FEDERAL AID TO FISH RESTORATION

ANNUAL PERFORMANCE REPORT

MAN-MADE LAKES INVESTIGATIONS

PROJECT NO. F-160-R

Study 7007. **Assessment of the significance of recruitment and angler exploitation to the walleye fishery at Rathbun Lake**
Job 1. **Assessment of cost and benefit of the walleye stocking program**
Job 2. **Assessment of the significance of harvest to the density of adult walleye in Rathbun Lake**

Study 7008. **Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations**
Job 1. **Population characteristics of bluegill, crappie and largemouth bass**
Job 2. **Physical and chemical components of the ecosystem that may affect bluegill and crappie populations**
Job 3. **Impact of angler harvest and largemouth bass predation on bluegill and crappie populations**
Job 4. **Statewide database statistics on bluegill and crappie**

Study 7009. **Microcomputer technical training and support**
Job 1. **Statewide database and other software development**
Job 2. **Personnel training and system maintenance**

Period covered: 1 July, 1998 - 30 June, 1999
Iowa Department of Natural Resources
Larry J. Wilson, Director
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STUDY 7007

Assessment of the significance of recruitment and angler exploitation
to the walleye fishery at Rathbun Lake

OBJECTIVE

To maintain the Rathbun walleye population (≥ 17 inches) at a minimum biomass of 3 lbs per acre, using the most cost effective stocking strategy.

JOB 1

Assessment of cost and benefit of the walleye stocking program

OBJECTIVE

To determine the cost/benefit ratios of stocking walleye to the fishery as age 1 fish by measuring abundance, mortality rates, and growth and costs

JOB 2

Assessment of the significance of harvest to the density of
adult walleye in Rathbun Lake

OJECTIVE

To delineate the importance of harvest by measuring exploitation rate, natural mortality, growth and abundance of walleye ≥ 17 inches.

ANNUAL REPORT
RESEARCH PROJECT SEGMENT

STATE: Iowa **TITLE:** Assessment of the significance of recruitment and angler exploitation in the walleye fishery in Rathbun Lake

JOB NO.: 1, 2

ABSTRACT

This investigation documented the changes in the walleye population at Rathbun Lake since 1984 when it was characterized by low recruitment, low density and large fish. The goal of the study was to triple population abundance by 1995 through a regimented stocking schedule of 2,000 fry per acre (1984-1995), 10 extensively-reared fingerlings per acre (1984-1990) and 5 intensively-reared fingerlings per acre (1991-1995). Fry stocking was most influential in establishing strong year classes at Rathbun Lake in 1985, 1986, 1993, 1995, 1997 and 1998. Densities of these year classes in November were 9-27 fish per acre. Intensively-reared fingerling survival was greater than those raised extensively 4 out of 5 years. On the average, overwinter survival of intensively-reared fingerling survival was 11 times greater than extensively-reared fish. The primary reason for better survival of intensively-reared walleye was size at stocking; mean length was 7.4 inches as opposed to 5.0 inches for extensively-reared walleye. Another factor influencing survival of extensively-reared fingerlings was the hauling stress involving a 6 hour, 300 mile trip. In 1991-1997 a comparison of survival was made between fall-stocked and overwintered, spring-stocked intensively-reared fingerlings. Six sample years out of eight yielded valid test statistics. Spring-stocked fingerling walleye survived better than fall-stocked fingerlings in 1994, 1995, 1997 and 1998, while fall-stocked fish survived better in 1992 and 1993. In July 1997 and 1998, fingerlings marked with oxytetracycline (OTC) were stocked in watershed streams to assess their contribution to the lake population. Summer sampling with seine and backpack electrofishing showed good survival and excellent growth. Fall otolith samples in the lake showed no OTC marked fish had moved to the lake proper. Cost of stocking various groups of walleye and benefits, based on survival, were analyzed to provide alternatives for stocking strategies. The goal of tripling the walleye population at Rathbun Lake was attained by increasing recruitment through a regimented stocking schedule, and most importantly, the angler was not penalized by harvest regulations.

INTRODUCTION

The walleye population in Rathbun Lake originated from an initial stocking of 800 fry per acre on May, 1970. Subsequent plants of fry and fingerling resulted in a walleye population that became an important source of broodfish for the state's hatchery system. The Rathbun Fish Hatchery, built in 1977, and located below the dam, has the capability of producing about 40 percent of the sac fry needed statewide. Annual gill net collection of walleye broodfish peaked in 1980 and 1981 at over 2,000 fish. A systematic decline in numbers of broodfish taken by netting crews began in 1982, and reached a low of 609 fish in 1987. Length-frequency distribution of brood walleye taken during the mid 1980's indicated poor recruitment was the primary cause of diminishing numbers. Larger fish dominated the population and recruitment of smaller fish into the populations was poor. Walleye caught by anglers fishing at Rathbun Lake, likewise, showed a similar trend of larger but fewer fish. Nearly 14,000 walleye were harvested by anglers in 1972; however, the number decreased to 4,600 by 1975, and varied between 1,000-3,000 through 1986.

This investigation was initiated in 1984 to evaluate walleye recruitment associated with an intensified stocking program and to determine a strategy necessary to triple the biomass of walleye at Rathbun Lake. A second objective was to evaluate the impact of angling upon the walleye population and, in particular, assess concerns of overharvest. Only sparse information was available on success of walleye stocked in large man-made impoundments and even less was known about the impact of angling upon walleye populations. Previous investigations focused primarily upon the assessment of walleye stocked in natural lakes (Jennings 1968, 1969, 1970, 1971; Rose 1955; Payne 1975; McWilliams 1976). Investigations on man-made impoundments < 1,000 acres were reported by Mayhew (1959, 1962, 1963) and Mitzner (1969, 1971).

Annual net collection of adult fish and creel surveys showed the haphazard stocking program implemented during the 1970's and early 1980's did not maintain the density of walleye in Rathbun Lake necessary to meet broodfish needs or angler expectations. A major component of this investigation was a substantial increase in the stocking rate of both fry and fingerling walleye. Annual stocking requests were increased to 2,000 fry per acre, while that for fingerling was 10, four to six-inch walleye per acre. The impact of this intensified stocking effort was evaluated, 1984-1994, in an effort to determine the differential mortality of fry-stocked and fingerling-stocked fish during their first year, particularly the first winter.

The survival of extensively, and intensively, reared walleye fingerlings was compared in studies conducted from 1984-1989. As a result, intensively reared walleye are now the only fingerling walleye stocked into Rathbun Lake and, because of improved survival, the stocking rate was reduced to 5 fingerlings per acre. Half are stocked in the fall, while the remaining half are overwintered at the hatchery and stocked in March.

