STUDY PERFORMANCE REPORT

State: Michigan **Project No.:** F-80-R-6

Study No.: 230654 **Title:** Evaluation of brown trout and steelhead competitive interactions in Hunt Creek, Michigan

Period Covered: October 1, 2004 to September 30, 2005

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 (1998–2005) adult steelhead were stocked into the TZ. Adult steelhead trout were stocked each spring from 1998 through 2003. Resident brown and brook trout populations were also estimated in reference zones (RZ's) without steelhead. Brown and brook 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.

Abundance of yearling-and-older brown trout in the Hunt Creek TZ has declined by about half compared to pre-steelhead levels. This occurred primarily because mean annual survival of young-of-the-year (YOY) brown trout declined from 36% to 23%. 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 abundance of YOY trout (brown trout and steelhead combined) was three times higher than the pre-steelhead abundance 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. Reduced abundance of the small population of yearling and older brook trout populations in the TZ may be unrelated to interactions with steelhead because similar declines also occurred in the Gilchrist Creek RZ.

Findings: Jobs 2, 3, 6, 7, and 10 were scheduled for 2004-05, 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.

Brown trout spawning activity in Hunt Creek was highest around 25-October during each year that redds were counted. I used this spawning date, water temperature data collected during the incubation period, and incubation time models (Crisp 1988) to predict median swim-up dates for each brown trout year class. Predicted swim-up dates ranged from 10-April to 14-May with a median swim-up date of 22-April. My analyses suggested that substantial numbers of brown trout alevins were still in redds when steelhead spawned each spring from 1998–2003. 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: <u>Monitor water stage and discharge.</u>–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 hourly throughout the year with a stage height recorder located 2 km upstream of the TZ.

Maximum spring runoff discharge ranged from a daily mean of 30 cfs in 1999 up to 88 cfs in March 1998. Peak spring discharges occurred before predicted median emergence dates in all years except 2002, a year when spring runoff discharge was less than twice as high as summer baseflow. The low variability in abundance of age-0 brown trout over the course of the study coupled with the timing and magnitude of spring runoff flows suggests that high flows had no adverse effect on their reproductive success. The 1998 flood did reduce brown trout reproductive success in the Gilchrist Creek RZ even though it occurred on 31-March when most brown trout alevins were not expected to have emerged. After the flood I observed that course substrates suitable for spawning had been mobilized during the flood. Thus, some redds were undoubtedly scoured and destroyed in Gilchrist Creek in 1998.

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 suggest that high flows did not adversely affect steelhead reproductive success during this study.

Job 6. Title: <u>Collect population and biological data.</u>–We made mark-and-recapture estimates of brown and brook trout populations during late summer in 2005 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 (1998–2005). Estimates were computed using the Chapman variation of the Petersen formulas (Ricker 1975). I stratified population estimates by 25-mm length groups. Age data from trout scales were used to apportion population estimates by length groups into estimates by age group. Abundance data were adjusted for wetted-stream-surface area and presented as numbers per hectare.

Scales collected in 2005 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 2004. I compared abundance between groups of years using one-way ANOVA analyses. Differences between means were judged to be significant for $P \leq 0.05$.

Brown trout year classes that had interacted with YOY steelhead in Hunt Creek during the year they hatched were less abundant than year classes produced before steelhead introductions (Table 1). Mean abundance of yearling and older brown trout hatched before steelhead trout were present was approximately twice as high as during the following years. Mean abundance of YOY brown trout was not different between periods. Yearling brook trout abundance also declined significantly after steelhead reproduced (Table 1), but a similar decline also occurred in the Gilchrist Creek RZ (Table 2). Mean brown trout abundance in the Gilchrist Creek RZ was similar for all age groups during the same years (Table 2).

Abundance of YOY brown trout in Hunt Creek compared to Gilchrist Creek did not change significantly during this study (Figure 1). However, yearling and older brown trout in Hunt Creek were only half as abundant after steelhead introductions, as compared to the Gilchrist Creek RZ.

The primary cause of reduced abundance of older brown trout that interacted with steelhead trout as YOY was a reduction in survival of brown trout YOY from 36% to 23% (Table 3). This change represents a 36% decline in survival rates for YOY. Mean survival rates of older brown trout in the TZ have not changed, but survival of yearling brown trout in the Gilchrist Creek RZ increased slightly from 27% to 35% (Table 3). No changes in brown survival were detected in the Hunt Creek RZ.

