STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-80-R-5

Study No.: 230654

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

Period Covered: October 1, 2003 to September 30, 2004

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 were evaluated by comparing population dynamics of resident trout in a 3.4 km treatment zone (TZ) before (1995-97) and after (1998-03) adult steelhead were stocked into the TZ. Resident trout populations were also estimated in reference zones (RZ's) without steelhead. We have made ten 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 1998-03. Brook and brown trout abundance, growth, and survival in the TZ were compared between the pre- and post-steelhead-stocking periods. Ratios of abundance and survival 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.

The primary effect of interactions between brown trout and steelhead has been a significant decline (from 36% to 21%) in annual survival of young-of-the-year (YOY) brown trout. This has reduced abundance of year classes of yearling-and-older brown trout that interacted with steelhead YOY to about half the size of year classes of brown trout hatched before steelhead were present. Similar temporal changes in survival and abundance of brown trout were not observed in the Gilchrist Creek RZ. Reduced survival of brown trout YOY probably occurred because total fall density of YOY trout (brown trout and steelhead combined) was three times higher than the pre-steelhead density of brown trout YOY. Mean fall abundance of YOY brown trout in the TZ has not changed significantly, relative to the Gilchrist Creek RZ, indicating that steelhead did not impair brown trout reproductive success. Few significant changes in growth rates of brown trout were detected following steelhead introductions. *Myxobolus cerebralis* spores were detected in both steelhead and brown trout during most years after steelhead were stocked. However, spore densities were low and no negative effects of whirling disease on either species have been detected. Minor changes in brook trout populations were probably unrelated to interactions with steelhead. Age-1 brook trout in the TZ were less abundant after steelhead introductions but the change was probably caused by recent declines in brook trout reproductive success. Similar, albeit statistically insignificant, declines in brook trout abundance were also observed in the RZ.

Findings: Jobs 2, 3, 6, 7, and 10 were active this year, and progress is reported below.

Job 2. Title: Monitor water temperature in treatment and reference zones.–I recorded water temperatures hourly using electronic thermometers at five 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.

I have reported on the potential implication of between-year variation in incubation temperatures in brown trout redds on reproductive success in previous progress reports. Briefly, my analyses suggested that substantial numbers of brown trout alevins were still in redds when steelhead spawned each spring from 1998-03. Thus, steelhead redds that were superimposed upon brown trout redds dug the previous fall probably caused some mortality of brown trout fry. However, in most years less than ten percent of brown trout redds were affected by superimposition of steelhead redds.

Job 3. Title: Monitor water stage and discharge.–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.

Discharge varied substantially among years during the period when most brown trout emerge from their redds. Maximum daily mean discharge during March or April ranged from 30 cfs in 1999 up to 88 cfs in March 1998. These discharge levels did not appear to impair brown trout reproductive success in the Hunt Creek TZ. However, the 1998 flood did reduce brown trout reproductive success in the Gilchrist Creek RZ. The 2001-year class of brown trout was relatively strong in all zones in spite of a brief flood peak of 80 cfs on 12-April 2001. Mean daily discharge in upper Hunt Creek on that date was 55 cfs.

Mean daily discharge during the primary steelhead incubation period (approximately 15-April to 15-June) was generally quite low and stable. The highest mean daily discharge during steelhead incubation (49 cfs) occurred on 14-June 1999. The paucity of significant high-flow events during steelhead incubation periods and consistently high numbers of steelhead YOY from 1998 through 2003 indicate that high flows did not adversely affect steelhead reproductive success during this study.

Job 6. Title: Collect population and biological data.–We again made mark-and-recapture estimates of brook and brown trout populations during late summer in 2004 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 made each year since 1995. Populations of juvenile steelhead were also estimated during years they were present (1998-04). Scales collected in 2004 have not been aged, to date. Hence, data analyses reported for this segment do not include comparisons of abundance, survival, or growth for years more recent than 2003.

Steelhead continued to reproduce at higher levels than brown trout in Hunt Creek. Average abundance of steelhead YOY in Hunt Creek has been 2.6 times higher than that of brown trout during years when steelhead were stocked (Table 1). Brown trout YOY abundance in the TZ during 1998-03 was significantly lower than during the pre-steelhead-stocking period of 1995-97 (ANOVA $P < 0.05$). However, the relative abundance of YOY brown trout in Hunt Creek compared to Gilchrist Creek has not changed significantly, indicating that environmental factors, may be the cause of recent lower YOY abundance in the TZ (Figure 1).

