STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-35-R-23

Study No.: 655

Title: The effects of different levels of summer dewatering and a validation test of the Instream Flow Incremental Methodology. (IFIM) in a Michigan brook trout stream.

Period Covered: April 1, 1997 to March 31, 1998

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. 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 stream segments located downstream from the TZ are used as references zones for analyses presented in this report.

Mean fall abundance of young of the year (YOY) brook trout in the TZ following diversion of 75% or 90% of summer baseflow was significantly higher than during years of normal flow (1986-90), or during years when 50% of baseflow was diverted (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, abundance of the largest brook trout in the TZ (> 20 cm total length) was significantly lower when 90% of baseflow was diverted than during other time periods.

Abundance of both 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 to determine if low correlation between trout abundance and WUA predicted by

PHABSIM modeling may be related to the presence of deep water refugia in the TZ that were not modeled. This sampling suggested that larger trout moved from the modeled portion of the TZ into deep-water habitat that was not modeled.

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. Upstream and downstream temperatures were similar when baseflow was reduced by 50%. During 1997 (90% flow reduction) summer mean daily water temperature increased 2.8 ^{0}F in the TZ and mean daily summer maximum temperature increased 3.5 ^{0}F. Mean daily summer maximum, minimum, and mean, water temperatures were each approximately 1.75 ^{0}F warmer at the downstream end of the TZ than at the upstream boundary during 75% dewatering experiments (1995-96).

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 summer of 1997 (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 during summer 1997 ranged from 0.95-1.7cfs.

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

Findings: During summer 1997 we measured water depths and velocities along 40 transects established within the TZ during 1991. These measurements will later be compared to depths and velocities predicted by the PHABSIM hydraulic model to assess the accuracy of predicted values.

During May 1997 we resurveyed water surface elevations, and bed elevations along all 40 transects relative to benchmarks established in 1991. We hypothesized that stream morphology might have changed as a result of several floods that occurred after the original survey. Data analysis indicated that no significant changes in elevations have occurred since the original survey.

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. The upstream and downstream thermometers are 465 meters apart. Thermometers were not placed at the exact station boundaries both to assure that they remained submerged at all flow levels and to reduce the possibility of theft or tampering. 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.

Appreciable warming of waters within the TZ occurred when 75-90% of baseflow was diverted whereas upstream and downstream temperatures were similar when baseflow was reduced 50% (Table 1). During 1997 (90% flow reduction) the mean daily summer water temperature increased 2.8 ^{0}F in the TZ and mean daily summer maximum temperature increased 3.5 ^{0}F. Water warming for the period of record was greatest during July 1997. Mean daily summer maximum, minimum, and mean, water temperatures were each approximately 1.75 ^{0}F warmer at the downstream end of the TZ than at the upstream boundary during 75% dewatering tests (1995-96). Contrasting changes in water temperature between the upstream and downstream boundaries were observed during the last two years of 50% dewatering experiments. During summer 1993 mean daily water temperature was 0.4 ^{0}F colder at the downstream end of the TZ whereas during summer 1994 downstream temperatures were 0.3 ^{0}F warmer than upstream.

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 reference zones. Two stream segments located downstream from the TZ and one segment located upstream from the TZ are used as references zones. 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 ratios of brook trout abundance in the TZ to their abundance in downstream reference zones of Hunt Creek to ascertain if the temporal variation in abundance observed might be unrelated to dewatering experiments. I computed 95% confidence bounds for these ratios and judged ratios to be significantly different if their confidence limits did not overlap. I did not use the stream section located upstream from the TZ as a reference zone because its trout population has been adversely affected by several beaver dam failures during the study period. Effects of these dam failures on trout populations in the TZ were probably minor because part of the flood flow is shunted through the diversion channel.

Point estimates of mean abundance of young of the year (YOY) brook trout in the TZ were higher during years when water was diverted than during pre-diversion years (Table 2). Fall abundance of YOY in the TZ following diversion of 75% or 90% of summer baseflow was significantly higher than during years of normal flow (1986-90), or when 50% of baseflow was diverted during 1991-94 (Table 2). The increase in YOY abundance in the TZ appeared partially attributable to factors unrelated to water withdrawal experiments because some increases in abundance were also observed in downstream reference zones (Table 2). Abundance of YOY during fall 1997 was significantly higher in both reference zones compared to other time periods (e.g. 1986-90, 1991-94, 1995-96).

Abundance of YAO brook trout in the TZ was significantly higher following diversion of 50%, 75%, or 90% of summer baseflow than during years of normal baseflow (Table 2). By contrast, YOA abundance in both downstream reference zones was significantly lower in 1997 than during 1986-90 or 1991-94. These data will be analyzed in further detail when all scale samples have been aged.

