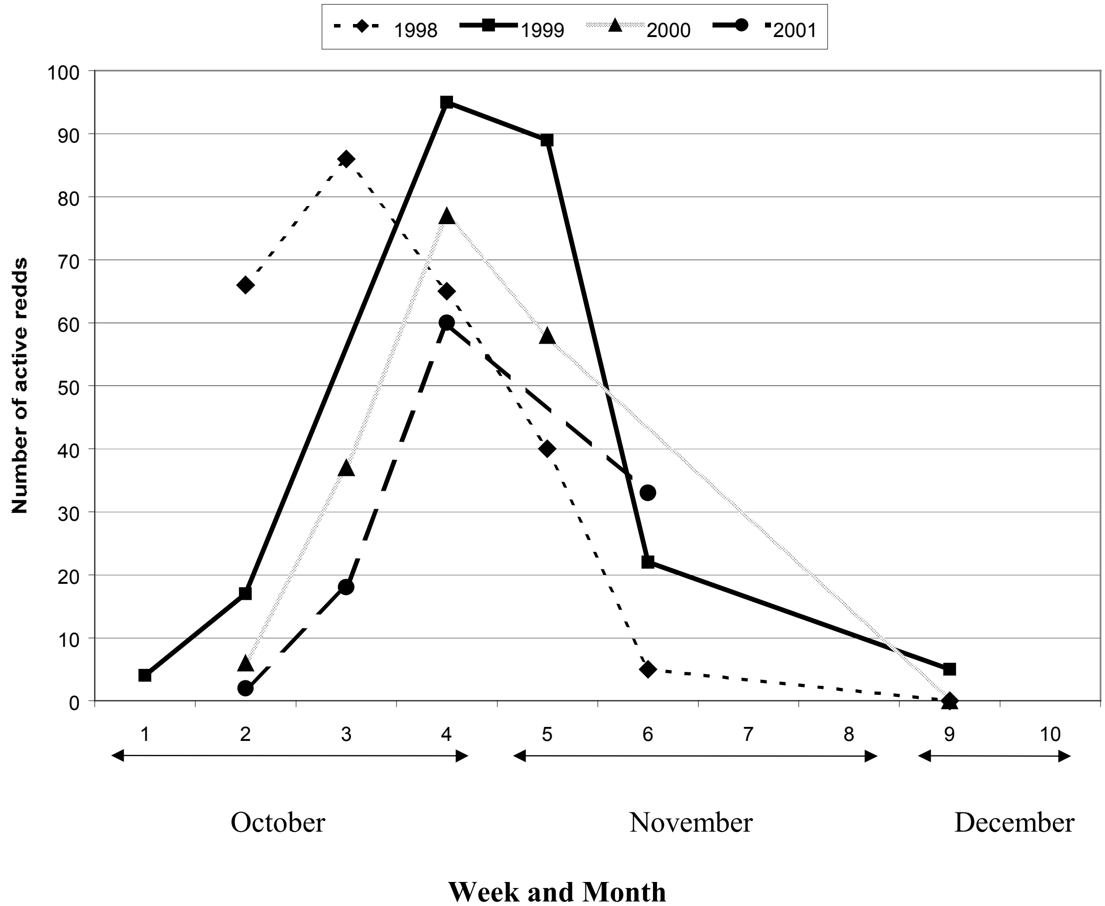

Figure 2.–Number of active brown trout redds by week in the 3400-m treatment zone of Hunt Creek during 1998-01. Week 1 is the first full week of October and week 9 is the first week of December. No counts were conducted during the last half of November to reduce conflicts with deer hunters on private properties along the creek. The December 2001 count has not been made.