The initial objective of tripling the walleye population in Rathbun Lake was attained during the early 1990's. In 1995, the objective of the project was changed and the study was redesigned to provide the recruitment necessary to double the already much improved walleye population. In an effort to accomplish this, three changes were made to our stocking strategies. These were 1) increase fry stocking rate from 2,000 to 3,000 per acre and stock the fry in the areas of the lake containing the most abundant plankton, 2) stock the overwintered walleye at the time of shad hatch instead of just after ice-out and 3) stock selected feeder streams above Rathbun Lake with small (2 inch) fingerlings. These methods will be examined through the year 2,000.

DESCRIPTION OF THE STUDY AREA

Rathbun Lake is an 11,000 ac impoundment and is within the Chariton River Basin in Appanoose, Wayne, Lucas, and Monroe Counties. The project was built during with 1960's with gate closure in 1969 and operated for flood control, recreation and navigation benefits. Normal reservoir operation discharge rates range from 10 to 1,200 cfs; however, the maximum discharge is 5,000 cfs. Storage at conservation pool (904 ft MSL) is 205,400 ac-ft and maximum volume is 551,600 ac-ft at crest elevation (926 ft MSL). The watershed to lake surface area ratio is 32:1 at conservation pool and 17:1 at spillway elevation. Mean depth at conservation pool is 19 ft, while at crest elevation it is 26 ft. Maximum depth at conservation pool is 49 ft and 74 ft at crest elevation. Shoreline is quite irregular with many small embayments; its development is 7.3. Thermal stratification develops only during hot, still periods.

Sport fish present in the lake include white and black crappie, channel catfish, white bass, walleye, largemouth bass, bluegill flathead catfish, northern pike, and black bullhead.

METHODS AND PROCEDURES

Young-of-the-Year (YOY) Walleye

Fry stocking during the 1984-1998 study period ranged from 18.7 million in 1986 to 38 million in 1997 (Table 1). Dates fry were stocked ranged from 17-30 April, 1986 to 6 - 13 May, 1997. Larval walleye were sampled twice weekly with a one meter conical net, harnessed with a circular bridal. The net was towed 6 ft/sec for 10 minutes at each of six stations. Larval fish were removed from the net and preserved in 5 percent formalin for laboratory analysis. Sampling commenced previous to fry stocking and continued through early June. Three of the six tow net stations were located in open water. These were stratified by depth -- surface (A) and 15 feet (B). Embayment stations were located in Honey Creek and Buck Creek, while a shoreline station was located midway in the reservoir near the northeast shore (Figure 1). Fingerling walleye were sampled during September-October and again April-May. Estimates of YOY walleye were obtained during the fall and spring by subsequent mark-recapture trials. The marked portion of the population was obtained by stocking fin-clipped or tagged (binary coded wire) hatchery fish. The population estimate was divided into the following two components: unmarked fingerlings which originated as fry-stocked fish and marked fingerlings which originated as hatchery produced fingerling fish. Intensively or extensively cultured fingerlings were uniquely marked, as were spring and fall stocked fish. After 1990, only intensively reared fish were stocked. Electrofishing gear, 230 V AC, was used to sample fish at night, both in spring and fall. Population density was estimated by the Schumacher-Eschmeyer modification of the Schnabel method (Ricker. 1975).

Table 1. Walleye fry and fingerlings stocked at Rathbun Lake, in number of fish per acre. S: Spring, SUM: Summer, F: Fall.

Year	Fry	Fingerlings	
		Extensively-reared	Intensively-reared
1970	800	--	--
1971	1,000	--	--
1972	818	--	--
1973	818	--	--
1974	1,000	--	--
1975	1,000	4.4	--
1976	1,000	4	--
1977	1,364	5.6	--
1978	1,500	2.4	--
1979	--	10.8	--
1980	--	8	--
1981	--	--	--
1982	600	2.5	--
1983	--	4.1	--
1984	2,636	4.6	--
1985	2,582	5.7	1.1
1986	1,700	13	1.5
1987	2,090	7.3	0.3
1988	2,173	5	0.4
1989	2,045	7.6	2.9
1990	2,682	--	6.5
1991	2,727	--	3.1
1992S	2,273	--	2.6
1992F	--	--	4.7
1993S	2,345	--	2.7
1993F	--	--	2.5
1994S	2,500	--	2.6
1994F	--	--	2.2
1995S	2,132	--	2.6
1995F	--	--	3.6
1996S	3,000	--	3.9
1996F	--	--	
1997S	3,477	--	6.4
1997SUM	--	3.6	
1997F	--	--	3.6
1998S	3,200	--	1.7
1998SUM	--	3.7	--
1998F	--	--	3.0
1999S	3,273	--	3.0

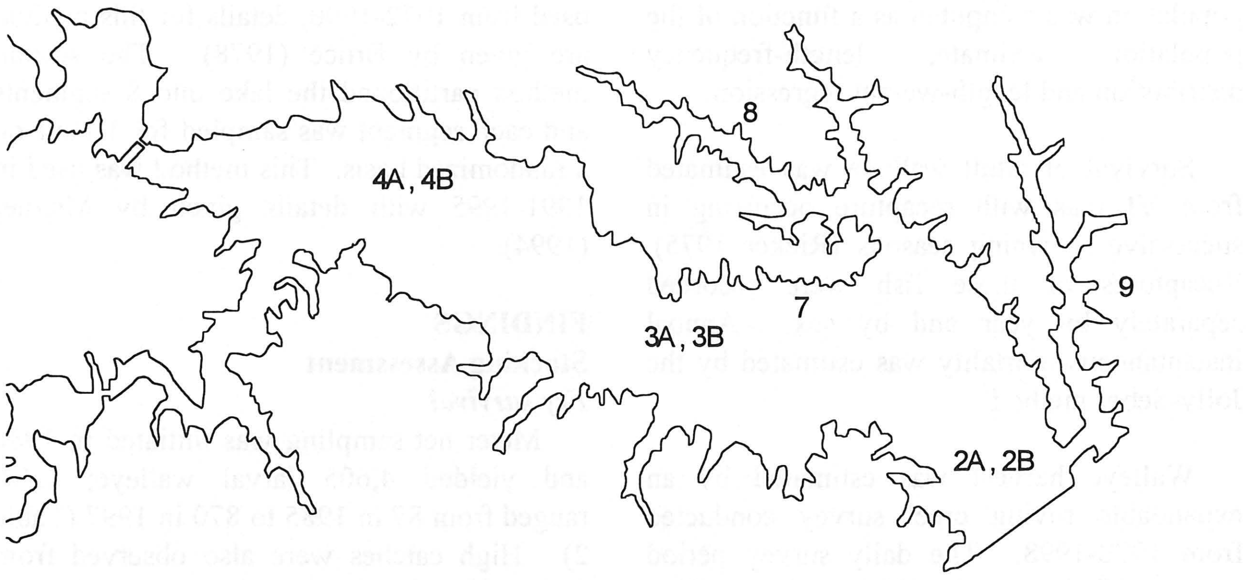

Figure 1. *Rathbun Lake showing meternet sampling stations for young-of-year walleye, 1984-1998.*

Differential mortality of fry- and fingerling-stocked fish was determined from the change in ratio of marked to unmarked fish at stocking (September) and at later intervals, such as the following spring (April-May). Analyses by Chi-square were based on the ratio of fingerlings present that originated from fry plants (unmarked) to the number of marked fingerlings. For example, in 1984 the fall population estimate of YOY walleye was 72,826 of which 34,031 were unmarked and 38,795 were stocked and fin-clipped. Therefore, the ratio of unmarked to marked fingerlings was 1:1.14. This ratio was 1:0.26 the following April and the total sample size was 177. Thus, the 2 x 2 table for Chi-square analysis for differential mortality was the following:

	Sept, 1984	April, 1985	Total
Unmarked Fish	83	141	224
Marked Fish	94	36	130
Total	177	177	354

The null hypothesis for all analyses was the ratio would not change over time if the mortality rate for each subpopulation was similar.

