STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-35-R-22

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, 1996 to March 31, 1997

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

Summary: Effects of withdrawing water from a brook trout stream are being evaluated in a 608-m experimental section (zone b) of Hunt Creek. Brook trout populations have been estimated in a 3.2 km section of Hunt Creek (which includes zone b) each September since 1949. From 1-June through 31-August, 1991-94 we diverted 50% of normal baseflow from zone b to simulate effects of summer irrigation withdrawals on a brook trout population. During the 1991-94 phase of the study a PHABSIM model was developed and used to make projections of weighted usable area (WUA) available for brook trout at different discharge levels (Baker and Coon 1995). During 1995-96 we diverted 75% of summer baseflow to determine if trout populations would change in the proportion or direction predicted by PHABSIM modeling. Zones in Hunt Creek that were not dewatered were used as reference zones for evaluations of temporal trout population parameter changes. For purposes of this analysis I used the years 1986-90 as a temporal reference period (baseflow was not altered in any zone) when comparing brook trout abundance, growth, and survival.

Summer flow reductions had mixed effects on brook trout abundance. Baker and Coon (1995) estimated that 692 m^2 and 672 m^2 of WUA was available in zone b for young-of-the-year (YOY) trout at summer water withdrawal levels of 50% and 75%, respectively, compared to 585 m^2 of WUA at normal flow. Abundance of YOY brook trout in the experimental section was significantly higher during 1995-96 (75% withdrawal) than during either 1991-94 (50% withdrawal) or 1986-90 (normal flow). YOY abundance when flow was reduced 50% was similar to abundance at normal flow. Thus, YOY abundance changed in the direction predicted by PHABSIM modeling at a summer withdrawal level of 75% but did not change significantly when baseflow was reduced by 50%. Abundance of yearling-and-older (YAO) trout did not decline significantly although PHABSIM modeling indicated that WUA in zone b would decrease from 539 m^2 to 423 m^2 when summer baseflow was reduced by 75%. Temporal variation in survival of YAO brook trout from April to September in the experimental section did not appear to be significantly associated with water withdrawals of 50 or 75%. PHABSIM modeling indicated that diurnal WUA for brook trout >20 cm would decline from 565 m^2 to 177 m^2 when summer baseflow was reduced from 16 cfs to 4 cfs. However, mean fall abundance of trout >20 cm following summers when baseflow was 4 cfs (1995-96) was similar to abundance following summers with baseflows near 16 cfs (1986-90). Mean length at age of brook trout in zone b did not change significantly following water withdrawals of 50% or 75%.

We operated inclined screen traps at the downstream end of zone b from 1-June through 31 August during 1990-96 to determine if water withdrawal would change the rate of downstream emigration. During 1991-96 we used similar traps to measure immigration into zone b from upstream. Downstream emigration from zone b at normal flow (1 year of data) was the same as mean emigration during four summers when 50% of baseflow was diverted (69 trout/summer). Downstream emigration was lowest during 1995-96, when 75% of baseflow was diverted (15.5 trout/summer).

During 1993-96 we used electronic thermometers to determine if water withdrawals would change the relationship between temperatures at the boundaries of zone b. Changes in temperature between the boundaries of zone b were determined from hourly temperature data collected from 1-June through 31-August 1993-96. Mean daily maximum, minimum, and mean, water temperatures were each approximately 1°C warmer at the downstream end of zone b than at the upstream boundary during 75% dewatering experiments. Contrasting changes in water temperature between the upstream and downstream boundaries were observed during the last two years of 50% dewatering experiments. From 1-June through 31-August 1993 mean daily water temperature was 0.18°C colder at the downstream end than at the upstream end of the zone b whereas during the same period in 1994 downstream temperatures were 0.17°C warmer than upstream.

