STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-35-R-24

Study No.: 655

Title: The effects of severe water withdrawal on the population and habitat of brook trout.

Period Covered: April 1, 1998 to September 30, 1999

Study Objective: To determine the impact of severe water withdrawal during the summer on a brook trout population, and to test the validity and accuracy of an existing PHABSIM model.

Summary: During 1989-90, a diversion channel was excavated around a 608-meter treatment zone (TZ) of Hunt Creek, MI. Bulkheads were installed at the upstream and downstream ends of the TZ to provide a way to control discharge and to physically support fish traps used to monitor fish movement. Inclined-screen fish traps were installed at the downstream bulkhead before summer 1990 and at the upstream bulkhead before summer 1991. These traps were constructed to monitor trout movement into and out of the TZ during each summer that water was diverted. The upstream bulkhead was used to divert approximately 50% of summer flow from the TZ from 1 June through 31 August, 1991-94 (hereafter referred to as summer). Approximately 75% of summer flow was diverted during 1995-96 and approximately 90% of summer flow was diverted during 1997-98. Water diversion experiments were conducted to simulate the impacts of a summer irrigation withdrawal on the brook trout *Salvelinus fontinalis* population and to evaluate the Physical Habitat Simulation System (PHABSIM) under controlled conditions in a natural stream.

Responses of brook trout populations to dewatering experiments are being evaluated based on semiannual estimates of brook trout abundance in the TZ and three reference zones. Brook trout populations have been estimated by mark-and-recapture methods in four contiguous sections of Hunt Creek during the third week of April and the third week of September every year since 1959. Two reference zones (RZ's) with a combined length of 1516 m are located downstream of the TZ and the other 1000-m RZ is located immediately upstream.

Mean fall abundance of young of the year (YOY) brook trout in the TZ was significantly higher when 75% of water was diverted than during the pretreatment period (1984-90) or when summer discharge was cut in half (1991-94). Mean fall abundance of yearling and older (YAO) brook trout in the TZ was significantly higher following diversion of 50%, 75%, or 90% of summer baseflow than during years of normal discharge. However, survival of YAO from spring to fall in the TZ was significantly lower after 90% dewatering than after any other summer discharge level. In addition, abundance of the largest brook trout in the TZ ($\geq$ 20 cm total length) was significantly lower when 90% of baseflow was diverted than during other time periods.

Abundance of YOY and YAO brook trout in the TZ was not significantly correlated with PHABSIM model predictions of weighted usable area (WUA) determined by Baker and Coon (1995). PHABSIM modeling based on bioenergetic habitat suitability criteria indicated that WUA at reduced discharge levels would decline most for brook trout > 20 cm (Baker and Coon 1995). However, regression analysis indicated that abundance of these larger trout was not

significantly related to WUA based on bioenergetic habitat suitability criteria. We modified sampling in 1997-98 to determine if low correlation between trout abundance and WUA predicted by PHABSIM modeling was related to the presence of deep water refugia in the TZ that were not adequately represented by the transects used for modeling. This sampling suggested that larger trout indeed moved from the modeled portion of the TZ into deep-water habitat that was not modeled. Revised estimates of WUA will be presented in the final report for this study based on data collected in 1998 along new transects were established in the "refuge" areas.

Water warming of the magnitude observed in Hunt Creek could have strong negative effects on trout populations in streams where summer water temperatures are closer to the maximum tolerance level for trout or where longer stream reaches are dewatered. Appreciable warming of waters within the TZ occurred when 75% or 90% of baseflow was diverted. We developed a model to predict warming based upon discharge and air temperature.

Downstream emigration from the TZ was inversely related to summer discharge. Fewer trout emigrated from the TZ during the summers of 1995-96 (75% flow reduction) and the summers of 1997-98 (90% flow reduction) than when discharge was reduced by 50% or when no water was diverted. Fish traps blocked emigration from the TZ in an upstream direction.

Job 1. Title: Operate and maintain the experimental diversion.