Adult Walleye

Walleye population densities were estimated by the Jolly-Seber method of mark-recapture (Ricker 1975). All fish ≥ 17 inches in total length (TL) brought into the hatchery for spawning in April were marked with a partial fin-clip or Visual Implant (VI) tag, stripped and returned to the lake. Marks were distinctive for each year of the investigation.

Angler-caught walleye were examined by the creel clerk for marks or tags. Biomass of the population was computed as a function of the population estimate, length-frequency distribution and length-weight regression.

Survival of adult walleye was estimated from VI tags with recapture occurring in successive spawning seasons (Ricker 1975). Recaptures of these fish were recorded separately by year and by sex. Annual instantaneous mortality was estimated by the Jolly-Seber method.

Walleye harvest was estimated by an expandable roving creel survey conducted from 1972-1998. The daily survey period was stratified by early (AM) and late (PM) fishing with further stratification by weekend and weekday, and boat and shore. Angler counts were made on an hourly basis within the stratified design. Information obtained from interviews included number in party, length of time fished, whether the trip was complete, number of each species caught, and determination of the target species. Lengths were taken on representative catches of walleye, as well as other species, throughout the survey period.

Two basic survey designs were used during the investigation. The first design divided the lake into 4 sample segments. Each segment was sampled individually for 8 hours on a random basis. This method was used from 1972-1990; details for this method are given by Bruce (1978). The second method partitioned the lake into 8 segments and each segment was sampled for 1 hour on a randomized basis. This method was used in 1991-1995 with details given by Mitzner (1994).

FINDINGS

Stocking Assessment

Fry survival

Meter net sampling was initiated in 1984 and yielded 4,605 larval walleye; catch ranged from 87 in 1985 to 870 in 1997 (Table 2). High catches were also observed from 1986-1990. Catches in 1997 were the highest on record. Station 7 produced, by far, the most walleye larvae with an average of 81 larvae per year. Catches at the surface (A) were generally greater than mid-depth (B), but there was no significant difference between strata. Computation of instantaneous daily mortality based on the geometric decrease in larval numbers with time showed a range of 0.07 in 1988 to 0.26 the previous year (Table 3). These values equated to a larval fish loss of 6.5% to 22.8% per day. Average mortality of larval walleye during the study was 12.3% per day for the first 25 days of life in the lake.

Table 2. Yearly catches of larval walleye in meter net tows at 9 stations, Rathbun Lake.

	Station									
Year	2A	2B	3A	3B	4A	4B	7	8	9	Total
1984	34	3	17	10	9	0	26	12	3	114
1985	2	1	4	5	12	22	31	6	4	87
1986	103	4	11	5	16	9	108	70	12	338
1987	7	5	19	12	23	12	170	93	3	344
1988	57	5	23	50	50	41	48	12	9	295
1989	13	2	40	24	39	12	195	60	80	465
1990	100	90	27	10	9	9	205	119	18	587
1991	4	7	25	15	47	2	34	10	2	146
1992	3	12	11	16	25	12	68	21	14	182
1993	15	4	19	10	54	19	19	2	3	145
1994	0	2	14	2	37	9	103	8	0	175
1995	11	2	14	26	17	75	35	22	3	205
1996	24	59	38	33	33	17	44	56	10	314
1997	118	289	19	39	81	157	67	78	22	870
1998	27	19	39	10	77	13	63	64	26	338
Total	518	504	320	267	529	409	1216	633	209	4605

Table 3. Instantaneous (Z) daily mortality, standard deviation (S_Z), confidence interval of Z, and percent daily loss of walleye larvae, Rathbun Lake.

Year	Daily Instantaneous (Z)	S_Z	95% CI of Z	Percent lost daily
1984	0.12	0.015	±0.049	11.3
1985	0.08	0.043	±0.118	7.7
1986	0.09	0.017	±0.043	8.9
1987	0.26	0.019	±0.048	22.8
1988	0.07	0.021	± 0.049	6.5
1989	0.20	0.024	±0.058	18.3
1990	0.13	0.030	±0.060	12.6
1991	0.12	0.021	±0.041	10.4
1992	0.20	0.240	±0.047	18.1
1993	0.10	0.038	±0.074	9.5
1994	0.13	0.037	±0.073	11.8
1995	0.14	0.025	±0.049	13.1
1996	0.08	0.012	±0.023	8.1
1997	0.22	0.041	±0.082	20.0
1998	0.20	0.044	±0.088	18.0

Daily loss estimates applied to the number of fry stocked yielded the estimated number of walleye remaining after 25 days. This ranged from 8 per acre in 1997 to 405 per acre in 1988. Density of YOY walleye at Rathbun Lake after 25 days was 25.6 per acre in 1998. The 25-day survival ranged from 0.5 percent to 19 percent depending on the initial number stocked and the average daily mortality rates. In 1998, 25-day survival from the initial fry stock was 1.2%.

The second density estimate of YOY walleye produced from fry plants was obtained during cove rotenone sampling in August. Greatest density of YOY walleye was attained in 1988 at 14 per acre; however, estimates calculated in 1977 and 1989 yielded 13 per acre (Table 4). Estimated densities rarely fell below 2 per acre as a result of fry stocking. The overall average density during the investigation was 7 per acre. The lowest density of 1.3 YOY walleye per acre was estimated in 1979, a year when no fry were stocked into Rathbun Lake. This finding verified limited natural reproduction of walleye in Rathbun Lake.

Table 4. Estimated density of YOY walleye, in number per acre, in Rathbun Lake using two sample methods and discounting fingerling-stocked fish.