The primary effect of interactions between brown trout and steelhead has been a significant decline (from 36% to 21%) in annual survival of brown trout YOY. This has reduced abundance of year classes of yearling-and-older brown trout that interacted with steelhead YOY to about half the size of year classes of brown trout hatched before steelhead were present. Therefore, in the following analyses I did not use a fixed set of years for before and after steelhead periods. Rather, I compared abundance of year classes of brown trout at each successive age (age 1 through 4) that interacted with steelhead as YOY (after) with year classes that did not interact with steelhead as YOY (before). For example, the before steelhead period used to evaluate changes in abundance for age-2 brown trout was 1995 through 1999 because these year classes were hatched before steelhead YOY were present. I used the same before and after periods for comparisons of abundance of brown trout in the Gilchrist Creek RZ to account for possible environmental effects on abundance unrelated to species interactions.

Older age classes of brown trout in the Hunt Creek TZ (ages 1 through 3) that interacted with steelhead as YOY were only half as abundant as during the pre-steelhead period (Table 1). Similar declines in abundance of older age classes of brown trout did not occur in the Gilchrist Creek RZ (Table 2). Hence, abundance of older age classes of brown trout in the TZ has declined significantly compared to the Gilchrist Creek RZ, as graphically illustrated in Figure 1.

A few significant changes in the abundance of the sparse populations of brook trout in both Hunt and Gilchrist Creeks were detected. In Hunt Creek, age-1 brook trout were significantly less abundant after steelhead (Table 1). In Gilchrist Creek, where no steelhead were present, abundance of age-2 brook trout was significantly lower from 1999 to 2003 (Table 2). Declines in brook trout abundance in both the TZ and RZ are probably due to lower reproductive success in recent years.

Steelhead introductions into Hunt Creek have significantly reduced survival of YOY brown trout. Before steelhead YOY were present in Hunt Creek, annual survival of YOY brown trout averaged 36 percent whereas it now averages only 21 percent (Table 3). Survival of one- and two-year-old brown trout in the Hunt Creek TZ has not changed, but survival of three-year-old brown trout has increased from 20% to 31% (Table 3). In the Gilchrist Creek RZ, survival of age-1 brown trout increased from 27% to 35%, but survival did not change significantly for other age classes. Mean annual survival of age-0 brown trout was twice as high in the TZ, relative to the Gilchrist Creek RZ, before steelhead YOY were present (Figure 2). Mean annual survival of age-1 brown trout in the TZ did not change significantly relative to the Gilchrist Creek RZ. However, survival of age-2 brown trout in the TZ decreased relative to the RZ while relative survival of age-3 brown increased (Figure 2).

Only a few significant differences in brown trout growth between before-and-after steelhead periods were detected. Age-2 brown trout were 15mm larger during the after-steelhead period in both Hunt and Gilchrist Creeks (Table 4). In Hunt Creek mean length of age-4 brown trout was 20 mm smaller for the after-steelhead period. Changes in brown trout growth were probably unrelated to interactions with steelhead because similar changes were observed in both streams.

Job 7. Title: <u>Test fish for BKD and other diseases</u>–Brown trout were collected for disease screening from Hunt Creek each summer during 1996-04 and from Gilchrist Creek during 1990, 1994, and 1999. In 1999 and 2001-04, we also collected juvenile steelhead downstream from the Hunt Creek TZ. Brown trout were screened for the presence of an array of bacterial and viral pathogens as well as for the presence of *Myxobolus cerebralis* (whirling disease) spores. No diseases or parasites were detected in any of the brown trout collected from Gilchrist Creek.

M. cerebralis spores were detected in Hunt Creek brown trout collected in 1998 and in each year from 2000 to 2003. Prior to 2003, relative spore density was determined by making five passes over a 22 by 22 mm cover slip at 200X magnification. Spore densities determined for brown trout by this method have been low. In most years, 60 fish heads were combined into approximately twelve pools before they were examined for spores. In 2002, spores were found in half of the pooled brown trout samples and spore density in positive pools ranged from one to four.

