STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-35-R-22

Study No.: 669

Title: Prey selection and predation rate of piscivorous fish

Period Covered: April 1, 1996 to March 31, 1997

Study Objective: To estimate survival of juvenile bluegills in ponds as a function of bluegill size and density and predator size and density, and to concurrently measure predator survival and growth.

Summary: During summer 1996 a 6-week experiment was conducted evaluating predation by adult largemouth bass on juvenile bluegills. Eight ponds were stocked in April with two sizes of juvenile bluegills. At the start of the experiment in June, six of the eight ponds were stocked with either “small” (314-354 mm total length, TL) or “large” (356-424 mm TL) or both small and large largemouth bass. The predators were given individual freeze brands, but the marks did not persist to the end of the experiment. Predator survival was 100% in three ponds and 89-90% in three ponds. Mean bass weight increased in all six ponds; the grand mean weight increased by 58 g from 653±132 (mean±SD) (N = 60) to 711±149 (N = 55) g.

A second experiment was conducted to evaluate predation by large adult bluegills (199-234 mm TL) on juvenile bluegills (45.6±4.8 mm, N = 156) during winter. Five ponds were stocked in December, 1996, and drained at the end of March, 1997. In two ponds stocked with large adult bluegills as potential predators, the overwinter survival of juvenile bluegills was 90% and 96%. Only 57% of stocked juveniles were recovered in a third pond, due in large part to a heavy growth of *Chara* that prevented complete recovery of the survivors. Juvenile bluegill survival was 95% in a control pond, even though that pond was found to contain fifteen juvenile largemouth bass (127-180 mm TL), four yellow perch (116-162 mm TL), and two large juvenile bluegills (111-115 mm TL). A survival estimate was not possible in a second control pond due to contamination by other juvenile bluegills. The ponds with relatively high survival of juveniles suggest that adult bluegills do not consume many juvenile bluegills during the winter.

A laboratory experiment was conducted to measure the maximum sizes of juvenile bluegills that could be consumed by adult bluegills (148-191 mm TL). Predictions for maximum prey length were made using equations for bluegill gape and maximum body depth. The adults were offered a range of prey sizes (33-59 mm TL) that was expected to include the largest juvenile bluegill that could be ingested. The adults consumed all prey offered, including prey 10-15 mm longer than the predicted maximum, so the upper size limit was not observed. In an attempt to explain this laboratory result, regressions were performed relating body depth, length, and relative weight. Relative weight made a significant contribution to predicted depth or length; for bluegills of a given length, fish with smaller relative weights had smaller body depths. For the sizes of juveniles used in this experiment, variations in relative weight could make a difference of 7-9 mm in maximum length of prey ingested by a predator. Additional laboratory experiments are planned using a larger range of prey sizes.

An experiment using juvenile walleye as predators and juvenile bluegills as prey will be conducted during summer 1997. The experiment evaluating overwinter consumption of juvenile bluegills by large adult bluegills will be repeated in winter 1997-98.

Job 1. Title: Stock ponds with bluegills and predators.

Findings: Ponds were stocked with juvenile bluegills and largemouth bass in summer 1996 in a design similar to that used by Rice et al. (1993). The design had four predator treatments, two replicates each, for a total of eight ponds. It was intended that each pond receive equal numbers of two sizes of juvenile bluegills as prey. The four treatments were: (SS) 12 smaller predators, (LL) 8 larger predators, (SL) 6 smaller and 4 larger predators, and (Control) no predators. Bluegills were stocked April 11-25, 1996. Due to a shortage of large juveniles, some ponds received fewer large juveniles than intended. Largemouth bass in the range 314-354 mm were considered “small” and those in the range 356-424 mm were considered “large.” Largemouth bass were stocked June 12, 1996 (Tables 1-3). Each bass was given an individual mark using a freeze-branding technique (Busack 1985), but the marks were not visible at the end of the experiment.

On June 28, 1996, bluegill nests were observed in ponds 5, 15, 16, and 17, and spawning was observed in Pond 17. Even though the mean length of the larger size of bluegills stocked in April was only 91-110 mm (Table 2), some had apparently grown large enough by June to reproduce.

Ponds were stocked on December 11, 1996, for a second experiment, which attempted to evaluate overwinter predation (cannibalism) by large adult bluegills on age-0 bluegills. Five ponds were stocked with age-0 bluegills; three of these ponds were stocked with large adults as predators (Tables 4 and 5). Adult bluegills for each pond were individually marked by clipping one of the soft rays on the dorsal fin, leaving a stub of about 2 mm to prevent movement of the adjacent rays.