Year	August Cove rotenone	October Mark-recapture	95% CL Lower	95% CL Upper
1977	13.0	--	--	--
1978	2.5	--	--	--
1979	1.3[1]	--	--	--
1984	--	2.0	1.8	2.3
1985	1.8	9.2	6.7	14.7
1986	5.5	27.5	21.0	39.7
1987	5.3	5.2	4.4	6.4
1988	14.0	2.7	2.5	3.0
1989	13.0	7.7	6.9	8.6
1990	2.0	3.7	2.9	3.9
1991	2.0	70.1[2]	--	--
1992	9.0	3.0	--	--
1993	--	9.3	6.2	15.8
1994	--	1.4	1.2	1.7
1995	--	13.4	8.6	31.3
1996	--	--	--	--
1997	--	3.6	3.5	11.0
1998	--	6.9	5.9	8.4

[1] no fry-stocked - natural reproduction

[2] biased sample

The extremely high density of fingerling walleye found in 1991 was probably due to a change in methods of stocking fish. Marked fingerlings were hauled, by boat, to the middle of the lake and released. Other years, fish were distributed at a variety of boat ramps around the lake. This clumping of marked fish relative to the native (fry-stocked) population was evidenced the following spring when the population estimate was 1.5 per acre as opposed to 70 per acre the previous fall. The second highest density of fall fingerling walleye produced from fry-stocked fish was 27.5 per acre in 1986. More common densities were in the 5-9 fish per acre range with a median of 5 per acre.

Since 1984, differential mortality was estimated between various subpopulations of stocked walleye fingerlings and those fingerlings that resulted from fry plants. The primary emphasis in the early phase of this study (1984-1990) was a comparison of survival of intensively reared and extensively reared fingerling fish. These findings were published by Mitzner (1992). The primary outcome of the early study was that intensively reared fingerlings had consistently better survival than extensively reared fish. Fingerlings which originated from fry and those intensively reared and stocked as fingerlings had equal survival.

Study emphasis since 1990 has centered on assessment of the survival of fingerlings stocked in the fall compared to fingerlings overwintered in the hatchery and stocked in the spring. Numbers of walleye fingerlings stocked are shown in Table 5 and ranged from 24,500 to 80,000 fish. During the study, the average number of fingerling walleye stocked was about 34,000 or 3.1 per acre.

Table 5. A summary ofwalleye fingerlings stocked in Rathbun Lake and fall estimates of those that were introduced to the lake as fry and spring stocked fingerling fish.

Year-Class		Number Stocked	Fall-stocked Fingerling Population Estimate	Fry-stocked Fingerlings Population Estimate
1991	F	33,860		771,256[1]
	S	28,895	17,900	16,196
1992	F	55,118		[2]
	S	29,353	37,052	32,077
1993	F	27,382		101,965
	S	28,844	36,253	59,643
1994	F	24,499		14,963
	S	28,925	8,630	11,870
1995	F	39,523		108,406
	S	38,278		
1996	F	none		
	S	80,000		
1997	F	39,573		65,351
	S	19,015		
1998	F			76,423
	S			

[1] biased estimate.

[2] no estimate -- high water.

The estimated abundance of fingerling walleye that originated from fry plants varied from 11,870 to 771,256 fish. The high estimate of 771,000 was undoubtedly biased as previously described. The more realistic estimate of 16,196 occurred the following spring. Such a high mortality of 98% was unlikely for fingerlings of that size (Mitzner 1992).

The estimate of walleye fingerlings in the 1995 year class, introduced as fry, was 108,406. These fish, approximately 10 fingerling per acre, contributed to the largest year class of walleye observed during the 15 years of the study.. Additional stockings of fingerling fish in the fall and spring yielded a density of 13.4 per acre in the fall of 1995 and 16.9 per acre the following spring. Spring densities in 1991, 1992, 1993, and 1994 were 5.7, 9.0, 8.9 and 4.4 per acre.

Fingerling Survival

Overwinter survival of fry-origin fingerlings and fall-stocked fingerlings were estimated from the above population estimates. Greatest overwinter survival occurred for fall-stocked fingerlings of the 1993 year class. The estimate of 36,253 age 1 walleye made in the spring was larger than the number actually stocked (27,382). The confidence intervals of the estimate, however, were large enough (±24%) to provide for survival of 95%. Overwinter survival for the other fall-stocked fingerling plants were 0.53, 0.67, and 0.35 for the 1991, 1992, and 1994 year classes. Overwinter survival of fry-origin fingerlings was 0.58 and 0.79 for the 1993 and 1994 year classes.

Survival of spring-stocked fingerlings compared to fall-stocked fingerlings favored fall-stocking of the 1992 and 1993 year classes, but favored spring-stocking of the 1994, 1995 and 1997 year classes. The 1991 comparisons could not be made because of poor sampling conditions due to high water during the fall 1992 sampling season. Only one spring-stocked and 5 fry-origin walleye fingerlings of the 1991 year class were sampled. Fall-stocked fingerlings were not sampled during this period. Samples for the 1992 year class during the fall 1993 included 10 recaptures from spring-stocked fingerlings, 21 from fall-stocked fingerlings and 30 from fry-origin fingerlings. The 1994 fall survey of the 1993 year class yielded 60 recaptures, of which 5 were spring-stocked, 12 were fall stocked and 43 were of fry-origin.

The 1995 year class was sampled as usual in the spring and fall of 1996. The sample yielded 120 and 308 fingerlings (spring and fall) of fry origin, 82 and 6 fingerlings (spring and fall) which were stocked in the fall of 1995, and 11 and 5 fingerlings (spring and fall) which were stocked in the spring of 1996.

The 1996 year class comparisons were not made because no fall stockings occurred. The rationale for not stocking the fall fingerlings was low levels of forage in the lake during 1996; shad density in the fall was particularly low. Similar conditions existed in 1994 and the results were extremely poor; only 1.4 fingerlings per acre were found that year. It was deemed unwise to make a second such disastrous stocking in 1996.

The 1997 year class showed spring stocked fingerlings survived better than fall stocked fingerlings. Assessment of this year class in the autumn of 1998 yielded 10 recaptures of spring stocked fish, 16 recaptures for fall stocked fish and 111 recaptures of fish not marked (fry stock origin). Walleye stocked were 19,015 (spring), 39,573 (fall) and the fall population estimate of fish not marked was 65,351. Comparison of fish stocked to the 1998 fall assessment showed survival of spring stocked fingerling walleye was 1.3 times better than survival of fall stocked fingerlings.

Spring and fall recaptures of walleye, 1992-1997, , provided comparisons of relative survival rates for each of the subpopulations. For example, the fall-stocked fingerlings of the 1992 year class had a relative survival rate 1.67 times better than the spring-stocked contingent. Similarly, fry-origin fingerlings of the 1992 year class had a relative survival rate 1.92 times better than spring-stocked fingerlings. There was no significant difference ($P>0.05$) between the fall-stocked and fry-origin fingerling mortality. Findings were much the same for the 1993 year class. Spring-stocked fingerling survival was poorest, while fall-stocked fingerling survived 1.91 times better. Fingerling survival of fry origin, however, was nearly identical to the fall-stocked group at a rate 1.06 times better.

Differential mortality between spring- and fall-stocked walleye of the 1994 year class favored spring-stocked fingerlings. During the 1995 spring sample, the ratio of fall to spring-stocked fish was 1:2.84. This ratio changed to 1:4.89 during the fall 1995 sample and 1:4.0 during the 1996 spring sample. For each spring-stocked walleye which perished 1.72 fall-stocked walleye perished. Chi-square was 1.38; $p< 0.25$.