M. cerebralis spores were not found in steelhead screened in 1999 but they were found in eight of twelve pools of steelhead examined in 2001, and in five of thirteen pools examined in 2002. Spore density in steelhead was low, 11 or fewer per screening slide in 2001. In 2002, four of five screening slides had three or fewer spores, but thirty spores were found in one pool of three steelhead heads. With one exception, no clinical signs of whirling disease have been observed in either brown trout or steelhead. One rainbow trout examined in 2002 exhibited a depression in the skull. The consistently high abundance of juvenile steelhead, over 2000 YOY/ha, indicates that whirling disease has not caused any significant mortality.

In 2003, trout were collected near the mouth of Hunt Creek, approximately 8 km downstream from the TZ, to determine if *M. cerebralis* spores were present in fish more distant from the steelhead stocking site. Defleshed fish cranial cartilages were enzyme-digested and homogenates examined microscopically with standard PCR assays to determine the presence of *M. cerebralis*. Whirling disease was less frequently found in both brown trout and steelhead from this site than from sites further upstream that were sampled in previous years. Spores were detected in only one brown trout (2 spores) and two steelhead (one spore each) out of samples of 60 fish of each species. Thus, whirling disease spores occurred less frequently as distance from the steelhead planting site increased. Seven brown trout (11.7%) and three steelhead (5%) were infected with *R. salmoninarum*, the causative agent of bacterial kidney disease. The percentage of BKD-infected trout was less than the average in Michigan waters (M. Faisal, Department of Pathobiology and Diagnostic Investigation, Michigan State University, personal communication).

Disease testing has not been completed, to date, for the fish collected in July 2004.

Job 10: Title: Analyze data and write progress report–This progress report was prepared.

Literature Cited:

Nuhfer, A.J., R. D. Clark, Jr., and G. R. Alexander. 1994. Recruitment of brown trout in the South Branch of the Au Sable River, Michigan in relation to stream flow and winter severity. Michigan Department of Natural Resources, Fisheries Research Report 2006, Ann Arbor.

Strange, E. M., P. B. Moyle, and T. C. Foin. 1992. Interactions between stochastic and deterministic processes in stream fish community assembly. Environmental Biology of Fishes 36:1-15.

Prepared by: Andrew J. Nuhfer
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Table 1.–August-September numbers of brown, rainbow, and brook trout per hectare, by age, in a 3.4-km treatment zone of Hunt Creek MI where adult steelhead were stocked each spring from 1998 through 2003. Data for years used for the before period for comparisons of brown and brook trout abundance are shaded.

Year	Age 0	Age 1	Age 2	Age 3	Age 4
Brown trout					
1995	1,616	509	199	130	20
1996	970	428	161	74	15
1997	1,283	414	145	64	15
1998	1,048	490	120	92	18
1999	947	297	163	70	26
2000	933	165	98	68	24
2001	1,019	176	64	49	18
2002	902	209	92	35	18
2003	1,008	156	74	35	10
Before[1] Steelhead	1,289[2]	460[2]	158[2]	83[2]	19
After[1] Steelhead	976[2]	201[2]	82[2]	40[2]	14
Rainbow trout					
1998	2,541	0	0	0	0
1999	2,241	340	0	0	0
2000	2,097	245	0	0	0
2001	2,341	357	2	0	0
2002	3,610	480	6	0	0
2003	4,482	379	45	0	0
Mean (1998-03)	2,885	360	17	0	0
Brook trout					
1995	22	8	0.7	0.5	0
1996	80	49	5	0	0
1997	102	51	6	0.4	0
1998	67	35	8	0	0
1999	41	10	2	1	0
2000	41	14	1	0	0
2001	20	7	2	0	0
2002	18	6	1	0	0
2003	17	7	1	0	0
Before[1] Steelhead	68	36[2]	4	0.4	0
After[1] Steelhead	34	9[2]	1	0	0

[1] Different periods were used for different age groups so that only year classes of brown and brook trout that interacted with steelhead as YOY were compared to the pretreatment period means. See text for explanation.

[2] Differences between abundance during before and after period are significantly different (One-way ANOVA, $P \leq 0.05$).

Table 2.–August-September 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, 1995-03. Data for years used for the before period for comparisons of brown and brook trout abundance are shaded.