A recording digital thermometer was deployed in Pond 7 on May 24 and retrieved on July 23, 1996. It was re-deployed on September 13 and retrieved on March 26, 1997 (Table 6).

Table 1.–Number of juvenile bluegills and adult largemouth bass stocked and recovered from ponds in summer 1996. Two sizes of bluegills were stocked on May 11-25, 1996; two sizes of largemouth bass were stocked on June 12, 1996. Ponds were drained on July 22-26, 1996.

Pond	Area (ha)	Juvenile bluegills stocked: Smaller	Larger	Total	Largemouth bass stocked: Smaller	Larger	Juvenile bluegills recovered: (No.)	(Percent)	Largemouth bass recovered: (No.)	(Percent)
Control										
15	0.29	1065	954	2019	0	0	1751	87	0	
17	0.24	885	695	1580	0	0	804[1]	51[1]	0	
Treatment SS: smaller predators										
5	0.30	1110	925	2035	6[2]	0	1876	92	6	100
6	0.28	1050	1050	2100	18[2]	0	1333	63	16	89
Treatment SL: smaller and larger predators										
7	0.26	975	975	1950	6	4	1199	61	9	90
14	0.21	796	650	1446	6	4	1128	78	9	90
Treatment LL: larger predators										
16	0.24	885	885	1770	0	8	1438	81	8	100
18	0.20	735	705	1440	0	8	1176	82	8	100

[1] A heavy growth of *Chara* prevented complete recovery of juvenile bluegills in Pond 17.
[2] Six largemouth bass intended for Pond 5 were inadvertently stocked into Pond 6.

Table 2.–Average length, weight (mean±SD), sample size (*N*) and biomass of juvenile bluegills stocked into eight ponds in April 1996 and recovered at pond draining in July 1996.

	Size at stocking								Size at draining			
	Small juveniles				Large juveniles				Both large and small juveniles			
Pond	Length (mm)	Weight (g)	*N*	Biomass (kg)	Length (mm)	Weight (g)	*N*	Biomass (kg)	Length (mm)	Weight (g)	*N*	Biomass (kg)
Control												
15	61±6	2.9±0.8	90	3.39	100±10	12.5±4.8	30	4.09[1]	98±13	14.8±6.0	206	26.7
					104±8	14.4±3.6	90	8.72[1]				
17	57±5	2.1±0.6	90	2.04	91±7	9.3±2.8	90	6.99	104±12	19.3±7.0	201	15.6
Treatment SS: smaller predators												
5	74±5	5.7±1.2	90	6.66	110±10	19.7±6.1	30	16.58	118±16	29.5±12.5	201	52.9
6	57±5	2.1±0.6	90	2.63	91±7	9.3±2.8	90	10.22	104±14	19.5±8.7	197	25.3
Treatment SL: smaller and larger predators												
7	57±5	2.1±0.6	90	2.32	91±7	9.3±2.8	90	9.08	107±15	22.0±9.8	211	26.1
14	74±5	5.7±1.2	90	4.75	110±10	19.7±6.1	30	6.63[2]	100±14	16.1±6.9	201	19.9
					104±8	14.4±3.6	90	4.30[2]				
Treatment LL: larger predators												
16	65±5	4.1±1.0	90	3.31	98±8	12.8±3.2	90	11.85	104±9	19.4±5.5	210	27.4
18	63±3	3.3±0.5	90	2.45	93±5	9.9±1.7	90	7.22	97±12	16.7±6.9	202	20.5

[1] Large juveniles for Pond 15 came from Pond 15 and Pond 8.
[2] Large juveniles for Pond 14 came from Pond 5 and Pond 8.

Table 3.–Average length, weight (mean±SD) and sample size (*N*) of adult largemouth bass stocked into six ponds on June 12, 1996 and recovered at pond draining in July 1996.

	Size at stocking			Size at draining		
Pond	Length±SD(mm)	Weight±SD (g)	*N*	Length±SD (mm)	Weight±SD (g)	*N*
			Treatment SS: smaller predators			
5	334±12	558±40	6[1]	349±8	623±40[2]	6
6	338±13	593±83	18[1]	344±15	621±113	16
			Treatment SL: smaller and larger predators			
7	353±28	647±128	10	365±24	737±112	9
14	352±21	669±122	10	360±19	708±138	9
			Treatment LL: larger predators			
16	371±10	720±54	8	377±13	797±83	8
18	375±22	778±211	8	380±22	834±220	8

[1] Six largemouth bass intended for Pond 5 were inadvertently stocked into Pond 6.
[2] One final weight measurement was lost, so *N* = 5 for this mean and SD.