Ratios for various components of the 1994 year class changed significantly between the fall 1995 and spring 1996 samples. For example, in October 1995 the ratio between October-stocked fingerlings and nonmarked fish (fry-origin) was 1:3.1 (47 to 146). However, in the spring 1996 sample, this ratio was 1:1.64 (70 to 115). Chi-square was 8.37, $p<0.005$. Therefore, during the fall of 1995 fish stocked as fingerlings comprised 24% of the population; however, by the spring of 1996 this lot of fish contributed 39% to the population. In order for this ratio to have changed, differential mortality was acting upon the two groups of fish. For every stocked fish which perished over the winter 1.9 nonmarked fish would have perished to attain the sample statistics of fall versus spring ratios. This was the first time in the study differential mortality occurred to this degree, favoring intensively reared hatchery fish.

Differential mortality of the 1995 year class showed fall stocked fingerlings survived at a much greater rate ($P < 0.05$) than fingerlings fish stocked as fry. Chi-square value was 11.85 for fry origin and fall stocked fingerlings sampled in the fall of 1995 and then again in the spring of 1996. For each fall stocked fingerling that perished during the winter, 2.1 fingerlings, introduced as fry, perished.

The next step was to examine the differential mortality between spring stocked, and fall stocked, fingerlings of the 1995 year class. For this evaluation the difference was examined between the spring 1996 sample and the fall 1996 sample. The difference in ratios was significant (Chi-square of 8.54) favoring spring stocked over fall stocked fingerlings. For each spring stocked walleye which perished between spring 1996 and fall 1996, an average of 6.2 fall stocked fingerling walleye perished.

Feeder Stream Survey

In preparation for stocking walleye fingerlings in feeder streams at Rathbun Lake during June, 1997, a stream survey was conducted in 1996 at selected sites. Five sites were examined on the Chariton River, South Fork Chariton River, and Wolf Creek. Sampling included two hours, 46 minutes of backpack electrofishing and this effort was expended on 8 separate runs.

Seventeen species of fish were collected as shown in Table 6. Most numerous were red shiner and bigmouth shiner, followed by sunfish species, mainly green sunfish. Sand shiner and fathead minnows were also important in the community. Few large predators were present; these included largemouth bass and larger creek chubs.

Table 6. Size characteristics and relative abundance of the fish community in Chariton River, South Fork Chariton River and Wolf Creek.

Species	Minimum length (in)	Mode (in)	Maximum length (in)	Number
Orangespotted sunfish	1.2	2.0	3.5	31
Green sunfish	0.8	2.4	4.7	136
Red Shiner	0.8	1.6	3.1	300
Black bullhead	3.1	6.3	7.5	40
Yellow bullhead	2.8	5.5	7.9	13
Bluegill	1.6	2.4	3.9	11
Largemouth bass	1.2	1.6	8.7	14
Fathead minnow	0.8	1.2	2.0	46
Sand shiner	1.2	2.0	2.8	67
Suckermouth minnow	0.8	1.2	3.1	22
Carpsucker	1.6	2.0	2.0	8
Bigmouth buffalo	1.2	2.0	2.0	11
Bigmouth shiner	1.2	2.0	2.4	103
Creek chub	2.4	5.1	6.7	25
Bullheads	2.8	6.3	7.9	53
Sunfish	0.8	2.4	4.7	178
Suckers	1.2	2.0	2.0	19

Physical characteristics of of 11 tributaries to Rathbun Lake were examined as potential stocking sites. These tributaries included the Chariton River (15 sites), South Fork Chariton River (11 sites), West Jackson creek (8 sites), Wolf creek (6 sites), Honey creek (5 sites), Jordan creek (5 sites), Ninemile creek (4 sites), Jackson creek (4 sites), Chariton creek (3 sites), and Dick creek (2 sites). Criteria used for selecting stocking sites were accessibility, proximity to the reservoir, riparian habitat, water conditions, and drainage area above the site. From these 69 possible sites, six sites were selected for normal to low flow conditions and six alternative sites were selected for high flow conditions.

Walleye Stream Stocking and Assessment

On June 18, 1998, 21,982 walleye fingerlings marked with Oxytetracycline

(OTC) were stocked at four sites in the Rathbun Lake watershed. Then on July 1, an additional 18,424 OTC marked fingerlings were stocked. The sites included the Chariton River (one in Lucas [n=2,377] and one in Wayne [n=4,157] Cos.), Wolf Creek [n=3,487] (Wayne Co.), Fivemile Creek [n=3,189] (Lucas Co.), South Fork, Chariton River [n=2,600] (Wayne Co.), Dick Creek [n=7,539] (Wayne Co.), Jordan Creek [n=1,948] (Wayne Co.), and Jackson Creek [n=5,141] (Wayne Co.).

Walleye fingerling size was 265 fish per pound on June 18, and 149 fish per pound on July 1. Length was approximately 3 inches. Distribution tank temperatures ranged from 72-76 F; while stream temperatures ranged from 64-72 F. Fingerlings were acclimated at the stocking sites before release.

The 1997 walleye year class was sampled at 4 stocking sites on July 8-9, 1997 with DC backpack shocker. Walleyes were abundant at each of the sites with 66 fish taken in 73 minutes of effort. The next sampling occurred August 27-29. During this period, 13 areas were sampled with 19 seine hauls, producing 13 fingerling walleye. The next sampling, 205 minutes of electrofishing effort, occurred September 5-10 at 6 areas and no walleye were sampled.

The 1998 year class was assessed from July 8, to August 11, 1998 with an effort of 345 minutes backpack shocker and 52 seine hauls totaling 2,495 yds. Twenty-eight sites were sampled; in all, 6 walleye were sampled.

Sampling next occurred in the reservoir October 20-29, 1998. After 25.3 hours of sampling with a DC boom electro-fishing boat, 1,302 fingerlings were captured of which 504 were marked fish from the hatchery and 798 contained no marks. Of the latter group, all or part of the fish had a probability of being marked with OTC. All unmarked fish were frozen and later otoliths were prepared for OTC examination.

Samples for the 1998 stocking will be examined with the new detection equipment purchased in the winter of 98-99. Equipment is presently being set up and fine-tuned for identification of the OTC marks.

Adult Walleye

Growth and Condition

Walleye growth from measurements of known age fish in October, in addition to back calculated lengths at age from otoliths and fin rays, showed females grew more rapidly than males (Mitzner 1992). Female walleyes averaged 22 inches after 5 years of life, about 2 inches larger than males (Table 7). By age ten, females averaged 27.6 inches, a length nearly 4 inches larger than males.

Table 7. Composite of back-calculated lengths at age and empirical measurements of known age Rathbun Lake walleye, 1984-1989.