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

Findings: We constructed a bulkhead structure on Hunt Creek during 1989 to provide the capability to divert water around a 608-m section (zone b) of the stream. Normal summer baseflow in zone b is approximately 16 cfs. From 1-June through 30-August, 1991-94 we diverted 50% of normal base flow around zone b. From 1-June through 30-August, 1995-96 we diverted 75% of normal base flow around zone b. Stream discharge estimates made at the upstream end of zone b during 1996 ranged from 3.7-4.3 cfs. Approximately 0.7 cfs of the diverted flow returned overland to zone b at a point located 200 m upstream from the downstream boundary. Thus, normal base flow was reduced to by approximately 72% of normal in 33% of the treated stream reach. Summer discharge will be reduced to approximately 2 cfs during 1997-98.

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

Findings: Baker and Coon (1995) collected habitat and hydraulic data along 40 transects in zone b and used PHABSIM modeling to predict habitat changes for brook trout at varying summer discharge levels. We measured water depths and velocities along the same transects during 1995-96 during periods when normal baseflow was reduced to approximately 4 cfs. These data will later be compared to depths and velocities predicted by hydraulic modeling. During 1997 we will again survey streambed elevations and water surface elevations at normal flow to determine if they have changed since the last survey. In addition, we will measure water depths, velocities, and surface elevations along all transects after reducing discharge to 2 cfs.

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

Findings: We have made mark-and-recapture estimates of brook trout populations in a 3.2 km section of Hunt Creek, which includes treatment zone b, during the third week of April each year since 1959 and during the third week of September since 1949. Scale samples were collected from a subsample of trout during each collection period to determine trout ages. Total lengths and weights of approximately 1000 trout were recorded during these sampling periods each year since 1993. I used the period from 1986-90 as a pre-treatment reference period for the analyses presented below because past experiments were known to affect trout population parameters during earlier years.

Diversion of up to 75% of summer base flow has not reduced fall abundance of any age class of brook trout in zone b (Table 1). Abundance of trout of different ages for 1996 is not shown in table 1 because all scale samples collected during 1996 have not been read. However, I used data from both 1995 and 1996 when evaluating YOY responses to 75% dewatering because YOY can be accurately identified from length frequency data. Baker and Coon (1995) estimated that 692 m^2 and 672 m^2 of WUA was available in zone b for YOY trout at summer water withdrawal levels of 50% and 75%, respectively, compared to 585 m^2 of WUA at normal flow. Abundance of YOY brook trout in the zone b was significantly higher during 1995-96 (75% withdrawal) than during either 1991-94 (50% withdrawal) or 1986-90 (normal flow). YOY abundance when flow was reduced 50% was similar to abundance at normal flow. Thus, YOY abundance changed in the direction predicted by PHABSIM modeling at a summer withdrawal level of 75% but did not change significantly when baseflow was reduced by 50%.

Total abundance of YAO trout did not decline significantly following diversion of 75% of baseflow although PHABSIM modeling indicated that WUA in zone b would decrease from 539 m^2 to 423 m^2 when discharge was reduced from 16 to 4 cfs. Age-1 brook trout were significantly more abundant when 50% or 75% of summer base flow was diverted than during normal flow conditions (Table 1). Significantly more age-1 trout were present during fall 1995 after a 75% reduction of summer base flow than during 1991-94 following 50% flow reductions. Mean abundance of both 2- and 3-year-old trout were significantly higher when 50% of water was diverted than during normal flow conditions. However, 95% confidence bounds for abundance of 2- and 3-year-old trout for 1995 (75% withdrawal) overlapped bounds for abundance at normal baseflow.

I also looked for changes in abundance of brook trout >20 cm long following different summer dewatering levels because diurnal WUA estimates derived from bioenergetic habitat suitability criteria indicated that WUA would decline from 565 m^2 to 177 m^2 when summer baseflow was reduced from 16 cfs to 4 cfs (Baker and Coon 1995). I found that abundance of brook trout >20 cm long did not decline significantly after diversion experiments. Fall abundance of brook trout >20 cm was significantly higher during years of 50% water withdrawals (23.1 ±3.7) compared to years prior to water withdrawal (16.9 ±1.1). Mean fall abundance of trout >20 cm subsequent to diversion of 75% of baseflow during 1995-96 (18.1 ±2.5) was similar to abundance during years prior to water diversion. The ratio of abundance of brook trout >20 cm long in zone B to their abundance in reference zones Z or A also did not change significantly due to water withdrawals.