Mean annual survival of YOY brown trout was 1.7 times higher in the TZ, relative to the Gilchrist Creek RZ, before steelhead YOY were present (Figure 2). Mean annual survival of yearling and older brown trout in the TZ relative to the Gilchrist Creek RZ was similar (Figure 2).

Mean lengths for age 2 and age 3 brown trout were higher in the TZ after steelhead introductions despite the fact that sampling was conducted nearly a month earlier in the years after 2001 (Table 4). The increase in mean length of brown trout in the Gilchrist Creek RZ suggests that environmental factors unrelated to interactions with steelhead account for some of the increase in growth observed in the TZ.

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 1996–2005 and from Gilchrist Creek during 1990, 1994, and 1999. 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. The spores were also detected in steelhead collected in 1999, and in each year from 2000 through 2003. The disease screening laboratory has not, to date, reported results from fish collected and examined in 2004 and 2005. 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. Consistently high abundance of juvenile steelhead (Table 1) indicates that whirling disease has not caused any significant mortality.

In 2003–05, 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. De-fleshed fish cranial cartilages were enzyme-digested and homogenates examined microscopically with standard PCR assays to determine the presence of *M. cerebralis*. In samples collected in 2003, 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. Thus, whirling disease spores occurred less frequently as distance from the steelhead planting site increased. Seven brown trout (11.7%) and three steelhead (5%) from the 2003 sample 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).

Results of disease testing have not been reported to me, to date, for the fish collected in 2004 and 2005.

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

Literature Cited:

Crisp, D. T. 1988. Prediction, from temperature, of eyeing, hatching and 'swim-up' times for salmonid embryos. Freshwater Biology 19:41–48.

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.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191.

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.

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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. Brown and brook trout year classes that did not interact as YOY with YOY steelhead are shaded. Mean abundance of shaded year class/age groups was compared to un-shaded year class groups.

	Age				
Year	0	1	2	3	4
Brown trout					
1995	1,618	511	199	133	21
1996	973	429	165	71	17
1997	1,286	416	147	66	16
1998	1,050	492	121	94	19
1999	950	299	164	71	28
2000	939	168	100	69	25
2001	1,023	178	65	50	20
2002	906	212	94	36	19
2003	1,011	158	76	37	11
2004	1,062	339	86	54	7
Means [1]	1,235	462 [2]	159 [2]	84 [2]	21 [2]
	980	226 [2]	84 [2]	44 [2]	12 [2]
Rainbow trout					
1998	2,545	0	0	0	0
1999	2,243	343	0	0	0
2000	2,100	248	6	0	0
2001	2,343	360	3	0	0
2002	3,614	484	7	0	0
2003	4,487	381	47	0	0
2004	2	561	27	0	0
Brook trout					
1995	24	10	1	1	0
1996	83	53	4	0	0
1997	106	53	8	0.4	0
1998	69	37	10	0	0
1999	54	11	2	2	0
2000	43	16	2	0	0
2001	22	9	2	0	0
2002	20	8	1	0	0
2003	19	9	1	0	0
2004	6	10	1	0	0
Means [1]	55	38 [2]	5	0.5	0
	38	11 [2]	1.5	0	0

[1] Different year classes were compared for different age groups so that only year classes of brown and brook trout that interacted with steelhead as YOY were compared to the treatment 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, 1995–2004. Mean abundance of shaded year class/age groups was compared to un-shaded year class groups. There were no steelhead present in Gilchrist Creek.

	Age				
Year	0	1	2	3	4
Brown trout					
1995	2,179	733	280	116	14
1996	1,870	405	175	60	17
1997	1,891	540	131	45	17
1998	1,035	697	135	64	25
1999	1,694	437	201	83	8
2000	1,746	464	141	72	17
2001	2,275	615	185	86	17
2002	2,105	609	237	73	18
2003	2,497	497	218	88	9
2004	2,645	712	180	76	24
Means[1]	2,146	594	184	73	17
	1,892	556	192	81	17
Brook trout					
1995	15	30	6	0	0
1996	23	32	5	0	0
1997	32	27	4	0	0
1998	26	17	6	0	0
1999	20	30	8	0	0
2000	2	11	2	0	0
2001	8	13	1	0	0
2002	11	6	2	0	0
2003	2	7	0	0	0
2004	1	10	2	0	0
Means[1]	18	27[2]	6[2]	0	0
	12	13[2]	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.