	Age											
	1	2	3	4	5	6	7	8	9	10	11	12
Male	6.1	11.5	15	17.4	19.1	20.9	21.7	23.1	23.5	23.6	24.2	24.4
Female	6.1	11.8	16.1	19.7	22.0	23.6	24.6	25.8	26.8	27.6	28.3	29.1

Growth of walleye was also calculated from VI tag returns from April broodfish collections. Walleye were not aged at that time, but a regression of length at year t against length at year t + 1 showed incremental growth as shown in Figure 2.

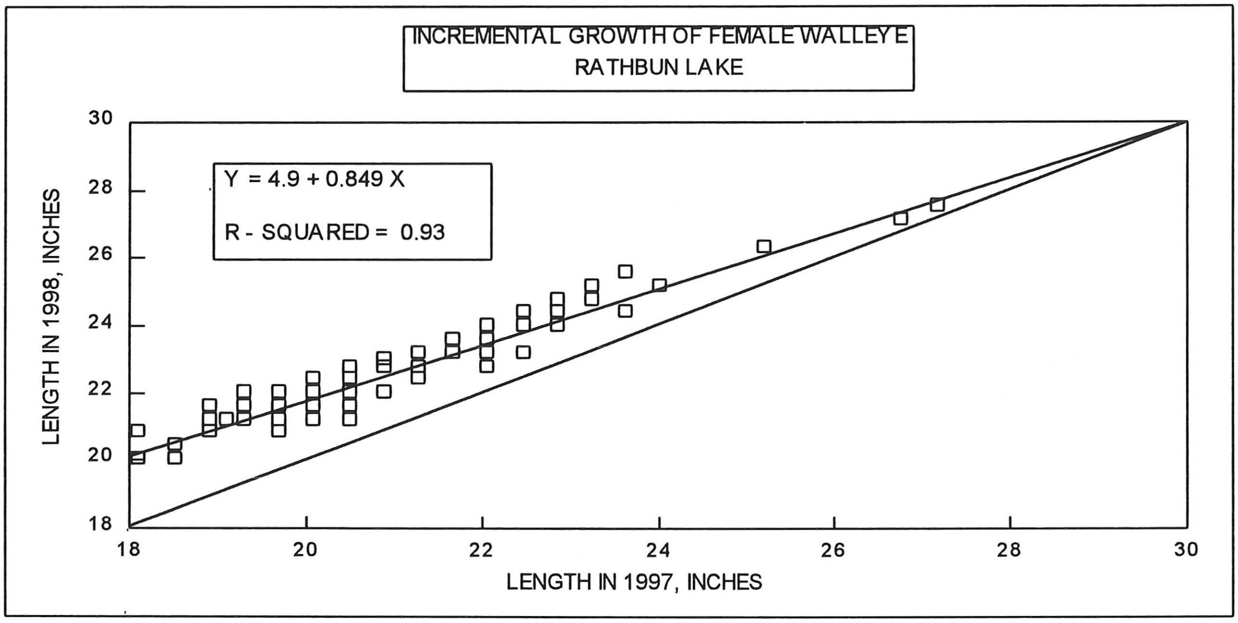

Figure 2. *Walford graph of VI-tagged female walleye captured and measured in April, 1997, and subsequently measured in April, 1998.*

Several measurements can be discerned from the regression. The first is the intercept. This is the theoretical length at one year of age. In Figure 2, this is 4.9 inches. Secondly, the regression slope is the decreasing rate of annual incremental growth. Thirdly, the maximum length (L_∞) which walleye can theoretically attain is calculated where the regression line intersects the Y = X line or the 1 : 1 line in the Figure 2. In this case maximum attainable growth for females sampled in 1997 and again in 1998 was 32.5 inches. Statistics for other years of collection are shown in Table 8.

Body condition of Rathbun Lake walleyes ranged widely between years and sexes. Green females consistently had greater W_r-values that ranged from an average of 98 in 1984 to 115 in 1988 (Table 9). Male walleye generally followed the same trend; W_r-values ranged from 94 in 1985 and 1986 to 108 in 1988. Body condition of males and green females differed significantly ($P<0.05$) except in 1984 and 1989. Analysis of W_r-values for female walleyes, only, showed body condition was significantly greater in 1987 and 1988 than any of the other study years. Similar analysis showed body condition of male walleye in 1988 was greater than for any other years. Length-weight regressions for Rathbun Lake walleye, 17-30 inches, are given in Table 9.

Table 8. Growth statistics for male and female walleye at Rathbun Lake, based on recapture statistics of VI Tags in subsequent years.

	Males			Females		
Year	Growth Coefficient (B)	Length Infinity	Intercept Length at age I	Growth Coefficient (B)	Length Infinity	Intercept Length at age I
1990	0.76	25.7	6.1	0.72	28.8	8.0
1991	0.78	25.2	5.6	0.76	29.2	7.1
1992	0.75	25.0	6.3	0.61	28.2	11.0
1993	0.83	27.4	4.6	0.79	30.2	6.3
1994	0.82	25.3	4.5	0.84	31.6	5.2
1995	0.77	25.4	5.9	0.75	28.6	7.0
1996	0.72	23.4	6.5	0.84	31.2	5.1
1997	0.73	24.1	6.6	0.85	32.4	4.9
1998	0.72	24.4	6.8	0.72	28.3	7.8
Average	0.76	25.1	5.88	0.76	29.8	6.9

Table 9. Length-weight regression constants of intercept (a) and slope (b) for male and green female walleye sampled from Rathbun Lake, 1984-1997, measurements in mm and gms.

	Male				Female			
Year	N	a	b	W_r	N	a	b	W_r
1984	55	-5.029	3.0206	98.0	58	-5.0639	3.0373	97.8
1985	53	-4.6938	2.8912	94.2	57	-5.1823	3.0861	102.0
1986	50	-5.4296	3.1600	93.5	52	-5.3802	3.1519	98.9
1987	51	-5.1805	3.0807	101.0	52	-4.6536	2.9075	111.6
1988	66	-5.1654	3.0857	107.7	37	-4.8848	2.9948	115.1
1989	50	-5.4279	3.1723	101.5	58	-6.2737	3.4843	102.7
1990	57	-4.2423	2.1750	89.6	84	-4.7536	2.9066	92.5
1991	658	-5.8319	3.3038	91.2	776	-5.4411	3.1708	97.7
1992	732	-5.4945	3.1723	87.4	239	-5.8080	3.2929	103.9
1993	777	-5.2719	3.0957	90.1	148	-5.9245	3.3580	103.4
1994	178	-4.8944	2.9612	92.3	111	-5.1115	3.0695	109.3
1995	136	-5.0742	3.0265	92.0	92	-5.0935	3.0602	107.0
1996	634	-5.2738	3.1046	94.9	127	-5.3215	3.1434	108.1
1997	1367	-4.3384	2.7636	98.4	180	-5.2504	3.1231	112.0
1998	1147	-5.2935	3.1106	94.0	294	-5.4028	3.1704	106.0

Abundance

Population estimates of walleye ≥ 17 inches were based on fish tagged during the April spawning run and recaptured in subsequent years during the same time period (Appendix A and Appendix B). The population estimates ranged from 3,013 in 1993 to 5,483 in 1997 (Figure 3). Male estimates were somewhat lower than females, ranging from 771 in 1991 to 2,230 in 1997. Female estimates ranged from 1,436 in 1995 to 3,253 in 1997. Abundance of mature walleye at Rathbun Lake in 1997 is the highest recorded, and is about 3 times the density of 1984 estimates when the investigation started. It should be noted that these estimates do not represent the total spawning population at Rathbun, but only the subpopulation that uses the dam for spawning.