Table 4.–Number of juvenile and adult bluegills stocked into ponds on December 11, 1996, and recovered in spring 1997 for evaluation of overwinter predation by large adult bluegills.

Pond	Area (ha)	Juveniles stocked	Adults stocked	Date drained	Juveniles recovered (number)	Juveniles recovered (percent)	Adults recovered (number)	Adults recovered (percent)
Controls								
7	0.26	1341	0	3/26/97	1271	95	[1]	
17	0.24	1770	0	3/26/97	6303[2]	356[2]	[2]	
Large adults present								
14	0.21	1094	6	3/27/97	619	57[3]	2[4]	33
15	0.29	1454	8	4/1/97	1392	96	3	38
16	0.24	1770	7	3/27/97	1594	90	4	57

[1] Other fish were found in Pond 7 at draining, including 15 juvenile largemouth bass (127-180 mm TL), 4 yellow perch (116-162 mm TL, all ripe males), 2 bluegills (111-115 mm TL), 2 brook sticklebacks, and about 20 fathead minnows.

[2] Adult bluegills had apparently been present in Pond 17 in late summer and produced a small year class. Four adult bluegills were found in the pond at draining (153, 155, 175, and 177 mm TL), as well as 32 other bluegills (80-107 mm TL).

[3] At pond draining, the macroalga *Chara* covered about two thirds of the bottom of Pond 14. Several dozen juvenile bluegills were retrieved from the *Chara* at draining, but an unknown number of bluegills remained.

[4] One of the two adults recovered at pond draining had recently died.

Table 5.–Average length, weight, and relative weight (mean±SD) and sample size (*N*) of juvenile bluegills stocked into five ponds on December 11, 1996 and recovered in spring 1997.

Pond	Length±SD (mm)	Weight±SD (g)	Relative weight±SD (%)	*N*
Source pond, December 1997				
9	45.6±4.8	1.20±0.37	86.4±5.3	156
Control ponds, Spring 1997				
7	45.3±4.9	1.13±0.39	82.9±4.4	200
17	37.2[1]±7.7	0.67[1]±0.42	87.4±7.1	104
Ponds with large adults, Spring 1977				
14	48.0±4.9	1.45±0.45	88.5±9.1	200
15	48.6±4.6	1.45±0.42	85.0±5.3	200
16	47.3±6.4	1.38±0.80	85.3±5.1	200

[1] Adult bluegills had apparently been present in Pond 17 in late summer and produced a small year class.

Table 6.–Daily mean water temperatures from May 1996 to March 1997, with monthly summaries, for Pond 7, Saline Fisheries Research Station. The monthly summaries are based on hourly values recorded with a digital thermometer (TempMentor S/N 902686, deployments 008 and 009). Pond 7 was drained on July 24, 1996, and on March 26, 1997.

	Daily mean temperature (°C)											
Day	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1			19.7	28.2			16.3	6.1	4.1	3.2	1.8	4.7
2			20.3	27.3			17.7	5.2	3.4	3.4	2.0	4.9
3			21.0	25.5			15.5	4.8	3.0	3.8	2.1	5.0
4			21.3	24.0			14.3	4.9	3.1	4.2	2.3	4.9
5			20.3	23.9			14.3	5.7	3.2	5.1	2.5	4.7
6			19.9	24.4			14.5	6.9	2.6	2.4	2.6	3.8
7			20.0	25.3			15.4	8.1	2.9	0.8	2.8	3.0
8			20.7	25.9			15.1	8.5	2.8	1.3	3.0	4.0
9			21.2	24.9			13.4	8.1	2.3	1.8	3.1	3.7
10			21.8	22.7			12.0	6.9	2.4	1.9	2.9	3.7
11			22.6	22.4			11.3	5.5	3.0	1.9	2.9	4.8
12			22.6	22.8			11.2	4.1	3.0	1.9	2.9	5.3
13			22.7	23.4			12.1	3.3	3.0	1.9	2.5	5.1
14			23.8	23.5		17.3	13.9	3.7	3.5	2.0	2.6	3.4
15			24.9	24.0		16.4	13.8	3.9	3.8	2.0	2.7	1.7
16			25.9	23.9		16.6	14.1	4.2	3.7	1.9	2.6	2.5
17			25.5	24.1		16.8	15.1	4.3	3.2	1.8	2.3	4.1
18			23.2	24.1		17.3	15.2	4.5	3.1	1.7	2.5	5.1
19			23.2	24.9		17.9	12.8	4.2	2.8	1.6	2.9	5.1
20			24.5	23.8		18.3	12.1	3.9	2.6	1.6	3.1	6.8
21			24.4	23.0		18.4	12.5	4.0	2.4	1.5	3.4	8.6
22			25.4	22.7		18.3	12.6	3.9	2.7	1.7	3.7	9.0
23			25.3			17.9	12.2	4.1	3.0	1.9	4.0	6.9
24			25.7			18.3	10.8	4.2	3.2	2.0	4.3	5.6
25		18.9	25.5			17.6	10.7	3.7	3.0	1.9	4.6	6.0
26		18.5	25.3			17.3	11.4	2.4	2.8	1.9	4.4	
27		17.5	25.8			17.2	12.8	2.2	2.5	1.9	4.8	
28		16.6	26.4			16.9	13.3	2.9	2.7	1.8	4.9	
29		17.4	27.3			15.8	11.8	3.2	3.1	1.7		
30		17.9	28.0			15.4	10.9	3.6	3.2	1.7		
31		18.9					7.8		3.2	1.7		
Monthly average		17.9	23.5	24.3		17.3	13.1	4.7	3.0	2.1	3.1	4.9
Monthly minimum		15.9	19.0	20.8		14.4	6.9	1.3	1.6	0.4	1.7	0.7
Monthly maximum		19.9	28.9	28.7		19.3	18.7	9.4	4.6	5.9	5.1	10.2
Ave. daily range		1.7	1.4	1.8		1.6	1.7	1.0	0.7	0.5	0.5	1.8
Cum. degree days		125.6	704.2	534.7		293.6	406.8	141.2	93.1	66.1	86.3	122.3
Number of days		7	30	22		17	31	30	31	31	28	25