Year	Age 0	1	2	3
Hunt Creek Treatment Zone				
1995	27	32	35	13
1996	43	34	40	23
1997	38	29	64	29
1998	28	33	59	30
1999	18	33	42	35
2000	19	39	51	28
2001	21	53	56	38
2002	17	36	39	30
2003	34	54	71	20
Before 1995–97	36 [1]	32	46	22
After 1998–2003	23 [1]	41	53	30
Hunt Creek Reference Zone				
1995	19	35	77	34
1996	51	124	64	26
1997	41	76	106	64
1998	18	41	78	25
1999	26	40	34	14
2000	14	18	37	30
2001	26	95	83	47
2002	68	19	59	43
2003	16	26	25	100
Before 1995–97	37	79	82	42
After 1998–2003	28	40	53	43
Gilchrist Creek Reference Zone				
1995	19	24	21	15
1996	29	32	26	29
1997	37	25	49	55
1998	42	29	62	13
1999	27	32	36	21
2000	35	40	61	24
2001	27	39	39	21
2002	24	36	37	13
2003	29	36	35	27
Before 1995–97	28	27 [1]	32	33
After 1998–2003	31	35 [1]	45	20

[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 1995–2004. Fish were sampled during September from 1995 to 2001, and during August in 2002 to 2004.

	Age				
Year	0	1	2	3	4
Hunt Creek					
1995	90	163	209	266	359
1996	90	164	214	270	333
1997	88	171	230	272	367
1998	91	173	224	273	325
1999	85	174	230	279	338
2000	91	168	230	274	338
2001	85	173	237	289	339
2002	83	170	234	298	346
2003	79	163	236	302	333
2004	81	162	242	303	352
Before 1995–97	89	166	218 [1]	269 [1]	353
After 1998–2004	85	169	233 [1]	288 [1]	339
Gilchrist Creek					
1995	81	153	198	264	339
1996	78	148	197	267	331
1997	80	150	214	273	334
1998	85	148	213	264	324
1999	86	166	217	278	357
2000	85	159	224	269	340
2001	80	152	218	266	338
2002	78	152	223	288	315
2003	69	149	217	277	329
2004	73	153	221	272	332
Before 1995–97	80	150	203 [1]	268	335
After 1998–2004	79	154	219 [1]	273	334