Year	Age 0	1	2	3	4
Brown trout					
1995	2,173	731	278	113	12
1996	1,867	403	173	57	16
1997	1,887	537	129	43	15
1998	1,032	694	133	62	23
1999	1,689	435	199	80	7
2000	1,741	461	140	70	15
2001	2,272	612	184	84	15
2002	2,101	597	242	70	17
2003	2,492	492	215	86	8
Before[1] Steelhead	1,976	591	182	71	15
After[1] Steelhead	1,888	519	195	80	13
Brook trout					
1995	14	27	6	0	0
1996	21	30	5	0.5	0
1997	30	22	6	0	0
1998	23	12	8	0	0
1999	17	33	0	0	0
2000	2	9	1	0.5	0
2001	7	10	1	0	0
2002	9	4	2	0	0
2003	2	4	0	0	0
Before[1] Steelhead	21	23	5[2]	0.2	0
After[1] Steelhead	10	12	1[2]	0	0

[1] Different periods were used for different age groups so that abundance of the same year classes of brown and brook trout compared in Hunt Creek were also compared in Gilchrist Creek. See text for explanation.

[2] Differences between abundance during before and after period are significantly different (One-way ANOVA, $P \leq 0.05$).

Table 3.–Annual 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
2000	19	39	50	27
2001	21	52	54	36
2002	17	35	38	29
Before 1995-97	36 [1]	32	47	20 [1]
After 1998-02	21 [1]	39	49	31 [1]
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
2000	13	16	37	29
2001	25	96	79	48
2002	65	16	55	38
Before 1995-97	36	80	80	38
After 1998-02	29	41	55	30
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
2000	35	40	60	22
2001	26	40	38	20
2002	23	36	35	12
Before 1995-97	28	27 [1]	31	31
After 1998-02	31	35 [1]	46	17

[1] Differences between survival during before and after period are significantly different (One-way ANOVA $P \leq 0.05$)

Table 4.–Mean total length at age (mm) of brown trout in Hunt and Gilchrist Creeks during August or September 1995-03. Fish were sampled during September from 1995 to 2001, and during August in 2002 and 2003.

Year	Age 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
2001	85	173	237	289	338
2002	83	170	234	298	345
2003	79	163	236	302	333
Before 1995-97	89	166	217 [1]	269	355 [1]
After 1998-03	86	170	232 [1]	286	335 [1]
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
2001	80	152	218	266	336
2002	78	152	221	287	313
2003	69	149	217	277	326
Before 1995-97	80	150	203 [1]	267	334
After 1998-03	81	154	218 [1]	273	332

[1] Differences between mean length at age during before and after period are significantly different (One-way ANOVA $P \leq 0.05$)