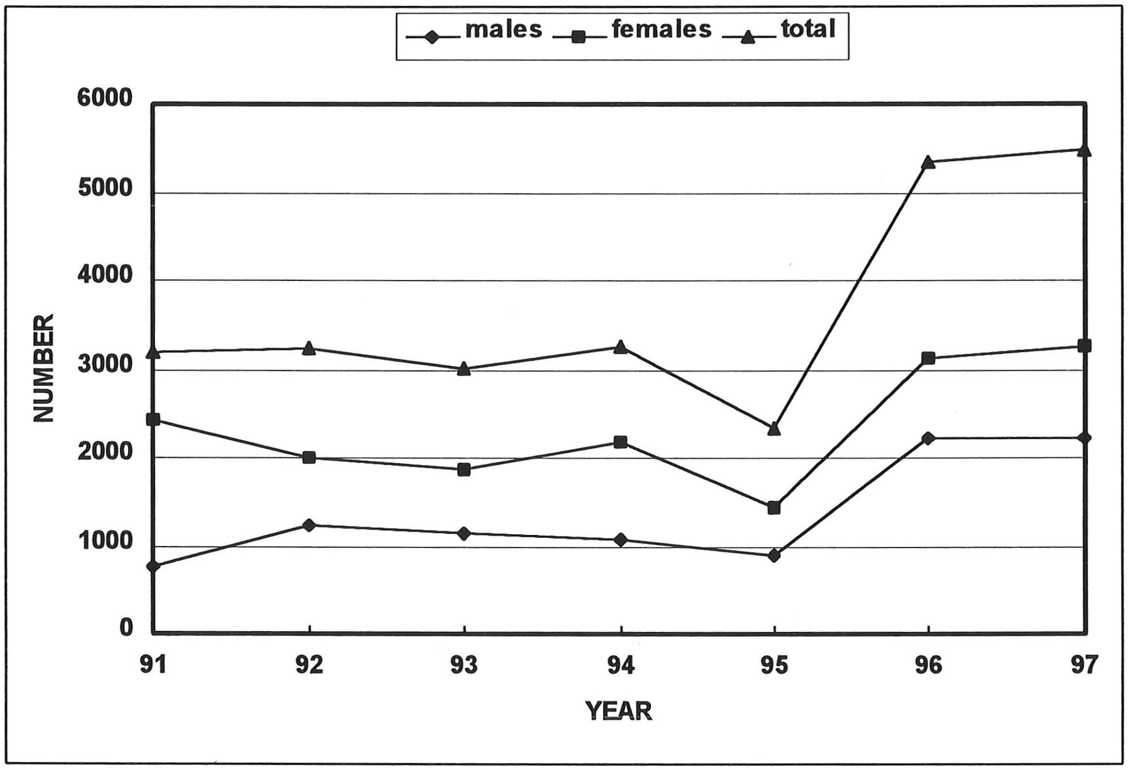

Figure 3. *Population estimates of male and female walleye, > 17.5 inches at Rathbun Lake, 1991-97.*

Size Structure

Length-frequency distribution of walleye caught in gill nets in April, 1984-1999, showed a decrease in size, particularly for female fish. The mode for females was 26 inches during 1984 and 20 inches in 1989. In 1999, female walleye were more uniformly distributed in all size groups from 18-30 inches with a mode at 21 inches (Figure 4). Findings were similar for male walleyes except lengths were about 3-4 inches smaller.

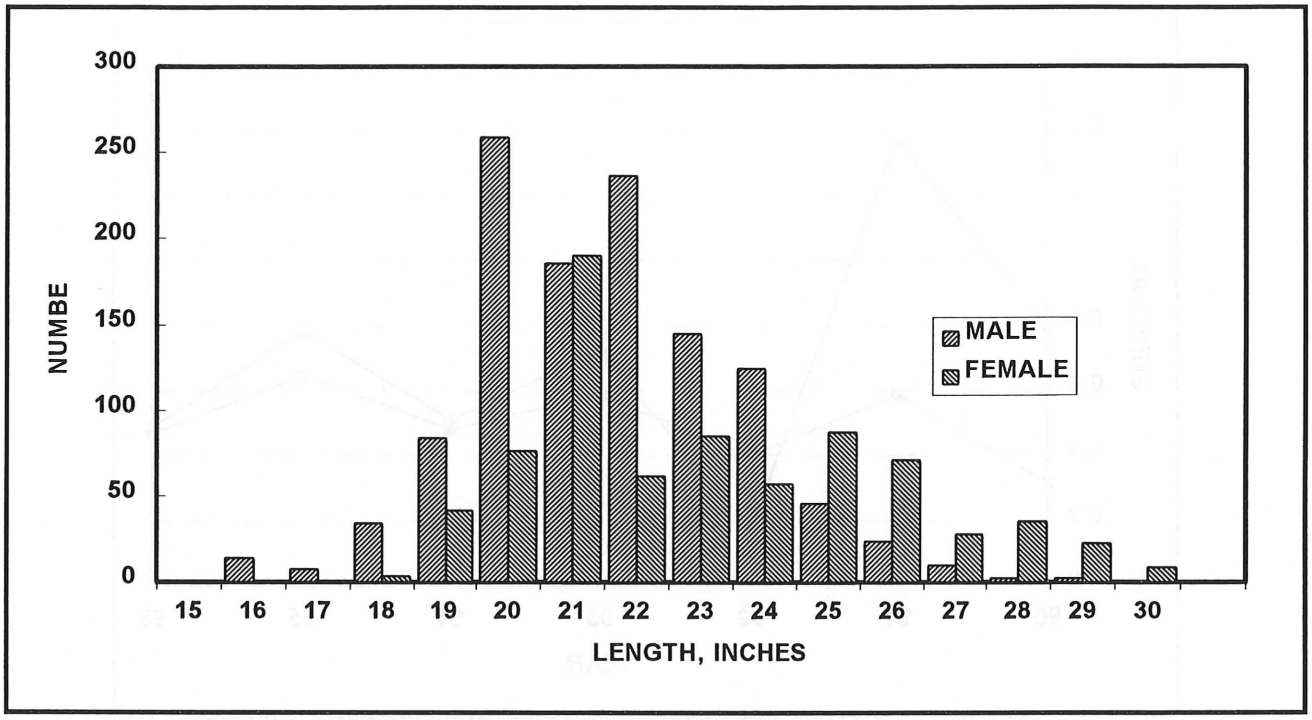

Figure 4. *Length-frequency distribution of male and female walleye captured during broodfish take at Rathbun Lake, 1999.*

Sources of Mortality

Survival estimates from Visual Implant tag returns, 1991-1998, were based upon recoveries shown in Appendix A and Appendix B. Annual survival rate for male walleye ranged from 0.65 for fish bearing 1995 tags to 0.32 for fish bearing 1990 tags. (Figure 5). Overall survival rate for male walleyes was 0.50 with no significant difference between years ($p>0.05$). Annual survival rate of female walleye was more variable between years and ranged from 1.37 for fish bearing 1991 tags to 0.18 for fish bearing 1992 tags (Figure 5). The overall average survival rate of 0.69 for females was significantly greater than that of males.