Findings: An L-shaped bulkhead containing stop logs is used to control the amount of water flowing through a 608-m TZ of Hunt Creek each year during the period from 31-May through 31 August. The amount of water diverted around the experimental stream section is controlled by changing the relative levels of stop logs in each arm of the bulkhead. Diverted water returns to the mainstem of Hunt Creek downstream from a second bulkhead located at the downstream TZ boundary.

Normal summer discharge in the TZ is 16 cfs. Summer discharge in this section was reduced to an average of 8 cfs during 1991-94. During 1995-96 summer discharge in the TZ averaged 4 cfs. Stream discharge measurements made at the upstream end of the TZ from June through August 1997-98 ranged from 0.92-1.7cfs. During June through August 1999 we randomly changed flow to 10%, 25%, 50%, or 100% of normal at approximately 4-d intervals. These water level manipulations were conducted to provide data on water warming in the TZ at different flow levels and air temperatures.

Job 2. Title: Measure depths, velocities and temperatures.

Findings: During summer 1998 we measured water depths and velocities along 40 transects established within the TZ to allow computation of WUA while stream discharge was approximately 2 cfs. These measurements will later be compared to depths and velocities predicted by the PHABSIM hydraulic model to assess the accuracy of predicted values.

Trout abundance over the course of the study has not been strongly related to estimates of WUA at different discharge levels. I hypothesized that trout may emigrate to refuge pools near the upstream and downstream ends of the TZ during periods of low discharge and that the 40 transects used for modeling WUA did not characterize habitat in these "refuges". Therefore, in 1998 we established 24 additional transects in the upstream and downstream ends of the TZ. We then measured water depth and velocity along these transects at four discharge levels (2, 4, 8, and 16 cfs). These data will be used to compute revised WUA estimates for the TZ and will be presented in the final report.

Electronic thermometers located near the upstream and downstream boundaries of the TZ have been used to record water temperatures once every hour since October 1992. I summarized temperature data by first determining daily maximum, minimum, and average temperature (based on 24 measurements/d) near both the upstream and downstream boundaries of the experimental section. I then calculated mean values for maximum, minimum, and average daily temperatures for each month when water was diverted (June, July, or August) and for the entire period of 1-June through 31-August. Differences in temperature between the upstream and downstream boundaries of the study section were then compared for different levels of summer discharge.

Initial analyses of temperature data indicated that substantial warming of the water occurred when 75% or more of the water was diverted from the TZ. However, I later determined that the downstream thermometer became inaccurate over time and was registering higher temperatures than the upstream thermometer when both were placed in the same water bath in fall 1997. Thus, the accuracy of downstream water temperature data collected from 1995-97 was questionable. In spring 1998 new thermometers were calibrated relative to each other and placed in the stream prior to dewatering. During summer 1998, mean daily water temperature increased a 3.8 ^{o}F per km in the TZ. During July, the hottest month, mean daily water temperature increased 4.5 ^{o}F per km. The average daily summer maximum water temperature in the TZ increased 6.8 ^{o}F and the average July maximum temperature increased 8.0 ^{o}F per km.

In summer 1999 we assessed the effects of both discharge level and air temperature on warming within the TZ. From September 1998 through September 1999, five calibrated thermometers were deployed in the TZ to provide replicate temperature measurements and to insure that data would be available even if some thermometers malfunctioned. An additional thermometer was deployed to collect air temperature data. Effects of different levels of dewatering on warming within the TZ were then determined at discharges ranging from 1.8 to 18.1 cfs during summer 1999. The change in temperature between the upstream and downstream ends of the TZ at different discharge levels was then regressed against flow and air temperature. Water temperature data collected during periods when discharge fluctuated due to precipitation were excluded from analysis. Regression analysis showed that warming was inversely related to discharge and positively related to air temperature. Sixty three percent of the variation in warming (^{o}F) per kilometer in the TZ was explained by the model shown below.

$$Y = -1.466 - 0.0828 * (\text{discharge in cfs}) + 0.04375 * (\text{mean air temperature})$$

Although this model appears useful it greatly under-predicts the amount of heating that was observed at low discharge during summer 1998.