Survival of YAO brook trout from April to September in zone b did not appear to be significantly associated with water withdrawals of 50 or 75%. The 95% confidence bounds for survival estimates at all discharge levels overlapped for brook trout of ages 1 to 3 in zone b. I computed ratios of survival in the experimental section to survival in each of the three reference zones during 1986-90, 1990-91, and 1995, because temporal differences in environmental conditions unrelated to water withdrawal could affect survival. I judged these ratios to be significantly different if 95% confidence bounds of the ratio of survival for age groups in the reference zones to survival in zone B did not overlap for different experimental periods. No significant differences were detected in the ratios of April to September survival for brook trout of ages 1 to 3 when zone Z was used as the reference zone (Table 2). Age-3 brook trout survived significantly better in zone B relative to zone A during the period when 50% of summer baseflow was diverted as compared to the pre-diversion period. Both age-1 and age-3 brook trout survived significantly better in zone B relative to zone C when 75% of summer baseflow was diverted as compared to the pre-diversion period.

To evaluate possible effects of dewatering on brook trout growth rates I looked for overlap of 95% confidence bounds for mean length at age between different experimental periods. I also performed a ratio analysis similar to that described above for survival analyses to determine if the mean lengths at age of brook trout in zone b changed relative to those in the reference zones. There were no significant differences in September mean lengths at age for brook trout collected from zone B at different summer discharge levels (Table 3). There was likewise no significant change in mean length at age of brook trout in zone B relative to any of the 3 reference zones.

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

Findings: We operated inclined screen traps at the downstream end of zone b from 1-June through 31-August during 1990-96 to determine if water withdrawal would change the rate of downstream emigration. During 1991-96 we used similar traps to measure immigration into zone b from upstream. Downstream emigration from zone b at normal flow (1 year of data) was the same as mean emigration during four summers when 50% of baseflow was diverted (69 trout/summer). Downstream emigration was lowest during 1995-96, when 75% of baseflow was diverted (15.5 trout/summer) (Table 4). During 1996 numbers of trout immigrating into and emigrating from zone b were similar. However, most immigrants were age-1 whereas most emigrants were YOY. The mean ratio of emigrants to immigrants in zone b did not appear different when mean summer discharge was 8 cfs versus 4 cfs. The mean ratio of emigrants to immigrants was 0.95 (range 0.27-1.77) when 50% of baseflow was diverted, compared to a mean of 0.78 (range 0.34-1.21) when 75% of baseflow was diverted.

Literature Cited:

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, Michigan.

Table 1.–Mean number of brook trout by age for fall populations in four zones of Hunt Creek, MI. Confidence bounds for the 95% level of significance are in parentheses.

Section, time period (% water diverted)	Age 0	Age 1	Age 2	Age 3
Treatment Zone B				
1986-90	726	269	85	8
(none)	(± 42)	(± 22)	(± 9)	(± 2)
1991-94	791	349	117	20
(50%)	(± 58)	(± 40)	(± 21)	(± 7)
1995	1097	463	96	9
(75%)	(± 108)	(± 49)	(± 33)	(± 7)
Reference Zone A				
1986-90	1266	470	235	37
(none)	(± 74)	(± 38)	(± 24)	(± 9)
1991-94	1324	600	243	26
(none)	(± 74)	(± 42)	(± 24)	(± 10)
1995	1350	637	186	21
(none)	(± 112)	(± 76)	(± 39)	(± 9)
Reference Zone Z				
1986-90	879	486	159	21
(none)	(± 47)	(± 35)	(± 22)	(± 5)
1991-94	819	450	193	26
(none)	(± 51)	(± 36)	(± 22)	(± 8)
1995	795	397	137	22
(none)	(± 84)	(± 63)	(± 21)	(± 11)
Reference Zone C				
1986-90	2287	604	209	34
(none)	(± 79)	(± 60)	(± 28)	(± 8)
1991-94	2299	708	278	46
(none)	(± 81	(± 62)	(± 45)	(± 10)
1995	1803	812	232	11
(none)	(± 114)	(± 71)	(± 64)	(± 5)

