# STUDY PERFORMANCE REPORT

**State:** Michigan

**Project No.:** F-80-R-1

**Study No.:** 655

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

**Period Covered:** October 1, 1999 to September 30, 2000

**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 a diversion channel was excavated around a 602-m treatment zone (TZ) in Hunt Creek, MI. Bulkheads were installed at the upstream and downstream ends of the TZ to provide a way to control discharge and to support fish traps used to monitor fish movement (referred to as the upstream and downstream bulkheads respectively in remainder of text). The upstream bulkhead allowed us to control the flow of water through the TZ of Hunt Creek. The upstream bulkhead was used to divert water between 1-June and 31 August each year of the study between 1991-98. During 1991-94, 50 percent of summer baseflow was diverted, in 1995-96, 75 percent was diverted, and during 1997-98, flow in the TZ was reduced by 90 percent.

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 were evaluated based on semiannual estimates of brook trout abundance in the TZ and in contiguous upstream and downstream reference zones (RZ's). 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. Relative abundance and survival of trout in upstream and downstream RZ's were examined to determine if temporal changes were similar to those in the TZ. Mean abundance of fall yearling-and-older (YAO) brook trout was highest in the TZ when 75% of summer baseflow was diverted. Survival from spring to fall in the TZ was also highest during the same test period. Temporal differences in abundance and survival in the RZ's were different than those observed in the TZ.

The study was amended to provide an additional year for data analysis and report writing. 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 if large percentages of water were diverted.

## Job 5. Title: Compare PHABSIM predictions to population response and write final report.

**Findings:** The study has been extended for a year to allow time for additional data analysis and report writing. In this progress report, I describe and compare abundance and survival of brook trout between periods and zones.

One of the assumptions underlying PHABSIM modeling is that fish abundance is linearly related to weighted usable area (WUA). Substantially reduced amounts of WUA in the TZ of Hunt Creek were predicted for older brook trout at discharge levels tested between 1995 and 1998 (Baker and Coon 1995). Declines in abundance could occur if survival decreased or emigration increased. However, both survival and emigration rates can be density dependent. Thus, I first compared abundance of YAO in April between test periods before I made comparisons of spring-to-fall survival between periods when water was diverted from the TZ. Abundance during a 7-year period from 1984-90 was used as a pre-treatment reference period (normal summer flow in the TZ) and compared to abundance in periods with reduced flows. I used the Bonferroni technique (Miller 1981) to identify significant differences in abundance or mortality between experimental periods within zones. Differences were judged significant for $P_{\alpha} < 0.05$).

Spring abundance of YAO brook trout in the TZ was significantly lower during the pre-treatment period than during any period when summer discharge was reduced (Table 1). Spring abundance was not significantly different between periods when discharge was reduced by 50, 75, or 90 percent. However, point estimates of mean abundance were highest prior to summers when flow was reduced to either 4 or 1.5 cfs.

Periods of highest spring-YAO abundance were different in the RZ's than in the TZ. Mean spring YAO abundance in the downstream RZ was significantly lower in 1995-96 (4 cfs test period), and in 1997-98 (1.5 cfs test period) than during 1984-90 when no flow was diverted from the TZ (Table 1). Mean YAO abundance in the downstream RZ was also lower during 1995-96 than during 1991-94. Spring populations of YAO were significantly less abundant in the upstream RZ in 1997-98 than during other time periods (Table 1). They were more abundant during 1991-94 than during 1984-90. The temporal trend in abundance from 1984-98 (slope of regression of spring YAO on year) was not significantly different from zero in either RZ. However, in the TZ, abundance of YAO increased significantly over the course of the entire study.

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. Note however, that spring abundance of YAO in the TZ was also lower during the pretreatment period. By contrast, fall abundance of YAO in the downstream RZ was higher during the pre-treatment period (1984-90) and during 1991-94 than during 1997-98 (Table 2). Fall numbers of YAO in the upstream RZ were significantly lower during 1997-98 than during any other experimental period. Abundance of YAO varied more in both RZ's than in the TZ over the course of the entire study. The slopes of regression lines of fall YAO abundance in the RZ's between 1984 and 1998 were not significantly different from zero. However, fall YAO abundance in the TZ increased significantly over the same time period. I did not examine TZ:RZ ratios of YAO to evaluate effects of reduced discharge because spring abundance of YAO had a strong influence on fall abundance. I judged that comparisons of survival from spring to fall were a better way to assess the effects of water diversion from the TZ.