Job 3. Title: <u>Estimate brook trout populations and collect biological data.</u>

Findings: Responses of brook trout populations to dewatering experiments are being evaluated based on semiannual mark-and-recapture estimates of brook trout abundance in the TZ and three RZ's. Two stream segments located downstream from the TZ and one segment located upstream from the TZ are used as RZ's. The combined length of the downstream reference zones is 1516 m and the upstream reference zone is approximately 1000 m long. Scale samples were collected from a sub-sample of trout during each collection period to determine trout ages. Total lengths of all trout captured during the marking run were measured to the nearest 0.1-inch and weights of scale-sampled trout were measured to the nearest 0.1 g. Population estimates and variances were computed using the Bailey modification of the Petersen mark-and-recapture method (Bailey 1951). I tested for significant differences in abundance between time periods by inspecting 95% confidence limits of population estimates for overlap. I also analyzed brook trout abundance, survival, and growth in the TZ relative to reference zones to ascertain if the temporal variation might be unrelated to dewatering experiments. I computed 95% confidence bounds for the TZ:RZ ratios and judged ratios to be significantly different if their confidence limits did not overlap.

In this progress report I focus primarily on responses of YAO trout to flow reductions because PHABSIM modeling conducted by Baker and Coon (1995) predicted greater loss of suitable habitat for older fish. One of the assumptions underlying PHABSIM modeling is that fish abundance should be lower if predicted WUA declines. Declines in abundance would presumably occur through either increased mortality or emigration. Before testing for changes in survival rates of YAO brook trout I first compared their abundance in April to determine if it was similar prior to initiation of each level of dewatering. Abundance during a 7-year period from 1984-90 was used as a pre-treatment reference period (normal summer flow) and compared to abundance in periods with reduced flows.

Spring abundance of YAO brook trout in the TZ was significantly lower during the pre-treatment period than during any of the periods when summer discharge was reduced (Table 1). Spring abundance was not significantly different between other time periods. However, point estimates of abundance were highest prior to summers when flow was reduced to either 4 or 1.5 cfs. Spring YAO abundance in reference zone Z located downstream from the TZ was significantly lower from 1995-96 than from 1991-94 (Table 1). However, there were no other significant temporal differences in abundance in the reference zones located downstream from the TZ (zones Z and A). Populations of YAO were significantly less abundant in the upstream reference zone (zone C) in 1997-98 than during other time periods (Table 1) and were generally less temporally stable than in other stream segments.

Fall abundance of YAO brook trout in the TZ was significantly higher in 1995-96 following summer flows of 4 cfs (25% of normal) than after summer flows of 16, 8, or 1.5 cfs (Table 2). Fall YAO in the TZ were significantly more abundant following all reduced flow experiments than during the pretreatment period of 1984-90. However, spring abundance of YAO in the TZ was also lower during the pretreatment period. Abundance of YAO in the three RZ's generally declined over the course of the study period (Table 2). I did not examine TZ:RZ ratios of YAO to evaluate effects of reduced discharge because it appeared that spring abundance of YAO had a stronger influence on fall abundance.

I hypothesized that if reduced summer flow rates in the TZ altered habitat suitability then survival of YAO from spring to fall during different time periods should be different than in the reference zones. Because spring and fall YAO abundance trends in the downstream reference zones Z and A were very similar I combined data from these zones before computing survival estimates. I next computed survival estimates for the TZ and determined the ratios (± 2SE) of survival in the TZ to survival in the combined downstream zones (Table 3).

Survival of YAO from spring to fall in the TZ was significantly lower at 1.5 cfs than at any other summer discharge level. Survival in the TZ was not significantly different following summer flow rates of 16, 8, or 4 cfs (Table 3). Survival of YAO in the RZ was very similar throughout the study period. Ratio analysis showed that YAO survival was significantly higher in the TZ when discharge was 4 cfs as compared to normal flows of 16 cfs. The TZ:RZ ratios of survival following summers when discharge averaged 8 or 1.5 cfs were not significantly different from other time period (Table 3).