Job 2. Title: Determine rate of predation.

Findings: In the summer experiment using largemouth bass as predators, several problems made it difficult to estimate the rate of predation on juvenile bluegills as planned. In five of the eight ponds, some of the larger juvenile bluegills grew enough to reproduce, and the extent of predation on the age-0 bluegills is not known. In Pond 7 there was reproduction by both largemouth bass and bluegills, and the additional predation by the age-0 largemouth bass is not known. Predator survival was 100% in three ponds and 89-90% in three ponds. Mean bass weight increased in all six ponds; the grand mean weight increased by 58 g from 653±132 (mean±SD) (*N* = 60) to 711±149 (*N* = 55) g.

The duration of the overwinter predation experiment was 105 d for the control ponds, 106 d for ponds 14 and 16, and 111 d for Pond 15 (Table 4). The average initial weight (mean±SD) of the adult bluegills was 180±35 (*N* = 21); average relative weight was 82±7%. The average final weight of the survivors was 183±34 (*N* = 8); average relative weight was 79±5%. Although there was an increase in mean weight, this must have been caused by the death of below-average individuals. Individual marks made it possible to show that all eight adult bluegills recovered alive had lost weight. The average loss was 3.3±1.8% of their body weight in December. Adult survival was poor. Only eight of twenty-one (38%) stocked adults were recovered alive.

In the overwinter predation experiment, only three of five ponds produced useful estimates of juvenile bluegill survival. Juvenile survival was 90% in Pond 16 and 96% in Pond 15, both containing adult bluegills, and 95% in a pond without adult bluegills (Table 4). The remaining two ponds did not produce useful estimates because one (Pond 17, a control pond) was contaminated with other small bluegills and the other (Pond 14) had a heavy growth of *Chara* preventing complete recovery of juveniles (Table 4). If the adult bluegills had all survived and had consumed juveniles at the rate observed in yellow perch (0.27% body weight/d) or walleye (0.38%BW/d), they might have consumed 18 or 25% of the juveniles in Pond 16, and 24 or 34% of the juveniles in Pond 15 (Schneider and Breck 1996). Using the geometric mean biomass of adults during the experiment, the estimated consumption might have been 13 or 18% of the juveniles in Pond 16, and 15% or 21% of the juveniles in Pond 15. The relatively high observed survival of juveniles suggests that adult bluegills do not consume many juvenile bluegills during the winter.

Job 3. Title: Drain ponds.

Findings: The experiment using largemouth bass was terminated by draining the eight ponds on July 22-26, 1996 (Tables 1-3). The freeze branding technique did not produce a visible mark that persisted for six weeks on adult largemouth bass. In addition to the stocked juvenile bluegills, age-0 bluegills were found in ponds 5, 7, 14, 15, and 17. Apparently some of the stocked juveniles grew large enough to reproduce. Age-0 largemouth bass were found in Pond 7.

The overwinter experiment was terminated in spring 1997 (Tables 4 and 5). The five ponds were drained on March 26, 27, and April 1, 1997. Clipping a soft-dorsal ray worked well to mark individual adult bluegills over winter.