Table 2.–Ratios of survival of brook trout from April to September in reference zones to survival in the experimentally dewatered zone B of Hunt Creek, MI. Confidence bounds of ratios for the 95% level of significance are in parentheses.

Section, time period	Age		
(% water diverted)	1	2	3
Ratio of survival in zone Z: zone B			
1986-90	2.205	1.406	1.005
(none)	(0.449)	(0.366)	(0.425)
1991-94	1.458	1.467	0.495
(50% in zone B)	(0.329)	(0.415)	(0.286)
1995	1.165	1.608	1.294
(75% in zone B)	(0.318)	(0.768)	(1.358)
Ratio of survival in zone A: zone B			
1986-90	1.185	1.804	1.510
(none)	(0.220)	(0.430)	(0.606)
1991-94	1.192	1.842	0.535
(50% in zone B)	(0.243)	(0.545)	(0.330)
1995	1.188	1.678	0.672
(75% in zone B)	(0.266)	(0.808)	(0.702)
Ratio of survival in zone C: zone B			
1986-90	0.977	1.404	2.279
(none)	(0.173)	(0.332)	(1.053)
1991-94	0.692	1.732	1.828
(50% in zone B)	(0.134)	(0.530)	(1.099)
1995	0.664	1.477	0.564
(75% in zone B)	(0.135)	(0.768)	(0.604)

Table 3–Mean September length at age (mm) for brook trout in four zones of Hunt Creek MI. Confidence bounds for the 95% level of significance are in parentheses.

Section, time period	Age			
(% water diverted)	0	1	2	3
Treatment Zone B				
1986-90	79.2	126.8	179.2	238.1
(none)	(6.1)	(12.6)	(22.4)	(48.1)
1991-94	79.7	126.4	173.9	220.1
(50%)	(7.4)	(17.5)	(31.5)	(81.1)
1995	73.7	124.7	172.2	215.4
(75%)	(10.0)	(16.6)	(63.7)	(166.6)
Reference Zone Z				
1986-90	90.3	143.6	191.8	239.4
(none)	(6.5)	(12.6)	(30.0)	(70.5)
1991-94	88.3	140.4	191.7	231.8
(none)	(7.0)	(13.2)	(29.5)	(63.9)
1995	89.5	135.8	196.4	241.0
(none)	(12.2)	(25.4)	(38.1)	(133.3)
Reference Zone A				
1986-90	84.3	134.1	183.4	232.9
(none)	(6.7)	(13.6)	(21.7)	(56.3)
1991-94	85.5	138.5	193.7	228.4
(none)	(6.1)	(11.5)	(27.2)	(84.0)
1995	86.5	136.9	193.8	237.0
(none)	(9.6)	(19.1)	(44.2)	(116.0)
Reference Zone C				
1986-90	78.2	132.0	179.3	226.9
(none)	(3.6)	(13.6)	(25.7)	(54.8)
1991-94	78.1	129.0	171.3	224.8
(none)	(3.9)	(13.2)	(28.1)	(47.8)
1995	75.5	121.9	167.4	231.7
(none)	(6.7)	(11.7)	(47.7)	(119.0)

Table 4.–Mean length (mm) and number of brook trout immigrating into and emigrating from zone b from 1-June through 31-August during the summer prior to water withdrawal, during the 50% withdrawal treatment period (1991-94), and during the 75% water withdrawal period (1995-96).

	Immigrants		Emigrants	
Year	Mean length (cm)	n	Mean length (cm)	n
1990	Traps not constructed		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

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Date: March 31, 1997