Mean fall abundance of young-of-the-year (YOY) brook trout in the TZ was significantly higher when 75% of water was diverted than during the pretreatment period or when summer discharge was cut in half (Table 4). By contrast, in reference zone A, located immediately downstream, there no significant differences in YOY between time periods. In general, YOY abundance in downstream reference zones Z and A was not highly variable during the study (Table 4). Abundance in the upstream reference zone C was stable from 1984-94 but declined significantly in 1995-96 and again in 1997-98. Thus, YOY in the TZ increased significantly during years when 75% of water was diverted whereas they either declined or remained stable in the RZ's.

Abundance of both YOY and YAO brook trout in the TZ was poorly correlated with PHABSIM model predictions of weighted usable area (WUA) determined by Baker and Coon (1995). The slopes of regression lines for the relationship of YOY or YOA to WUA were not significantly different from zero. PHABSIM modeling based on bioenergetic habitat suitability criteria indicated that WUA at reduced discharge levels would decline most for brook trout > 20 cm (Baker and Coon 1995). However, regression analysis indicated that abundance of these larger trout was not significantly related to WUA based on bioenergetic habitat suitability criteria.

Poor correlation between WUA and trout abundance may be related to, in part, to refugia outside the portion of the TZ where habitat was modeled by PHABSIM. Baker and Coon (1995) did not model habitat in a section of impounded water at the downstream end of the TZ or in a section of habitat downstream from the upstream bulkhead. During 1998 we measured depths and velocities needed to determine WUA along transects established at both ends of the TZ when stream discharge was 16, 8, 4, and 2 cfs. This should provide more accurate estimates of total WUA in the entire TZ. Revised estimates of WUA and relationships to trout abundance will be presented in the final report for this study.

I tested the hypothesis that changes in summer flow would influence trout growth by comparing fall mean length at age among study periods. Confidence limits (mean ± 2SE) were examined for overlap to determine significant differences. No differences in mean length at age following different levels of summer flow were detected in the TZ (Table 5). However, point estimates of mean length of age-3 brook trout declined linearly in proportion to discharge (R^2 = 0.96) in the TZ whereas no similar trend was evident in the RZ's.

Job 4. Title: <u>Monitor movement into and out of the treatment section</u>

Findings: Downstream emigration from the TZ was inversely related to summer discharge. Fewer trout emigrated from the TZ when discharge was reduced by 75-90% than when discharge was reduced by 50% or when no water was diverted (Table 6). The mean number of downstream emigrants when 50% of water was diverted was 69.5 fish compared with 15.5 fish when 75% of baseflow was diverted and 18 fish when 90% of water was diverted. Trout attempting to immigrate into the TZ during 1997 outnumbered emigrants by about 2:1. However, about half of the fish attempting to immigrate died in the fish traps so there was essentially no net change in the TZ trout population attributable to immigration or emigration. Similarly, in 1998 live immigrants outnumbered emigrants by only 2 fish. The mean total lengths of immigrating and emigrating trout were similar among years (Table 6).

During the initial years of the study (1990-96) we operated the fish traps only during the dewatering period, 1-June through 31-August. The observation of significantly higher abundance of YOY and higher survival of YAO from spring to fall during 1995-96 led me to speculate that fall populations in the TZ could be inflated by immigrants from adjacent stream areas during May and September. Therefore, beginning in 1997 we activated the traps shortly after spring populations were estimated during the third week in April and continued to operate them until fall estimates were completed near the end of September. Thus, most immigration and emigration between the times when populations were estimated was accounted for in 1997-98. However, during periods of high spring flow debris plugs the trap screens allowing fish to immigrate or emigrate without being counted. During May and September 1997 we trapped 114 trout attempting to immigrate into the TZ whereas only 33 trout emigrated during the same time. Virtually all of these trout were YAO and if 90% of them had not perished in the traps during high water periods experienced in May they would have comprised a maximum of 5% of the fall YAO population if they all lived through summer. By contrast, in May and September 1998 only 27 trout immigrated compared to 25 emigrants. I conclude that immigration into the TZ during years when the traps were not operated in May and September probably had a negligible effect on fall populations or estimated survival rates.