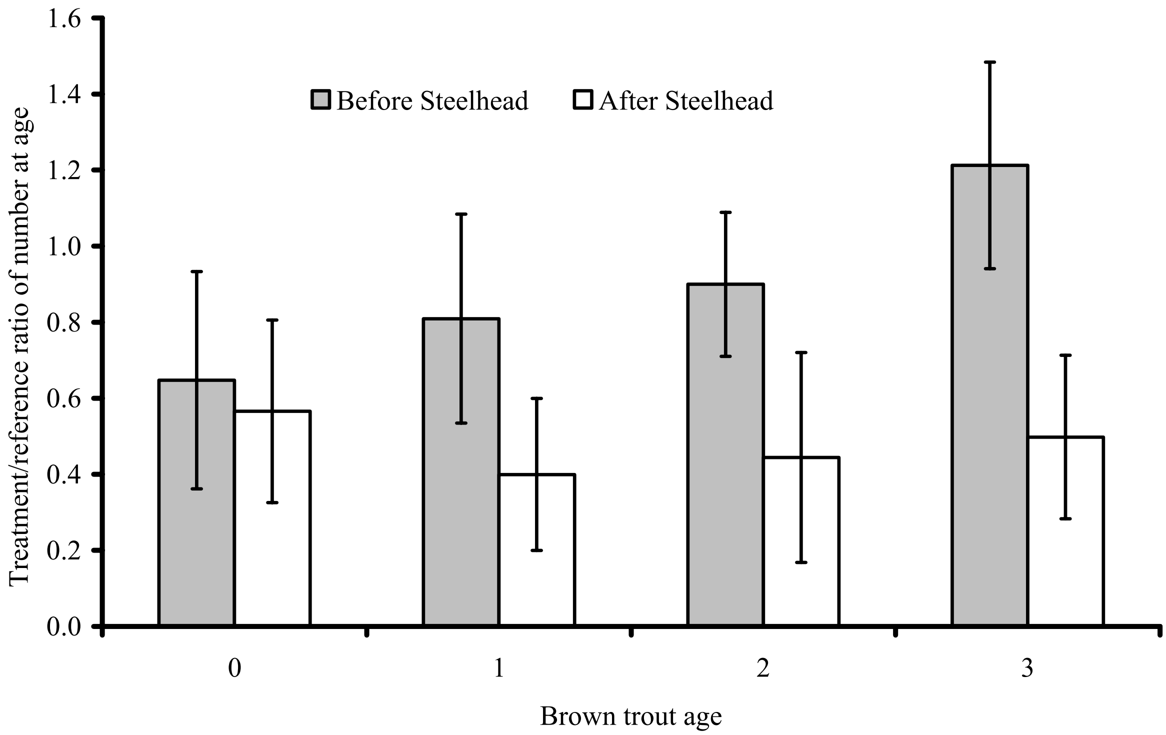

Figure 1.–Mean ratios of the number/ha of brown trout in the treatment zone of Hunt Creek to number/ha in the Gilchrist Creek reference zone. No steelhead were present in the reference zone. Before and after steelhead periods vary by age group so that the abundance ratios of year classes of brown trout that interacted with steelhead as YOY are compared to year classes hatched before steelhead YOY were present. Error bars are 95% confidence limits for the mean ratios. Mean ratios for age-1-and-older brown trout were significantly higher before steelhead (One-way ANOVA $P < 0.05$)

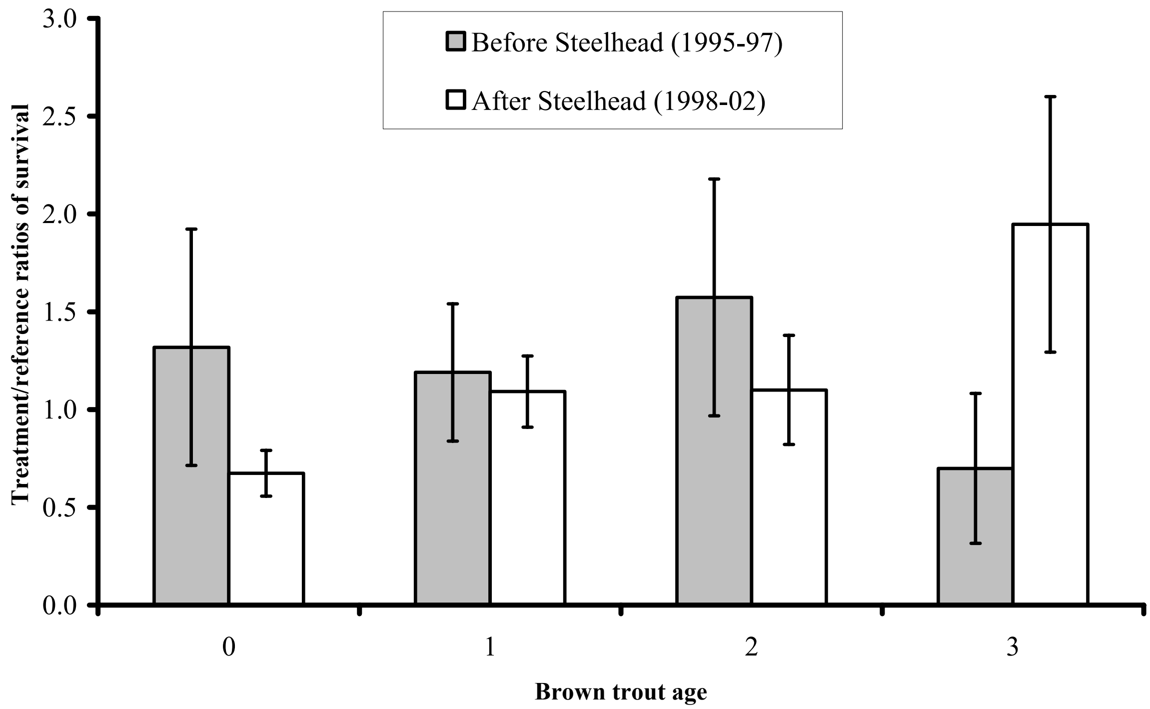

Figure 2.–Mean ratios of annual brown trout survival in the treatment zone of Hunt Creek to survival in the Gilchrist Creek reference zone. No steelhead were present in the reference zone. Error bars are 95% confidence limits for the mean ratios. Mean ratios for age-0, age-2, and age-3 brown trout were significantly different between before and after periods (One-way ANOVA $P < 0.05$)