Fall abundance of brook trout > 20 cm was significantly higher in the TZ during years when 50% of normal summer flow was diverted than during 1986-90 before water was withdrawn. Abundance of trout > 20 cm when 90% of baseflow was diverted was similar to abundance at normal flow and abundance when 75% of baseflow was diverted ($P > 0.05$). However, the *relative* abundance of brook trout > 20 cm in the TZ to their abundance in a reference zone (RZ) was significantly lower when 90% of baseflow was diverted than during each of the other treatment periods (50 or 75% dewatering) or during the period before water was diverted. The RZ used for this analysis was a 1-mile-long stream section located immediately downstream from the TZ. TZ:RZ ratios were not significantly different for discharge levels ranging from 4-16 cfs (0-75% baseflow reduction.

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 disturbed habitat downstream from the upstream bulkhead. During late August 1997, we estimated the population of trout in a 101-m-long stream section above the downstream bulkhead and in a 113-m-long section below the diversion bulkhead. After the population for the entire TZ was determined, I calculated the percentage of the total population that was residing near the upstream and downstream ends during August. Approximately 26% of YOY and 46% of YAO brook trout resided in these un-modeled stream segments, which represented 35% of the lineal length of the TZ. Nearly 80% of trout > 200 cm long were located in these stream segments during August 1997. This suggests that larger brook trout were selecting habitats outside the modeled reach. However, because we did not determine fish abundance in subsections of the TZ during previous years we can not directly test the hypothesis that the stream segments that were not modeled were used as refuge. When summer water diversion experiments are completed after 1998 we will estimate fish distribution in subsections of the TZ at normal flow.

During 1998 we will determine WUA for the stream segments at both ends of the TZ when stream discharge is 16, 8, 4, and 2 cfs. This should provide more accurate estimates of total WUA in the entire TZ. In addition, we will again estimate the percentage of trout residing in the subsections that were not previously modeled.

Job 4. Title: Monitor movement into and out of the treatment section

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 3). 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 13 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. The mean total lengths of immigrating and emigrating trout were similar (Table 3). During 1997, movement into the TZ from downstream was blocked by the fish traps attached to the downstream bulkhead from May through September. The upstream bulkhead blocked upstream movement out of the TZ during the same period. During previous years the fish traps were operated only during the period from 1-June through 31 August.

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.

Table 1. Average daily mean and daily maximum water temperature (^{0}F) near the upstream and downstream boundaries of an experimentally dewatered section of Hunt Creek at three discharge levels. Daily mean and maximum temperatures are derived from hourly temperature measurements.

		Average of Daily mean temperatures		Average of Daily maximum temperatures	
Year	Discharge (cfs)	Upstream	Downstream	Upstream	Downstream
		June			
1993	8	53.8	53.3	57.1	56.1
1994	8	55.9	56.1	59.5	60.2
1995	4	56.4	58.1	60.8	62.9
1996	4	54.9	56.4	57.8	59.2
1997	2	55.6	58.5	60.2	63.8
		July			
1993	8	58.5	58.2	62.0	61.3
1994	8	58.3	58.6	61.3	61.8
1995	4	58.2	60.0	61.7	63.6
1996	4	57.0	58.7	60.1	61.5
1997	2	57.3	60.3	61.0	64.8
		August			
1993	8	57.7	57.5	60.3	59.8
1994	8	56.4	56.8	59.2	59.5
1995	4	58.9	60.9	61.8	63.8
1996	4	58.0	59.6	61.0	61.6
1997	2	55.3	57.8	57.8	60.7
		1-June through 31-August			
1993	8	56.7	56.3	59.8	59.1
1994	8	56.9	57.2	60.0	60.5
1995	4	57.9	59.7	61.5	63.5
1996	4	56.6	58.3	59.6	60.8
1997	2	56.1	58.9	59.6	63.1

Table 2.—Fall number of young of the year and yearling and older brook trout in an experimentally dewatered zone and two reference zones of Hunt Creek. Confidence bounds for the 95% level of significance are in parenthesis. Summer baseflow discharge in the dewatered zone was 16 cfs from 1986-90, 8 cfs from 1991-94, 4 cfs from 1995-96 and 2 cfs in 1997.

Section Time Period	Size category of brook trout Young of the year	 Yearling and older
Dewatered zone		
1986-90	697 (±38)	393 (±16)
1991-94	743 (±51)	537 (±24)
1995-96	1025 (±81)	650 (±38)
1997	1025 (±180)	532 (±49)
Downstream reference zone A		
1986-90	1174 (±68)	839 (±28)
1991-94	1253 (±69)	949 (±31)
1995-96	1229 (±75)	869 (±38)
1997	1449 (±115)	750 (±51)
Downstream reference zone Z		
1986-90	764 (±39)	787 (±25)
1991-94	752 (±44)	742 (±26)
1995-96	796 (±63)	584 (±31)
1997	1167 (±115)	600 (±42)

Table 3.—Size 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 when 90% of baseflow was diverted.

	Upstream Bulkhead (immigrants)		Downstream Bulkhead (emigrants)	
Year	mean length (cm)	n	mean length (cm)	n
1990	Traps not constructed		10.9	69
1991	10.2	39	10.3	43
1992	11.3	30	9.0	53
1993	12.6	199	12.6	132
1994	8.5	183	8.3	50
1995	10.7	41	9.4	14
1996	12.4	14	6.4	17
1997	10.4	33	10.2	13

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