Literature Cited:

Bailey, N.J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38:293-306.

Baker, E.A. and T.G. Coon. 1995. Comparison of predicted habitat change and brook trout population response to a simulated irrigation withdrawal in Hunt Creek, Michigan. Michigan Department of Natural Resources Fisheries Division Research Report 2018. Ann Arbor, Michigan.

Prepared by: Andrew J. Nuhfer
Date: September 30,1999

Table 1.–Spring number (± 2SE) of yearling-and-older brook trout per hectare in an experimentally dewatered zone and three reference zones of Hunt Creek. Zones Z and A are located downstream of the treatment zone and Zone C is located immediately upstream. Summer baseflow discharge in the dewatered zone averaged 16 cfs from 1984-90, 8 cfs from 1991-94, 4 cfs from 1995-96, and 1.5 cfs in 1997-98.

		Reference Zones		
Year	Dewatered Zone	Zone Z	Zone A	Zone C
16 cfs period:				
1984	2,773 ± 320	2,069 ± 144	1,995 ± 134	4,349 ± 265
1985	2,414 ± 210	3,471 ± 250	2,384 ± 145	3,670 ± 213
1986	2,958 ± 296	2,305 ± 148	2,387 ± 242	3,705 ± 359
1987	3,160 ± 383	2,309 ± 198	2,591 ± 277	4,457 ± 266
1988	2,144 ± 281	2,629 ± 230	1,947 ± 128	2,960 ± 229
1989	2,851 ± 383	2,129 ± 221	2,078 ± 190	3,003 ± 239
1990	2,339 ± 341	1,473 ± 267	1,187 ± 190	1,892 ± 189
Average	2,663 ± 121	2,341 ± 80	2,081 ± 73	3,434 ± 97
8 cfs period:				
1991	2,502 ± 307	2,176 ± 234	1,589 ± 155	3,906 ± 269
1992	2,833 ± 333	2,324 ± 267	1,963 ± 169	3,668 ± 294
1993	3,902 ± 474	2,924 ± 285	2,690 ± 156	5,215 ± 542
1994	2,817 ± 256	1,814 ± 166	1,672 ± 186	2,107± 149
Average	3,014 ± 176	2,310 ± 121	1,978 ± 83	3,724 ± 172
4 cfs period:				
1995	3,174 ± 294	1,761 ± 149	1,874 ± 126	4,114 ± 235
1996	3,465 ± 313	1,886 ± 211	2,028 ± 248	2,859 ± 190
Average	3,319 ± 215	1,824 ± 129	1,951 ± 139	3,487 ± 151
1.5 cfs period:				
1997	3,682 ± 486	1,547 ± 212	1,403 ± 177	1,878 ± 230
1998	2,988 ± 299	2,859 ± 231	2,408 ± 160	2,973 ± 257
Average	3,335 ± 285	2,203 ± 157	1,905 ± 119	2,425 ± 172

Table 2.–Fall number (± 2SE) of yearling-and-older brook trout per hectare in an experimentally dewatered zone and three reference zones of Hunt Creek. Zones Z and A are located downstream of the treatment zone and Zone C is located immediately upstream. Summer baseflow discharge in the dewatered zone averaged 16 cfs from 1984-90, 8 cfs from 1991-94, 4 cfs from 1995-96, and 1.5 cfs in 1997-98.