Job 4. Title: Measure capture probability.

Findings: Laboratory experiments were conducted in December, 1996, to evaluate the probability of capture of juvenile bluegills of various sizes by adult bluegills ranging from 148 to 191 mm total length (Table 7). The experiments were conducted in aquaria by Erika Gilmore. All experiments were done at room temperature. The adult bluegills were fed guppies for several days before the experiment began.

Bluegill gape (*G*, mm) was estimated using the regression of Werner (1974). The factor of 1.278 from Beckman (1948) was used to convert total length (*L*, mm) to standard length as used by Werner (1974).

$$G = 0.217 + 0.093\left(\frac{L}{1.278}\right)$$

The predicted length of bluegill having a given maximum body depth (*D*, mm) was calculated using an equation from Schneider and Breck (1996):

$$\log_{10} L = 0.728(\pm 0.017) + 0.8383(\pm 0.0020)\log_{10} D \ ,$$

where $r^2 = 0.997$, $N = 416$, for bluegills from 19-220 mm total length, with maximum body depths ranging from 4.1-89 mm.

Unexpectedly, the adult bluegills ingested all sizes of juvenile bluegill offered as prey (Table 7). This made it impossible to use this experiment to define the maximum prey size for adult bluegills.

Table 7.–Predator length, predicted gape, predicted maximum prey length, and prey sizes offered and consumed in laboratory experiments evaluating effects of prey size on prey capture. Both predators and prey were bluegills.

Predator length (mm)	Predator weight (g)	Predicted gape (mm)	Predicted max. prey length (mm)	Lengths of prey offered (mm)	Prey consumed (mm)
148	50.9	11.0	39.9	39, 43, 45, 47, 48, 49, 50, 50, 52, 55	all
150	50.4	11.1	40.3	33, 39, 40, 41, 43, 45, 47, 48, 49, 51, 53	all
156	56.4	11.6	41.6	38, 41, 44, 46, 47, 49, 50, 52, 53, 53, 54	all
158	69.0	11.7	42.1	38, 42, 43, 44, 44, 47, 48, 51, 52, 52, 53	all
170	73.5	12.6	44.7	38, 41, 43, 45, 46, 47, 48, 48, 52, 54	all
171	87.8	12.7	44.9	39, 41, 42, 43, 44, 46, 47, 50, 52, 53, 53, 54	all
183	114.8	13.5	47.5	41, 45, 46, 48, 48, 49, 50, 53, 54, 56	all
184	79.7	13.6	47.7	43, 46, 48, 50, 51, 52, 53, 54, 55, 57	all
189	127.6	14.0	48.8	45, 47, 49, 50, 51, 51, 52, 53, 54, 57	all
191	105.8	14.1	49.2	47, 48, 49, 50, 52, 53, 54, 56, 58, 59	all

One explanation for these results may be that the juvenile bluegills used as prey were in poor condition and consequently had a reduced body depth. The juvenile bluegills used as prey were taken from the ponds in December and had not yet converted to feeding in the lab. They may have had a smaller body depth than the bluegills used to develop the original regression. A new regression was performed using both body depth and relative weight (W_r, as a fraction of standard weight) as predictor variables for bluegill length:

$$\log_{10} L = 0.7025(\pm 0.0051) + 0.8362(\pm 0.0031)\log_{10} D - 0.3034(\pm 0.0162)\log_{10} W_r \ ,$$

where r^2 = 0.994, N = 450, for bluegills from 51-220 mm total length, with maximum body depths ranging from 13-89 mm and W_r ranging from 0.55 to 1.04. Table 8 shows that it can be important to account for the effect of relative weight when estimating the sizes of prey that can be ingested by piscivores. For body depths (and predator gapes) from 11 to 14 mm, the predicted maximum bluegill length varies by 7-9 mm as relative weight changes from 0.60 to 1.10.

Table 8.–Predicted length of juvenile bluegills having a given maximum body depth and relative weight.

Body depth	Relative weight					
(mm)	0.60	0.70	0.80	0.90	1.00	1.10
11	43.7	41.7	40.1	38.7	37.4	36.4
12	47.0	44.9	43.1	41.6	40.3	39.1
13	50.3	48.0	46.1	44.4	43.1	41.8
14	53.5	51.0	49.0	47.3	45.8	44.5

The corresponding new equation for predicting maximum body depth from length and relative weight is:

$$\log_{10} D = -0.8259(\pm 0.0090) + 1.1887(\pm 0.0043)\log_{10} L + 0.3592(\pm 0.0194)\log_{10} W_r \ ,$$

where r^2 = 0.994, N = 450.

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Prepared by: James E. Breck
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