Average survival of YAO from spring to fall was significantly higher in the TZ when 75% of water was diverted than when no water was diverted or when 90% of summer flow was diverted (Table 3). The average percentage of YAO surviving from spring to fall ranged from 57 percent at 16 cfs, 61 percent at 1.5 cfs, up to 80% at 4 cfs (Table 3). Average survival in the TZ during the 4 years when half the normal summer flow was diverted (68%) was not different from survival following other discharge levels. By comparison, mean spring-to-fall survival in the downstream RZ was not different between study periods (Table 3). It ranged from an average of 76 percent during 1984-90 up to 81 percent during 1991-94. Similarly, average spring-to-fall survival in the upstream RZ was not different between study periods but was slightly more variable, ranging from 60% during 1984-90 up to 70% in 1997-98 (Table 3).

Mean fall abundance of young-of-the-year (YOY) brook trout in the TZ was significantly higher following summers when discharge was 4 cfs than after summers when discharge averaged 8 or 16 cfs (Table 4). By contrast, there were no significant differences in mean fall abundance of YOY in the downstream RZ between the same periods (Table 4). Mean YOY abundance in the downstream RZ was significantly higher in 1997-98 than for other study periods. Upstream of the TZ, fall abundance of YOY declined over the course of the entire study. Mean YOY abundance in the upstream RZ was higher in 1984-90 than in 1995-96. YOY were also more abundant from 1991-94 than in either 1995-96 or in 1997-98. Finally, YOY in the upstream RZ were more abundant in 1995-96 than in 1997-98.

## 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 Research Report 2018, Ann Arbor.

Miller, R. G. 1981. Simultaneous statistical inferences. Springer-Verlag, New York.

**Prepared by:** Andrew J. Nuhfer
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Table 1.–Spring number (± 2SE) of yearling-and-older brook trout in an experimentally dewatered zone and in reference zones of Hunt Creek. 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 | Downstream | Upstream |
| 16 cfs period: | | | |
| 1984 | 681 ±79 | 1,826 ±89 | 1,937 ±118 |
| 1985 | 593 ±52 | 2,552 ±120 | 1,634 ±95 |
| 1986 | 727 ±73 | 2,122 ±140 | 1,650 ±160 |
| 1987 | 776 ±94 | 2,232 ±164 | 1,985 ±119 |
| 1988 | 526 ±69 | 2,008 ±109 | 1,318 ±102 |
| 1989 | 700 ±94 | 1,893 ±130 | 1,337 ±106 |
| 1990 | 575 ±84 | 1,176 ±141 | 843 ±84 |
| Average | 654 ±30 | 1,973 ±49 | 1,529 ±43 |
| 8 cfs period | | | |
| 1991 | 615 ±75 | 1,650 ±120 | 1,739 ±120 |
| 1992 | 696 ±82 | 1,904 ±134 | 1,633 ±131 |
| 1993 | 958 ±117 | 2,512 ±134 | 2,322 ±241 |
| 1994 | 692 ±63 | 1,560 ±116 | 938 ±66 |
| Average | 740 ±43 | 1,907 ±63 | 1,659 ±77 |
| 4 cfs period | | | |
| 1995 | 779 72 | 1,648 ±87 | 1,832 ±105 |
| 1996 | 851 77 | 1,776 ±153 | 1,273 ±85 |
| Average | 815 ±53 | 1,712 ±88 | 1,553 ±67 |
| 1.5 cfs period | | | |
| 1997 | 904 119 | 1,318 ±122 | 836 ±102 |
| 1998 | 734 74 | 2,339 ±121 | 1,324 ±114 |
| Average | 819 ±70 | 1,828 ±86 | 1,080 ±77 |