		Reference Zones		
Year	Dewatered Zone	Zone Z	Zone A	Zone C
16 cfs period:				
1984	1679 ± 242	1965 ± 197	1725 ± 160	2763 ± 302
1985	1517 ± 253	2120 ± 289	1390 ± 159	2099 ± 269
1986	1879 ± 156	2171 ± 241	1841 ± 194	2155 ± 444
1987	1532 ± 205	1897 ± 294	1770 ± 261	2135 ± 450
1988	943 ± 173	1963 ± 264	1239 ± 194	1982 ± 271
1989	1587 ± 206	1789 ± 227	1425 ± 183	2051 ± 200
1990	1468 ± 307	1257 ± 224	755 ± 93	1268 ± 216
Average	1515 ± 85	1880 ± 95	1449 ± 69	2065 ± 121
8 cfs period:				
1991	2091 ± 324	1407 ± 221	1201 ± 145	2478 ± 341
1992	1952 ± 266	2225 ± 232	1592 ± 199	2692 ± 283
1993	1909 ± 464	2120 ± 266	2306 ± 209	2446 ± 442
1994	2022 ± 399	1530 ± 215	1512 ± 181	1705 ± 305
Average	1994 ± 185	1821 ± 117	1653 ± 93	2330 ± 174
4 cfs period:				
1995	2319 ± 243	1519 ± 183	1617 ± 162	2377 ± 215
1996	2976 ± 391	1357 ± 148	1409 ± 169	1881 ± 151
Average	2647 ± 230	1438 ± 118	1513 ± 117	2129 ± 132
1.5 cfs period:				
1997	2132 ± 244	1583 ± 139	1377 ± 143	1328 ± 106
1998	1906 ± 215	1681 ± 180	1353 ± 161	2053 ± 127
Average	2019 ± 163	1632 ± 113	1365 ± 108	1691 ± 83

Table 3.–Fraction (± 2SE) of yearling-and-older brook trout surviving from spring to fall in a 608-m dewatered zone and in a 1516-m reference zone. Ratios (± 2SE) of survival in the dewatered zone to survival in the reference zone are shown in the bottom 1/3 of the table. Upper and lower 95% confidence limits were approximated as means (± 2SE). Summer discharge in the reference zone ranges from approximately 17 cfs at the upstream end to 28 cfs downstream.

			95% confidence limits	
Time Period	Discharge	Surviving fraction	Lower	Upper
Dewatered Zone:				
1984-90	16.0 cfs	0.568 ± 0.041	0.527	0.610
1991-94	8.0 cfs	0.683 ± 0.073	0.610	0.756
1995-96	4.0 cfs	0.795 ± 0.089	0.706	0.883
1997-98	1.5 cfs	0.608 ± 0.083	0.525	0.692
Downstream reference zones Z and A combined:				
1984-90	Normal	0.762 ± 0.036	0.726	0.797
1991-94	Normal	0.811 ± 0.046	0.765	0.857
1995-96	Normal	0.785 ± 0.062	0.723	0.847
1997-98	Normal	0.790 ± 0.065	0.725	0.855
Ratio of survival in dewatered to reference zone:				
1984-90	N/A	0.746 ± 0.065	0.682	0.811
1991-94	N/A	0.842 ± 0.101	0.741	0.943
1995-96	N/A	1.013 ± 0.138	0.874	1.151
1997-98	N/A	0.770 ± 0.123	0.647	0.893

Table 4.–Fall number (± 2SE) of young-of-the-year brook trout per hectare in a dewatered zone and three reference zones of Hunt Creek. Zones Z and A are located downstream of the treatment zone and Zone C is located immediately upstream. Summer baseflow discharge in the dewatered zone was approximately 16 cfs from 1984-90, 8 cfs from 1991-94, 4 cfs in 1995-96 and 1.5 cfs in 1997-98.