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

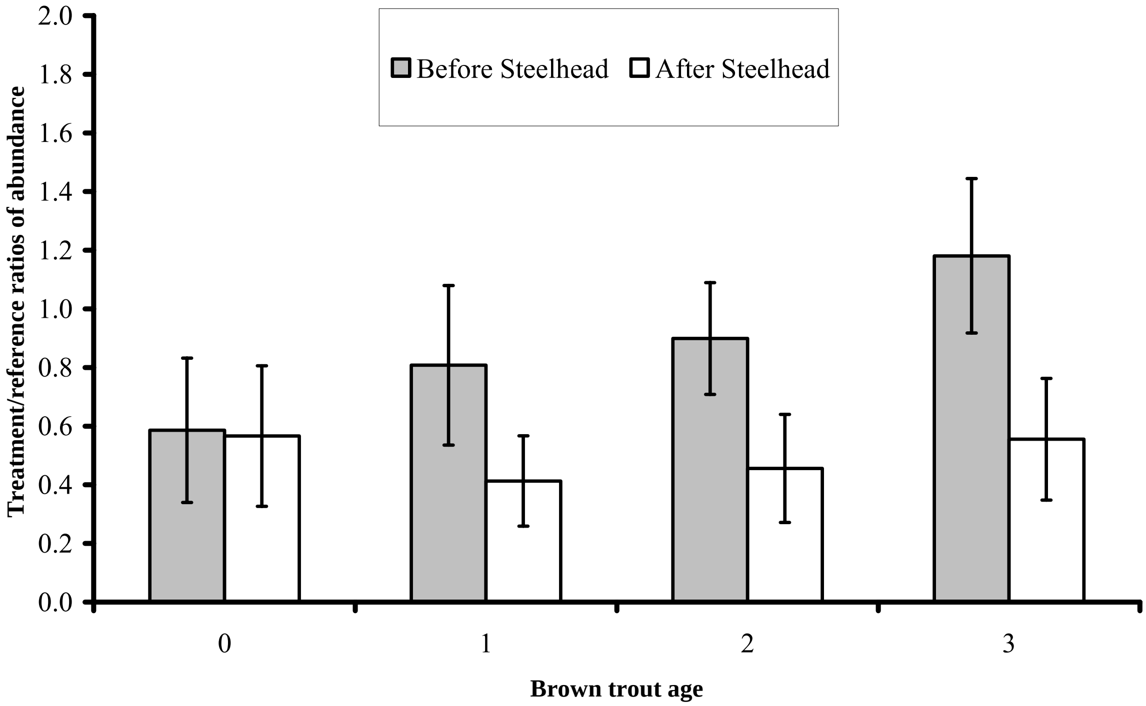

Figure 1.–Mean ratios of the number/ha of brown trout in the treatment zone of Hunt Creek to number/ha in the Gilchrist Creek reference zone. No steelhead trout were present in the reference zone. Before and after steelhead periods vary by age group so that the abundance ratios of year classes of brown 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 $P \leq 0.05$).

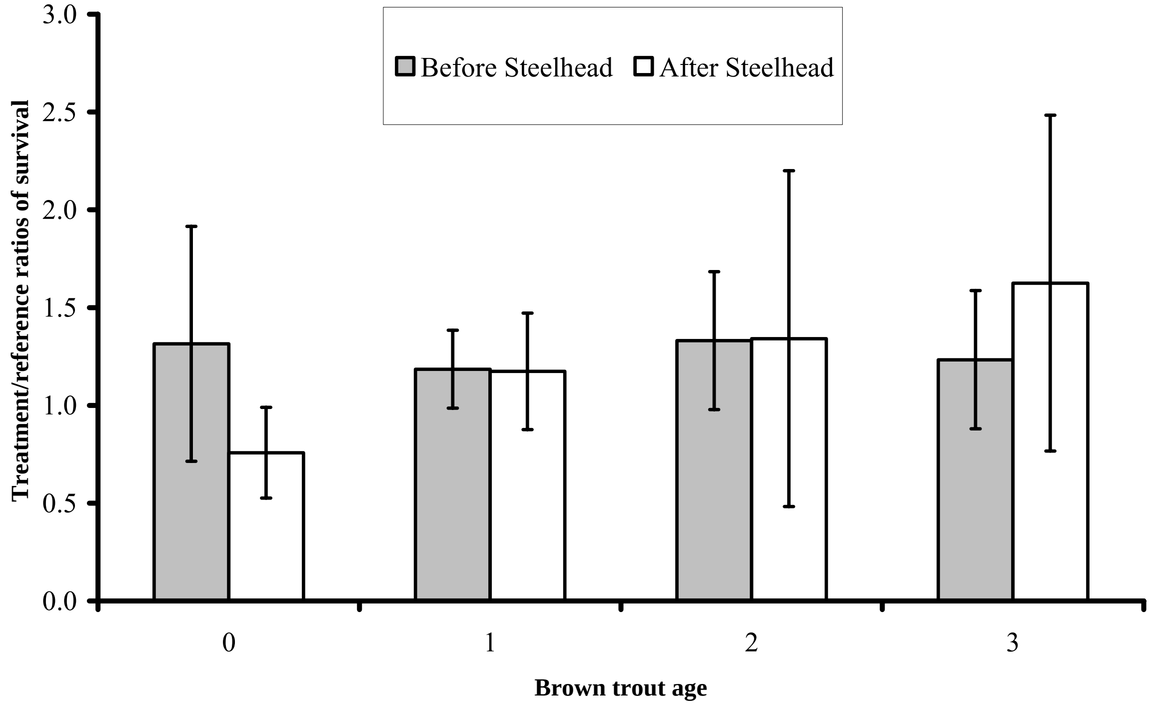

Figure 2.–Mean ratios of annual brown trout survival in the treatment zone of Hunt Creek to survival in the Gilchrist Creek reference zone. No steelhead trout were present in the reference zone. Error bars are 95% confidence limits for the mean ratios. Mean ratios for age-0 brown trout were significantly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