Table 2.–Fall number (± 2SE) of yearling-and-older brook trout in an experimentally dewatered zone and reference zones of Hunt Creek. 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 | Downstream | Upstream |
| 16 cfs period: | | | |
| 1984 | 412 ± 60 | 1,644 ±112 | 1,230 ± 134 |
| 1985 | 373 ± 62 | 1,524 ±136 | 935 ± 120 |
| 1986 | 461 ± 38 | 1,783 ±136 | 960 ± 198 |
| 1987 | 376 ± 50 | 1,643 ±176 | 951 ± 200 |
| 1988 | 232 ± 42 | 1,385 ±142 | 883 ± 121 |
| 1989 | 390 ± 51 | 1,420 ±128 | 913 ± 89 |
| 1990 | 361 ± 75 | 867 ±96 | 565 ± 96 |
| Average | 372 ± 21 | 1,466 ±51 | 920 ± 54 |
| 8 cfs period | | | |
| 1991 | 514 ± 80 | 1,159 ±112 | 1,104 ± 152 |
| 1992 | 479 ± 65 | 1,670 ±136 | 1,199 ± 126 |
| 1993 | 469 ± 114 | 2,010 ±148 | 1,089 ± 197 |
| 1994 | 497 ± 98 | 1,370 ±125 | 759 ± 127 |
| Average | 490 ± 46 | 1,552 ±66 | 1038 ± 77 |
| 4 cfs period | | | |
| 1995 | 569 ± 60 | 1,422 ±110 | 1,058 ± 96 |
| 1996 | 731 ± 96 | 1,251 ±105 | 838 ± 67 |
| Average | 650 ± 57 | 1,337 ±76 | 948 ± 59 |
| 1.5 cfs period | | | |
| 1997 | 524 ± 60 | 1,318 ±92 | 591 ± 47 |
| 1998 | 468 ± 53 | 1,342 ±108 | 914 ± 57 |
| Average | 496 ± 40 | 1,330 ±71 | 753 ± 37 |

Table 3.–Fraction (± 2SE) of yearling-and-older brook (YAO) trout surviving from spring to fall in a dewatered zone, a downstream reference zone, and an upstream reference zone of Hunt Creek, Michigan. Upper and lower 95% confidence limits were approximated as means (± 2SE).

| | | | 95% confidence limits | |
|---|---|---|---|---|
| Time Period | Discharge | Surviving fraction | Lower | Upper |
| | | **Dewatered Zone** | | |
| 1984-90 | 16 cfs | 0.568 ± 0.041 | 0.527 | 0.610[a] |
| 1991-94 | 8 cfs | 0.683 ± 0.073 | 0.610 | 0.756 |
| 1995-96 | 4 cfs | 0.795 ± 0.089 | 0.706 | 0.883[a,b] |
| 1997-98 | 1.5 cfs | 0.608 ± 0.083 | 0.525 | 0.692[b] |
| | | **Downstream reference zone** | | |
| 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 |
| | | **Upstream reference zone** | | |
| 1984-90 | Normal | 0.601 ± 0.039 | 0.562 | 0.640 |
| 1991-94 | Normal | 0.626 ± 0.054 | 0.571 | 0.680 |
| 1995-96 | Normal | 0.611 ± 0.046 | 0.565 | 0.657 |
| 1997-98 | Normal | 0.697 ± 0.060 | 0.637 | 0.757 |

Table 4.–Fall number (± 2SE) of young-of-the-year brook trout in a dewatered zone and 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 | |
|---|---|---|---|
| Year | Dewatered Zone | Downstream | Upstream |
| 16 cfs period: | | | |
| 1984 | 842 ± 115 | 2,782 ±185 | 2140 ± 133 |
| 1985 | 729 ± 84 | 2,187 ±178 | 2211 ± 111 |
| 1986 | 709 ± 77 | 2,482 ±197 | 2738 ± 214 |
| 1987 | 519 ± 68 | 2,090 ±229 | 1899 ± 225 |
| 1988 | 901 ± 99 | 2,121 ±176 | 2212 ± 124 |
| 1989 | 749 ± 89 | 2,089 ±187 | 2006 ± 133 |
| 1990 | 750 ± 124 | 1,942 ±179 | 2577 ± 169 |
| Average | 743 ± 36 | 2,242 ±72 | 2255 ± 62 |
| 8 cfs period | | | |
| 1991 | 763 ± 87 | 1,935 ±158 | 2520 ± 151 |
| 1992 | 791 ± 108 | 2,153 ±174 | 2249 ± 163 |
| 1993 | 682 ± 104 | 1,906 ±151 | 1328 ± 149 |
| 1994 | 928 ± 155 | 2,576 ±230 | 3099 ± 181 |
| Average | 791 ± 58 | 2,143 ±90 | 2299 ± 81 |
| 4 cfs period | | | |
| 1995 | 1,097 ± 108 | 2,145 ±140 | 1803 ± 114 |
| 1996 | 952 ± 120 | 2,139 ±167 | 1899 ± 145 |
| Average | 1025 ± 81 | 2,142 ±109 | 1851 ± 92 |
| 1.5 cfs period | | | |
| 1997 | 1,033 ±181 | 2,647 ±165 | 1665 ± 143 |
| 1998 | 723 ±92 | 2,407 ±162 | 1389 ± 122 |
| Average | 878 ±101 | 2,527 ±116 | 1527 ± 94 |