		Reference Zones		
Year	Dewatered Zone	Zone Z	Zone A	Zone C
16 cfs period:				
1984	3,430 ± 466	3,186 ± 273	3,016 ± 292	4,805 ± 298
1985	2,968 ± 343	2,421 ± 282	2,428 ± 272	4,966 ± 248
1986	2,887 ± 315	2,631 ± 284	2,837 ± 314	6,149 ± 481
1987	2,113 ± 276	2,355 ± 283	2,291 ± 382	4,265 ± 505
1988	3,668 ± 402	2,425 ± 285	2,301 ± 265	4,968 ± 278
1989	3,051 ± 361	2,376 ± 235	2,276 ± 313	4,505 ± 299
1990	3,055 ± 504	2,079 ± 312	2,206 ± 258	5,787 ± 379
Average	3,025 ± 147	2,496 ± 106	2,479 ± 114	5,064 ± 139
8 cfs period:				
1991	3,105 ± 353	1,766 ± 270	2,412 ± 231	5,660 ± 339
1992	3,219 ± 439	2,144 ± 261	2,557 ± 272	5,051 ± 367
1993	2,777 ± 425	2,158 ± 286	2,083 ± 202	2,983 ± 335
1994	3,780 ± 632	2,780 ± 293	2,911 ± 381	6,960 ± 408
Average	3,220 ± 237	2,212 ± 139	2,491 ± 140	5,163 ± 182
4 cfs period:				
1995	4,467 ± 439	2,146 ± 227	2,540 ± 211	4,049 ± 257
1996	3,878 ± 489	2,431 ± 295	2,332 ± 237	4,265 ± 326
Average	4,172 ± 328	2,289 ± 186	2,436 ± 159	4,157 ± 208
1.5 cfs period:				
1997	4,207 ± 738	3,188 ± 315	2,760 ± 221	3,738 ± 321
1998	2,945 ± 373	2,566 ± 265	2,741 ± 243	3,120 ± 275
Average	3,576 ± 413	2,877 ± 206	2,750 ± 164	3,429 ± 211

Table 5.–Fall mean length at age in mm (± 2SE) of brook trout in a dewatered zone and three reference zones of Hunt Creek. Summer baseflow discharge in the dewatered zone was approximately 16 cfs from 1984-90, 8 cfs from 1991-94, 4 cfs in 1995-96, and 1.5 cfs in 1997-98.

		Reference Zones		
Time Period	Dewatered Zone	Zone Z	Zone A	Zone C
Age-0:				
1984-90	79 ± 5	89 ± 5	83 ± 5	77 ± 3
1991-94	80 ± 7	88 ± 7	85 ± 6	78 ± 4
1995-96	75 ± 8	88 ± 9	87 ± 8	77 ± 5
1997-98	75 ± 11	83 ± 8	83 ± 7	76 ± 6
Age-1:				
1984-90	128 ± 10	142 ± 10	134 ± 10	131 ± 10
1991-94	126 ± 17	140 ± 13	138 ± 12	129 ± 13
1995-96	125 ± 14	138 ± 16	137 ± 15	126 ± 9
1997-98	126 ± 15	139 ± 14	138 ± 15	129 ± 8
Age-2:				
1984-90	180 ± 21	191 ± 24	186 ± 18	178 ± 26
1991-94	174 ± 32	192 ± 30	194 ± 27	171 ± 28
1995-96	169 ± 45	194 ± 37	193 ± 32	174 ± 30
1997-98	175 ± 40	198 ± 32	196 ± 32	183 ± 30
Age-3:				
1984-90	241 ± 49	241 ± 64	241 ± 50	224 ± 45
1991-94	220 ± 61	232 ± 64	228 ± 84	225 ± 48
1995-96	218 ± 102	231 ± 93	231 ± 100	231 ± 85
1997-98	210 ± 102	232 ± 104	230 ± 101	227 ± 73

Table 6.–Mean total length and number of brook trout caught in inclined screen traps located at the upstream and downstream boundaries of the treatment zone from 1-June to 31-August during the summer prior to water withdrawal (1990), the summers when 50% of baseflow was diverted (1991-94), the summers when 75% of baseflow was diverted (1995-96), and during 1997-98 when 90% of baseflow was diverted.

Year	Upstream Bulkhead (immigrants)		Downstream Bulkhead (emigrants)	
	mean length (mm)	number	mean length (mm)	number
1990	NA*	NA*	109	69
1991	102	39	103	43
1992	113	30	90	53
1993	126	199	126	132
1994	85	183	83	50
1995	107	41	94	14
1996	124	14	64	17
1997	104	33	102	13
1998	109	31	125	23

* Traps not constructed