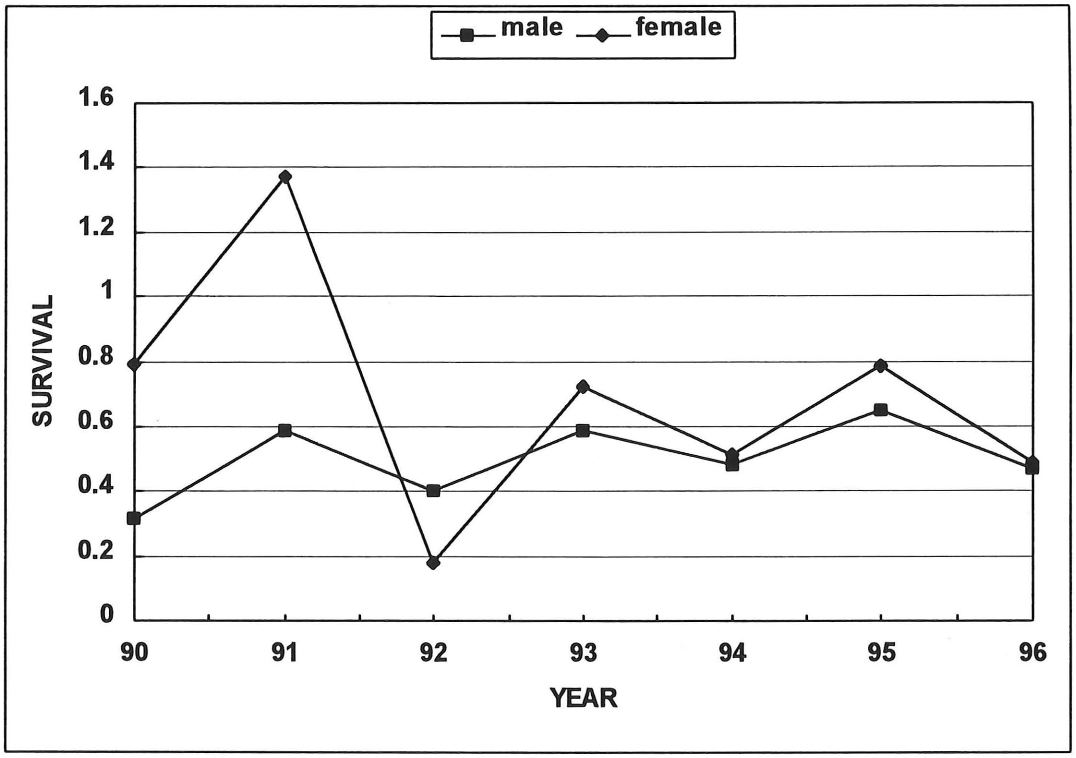

Figure 5. *Survival estimates of male and female walleye at Rathbun Lake, 1990-96.*

Walleye harvest at Rathbun Lake ranged from 13,585 in 1972 to approximately 900 in 1986 and 1995 (Table 10). Trends in harvest showed the lack of recruitment in the late 70's and early 80's. This was evident by low harvest and large fish in the creel. For example, catches in 1981-1985 showed annual harvest of about 1,000 walleye with mean length in the creel increasing to 18.7 inches. Intensified and more uniform stocking commenced in 1984 and these year classes began to recruit to the sportfishery in 1987. This was shown by increased catches and decreasing size. In 1988, harvest had increased to 9,242 fish with fluctuation since then between 1,200 in 1993 and 8,500 in 1996. The low catch in 1993 and 1995 was attributed to the record floods and high water those years. Size of harvested fish ranged from 18.7 inches in 1985 to 14.0 inches in 1989. Mean length of walleye caught increased to 17.5 inches in 1992, but decreased to 14.9 inches in 1995, followed by an increase to 16.7 inches in 1997.

Creel census was not completed or expanded in 1998 and 1999. This occurred because of personnel problems and quality control of data collected. Exploitation rate was estimated by the ratio of marked to unmarked fish ≥17 examined by the creel clerk. These estimates ranged from 6% in 1986 to 28% the following year (Table 10). Over the 12-year period, exploitation rate averaged 16% with a median of 18%. Exploitation rate was not computed in 1995, because only 5 walleyes, ≥ 17 inches, were examined by the creel clerk and no recaptures were found. Exploitation rate in 1997 was estimated at 11% based on volunteer angler diary information as well as walleyes examined by the creel clerk. In April, 1997, 1,497 walleye were VI tagged. During the fishing season 105 walleye ≥ 18 inches were examined or reported in diaries, and of these

22 carried 1997 VI tags. Expansion of the creel survey data revealed an estimated 758 walleye ≥ 18 inches were harvested, thus exploitation rate was estimated at 11%. Exploitation rate of walleye less than 18 inches was unknown.

Table 10. Walleye harvest, number released, mean length harvested and exploitation rate at Rathbun Lake.

Year	Harvest	Released	Mean length (inches)	Exploitation rate ≥ 17 inches
1972	13,585		--	
1973	9,194		13.3	
1974	4,627		14.8	
1975	7,131		15.2	
1976	1,292		14.2	
1977	1,746		14.1	
1978	2,929		15.0	
1981	1,345		11.0	
1984	1,064		19.8	.12
1985	1,317	2,160	18.7	.11
1986	872	1,247	16.3	.06
1987	6,456	8,069	15.2	.28
1988	9,242	7,823	15.2	.24
1989	5,823	7,765	14.0	.22
1990	--	--	14.5	--
1991	2,223	9,686	15.0	.15
1992	5,142	1,136	17.5	.21
1993	1,167	10,276	16.9	.09
1994	5,213	33,824	16.1	.23
1995	845	11,325	14.9	--
1996	8,492	10,560	16.5	.07
1997	4,457	10,172	16.7	.11

Length distribution of walleye in the creel showed anglers harvested walleye when they reached 14-15 inches in length (Figure 6). This length was a self-imposed length limit and was apparent throughout the entire study. The creel clerk also inquired how many walleyes were released and the estimated lengths of these fish. The size distribution of released fish indicated 98.7% of the fish were < 13 inches. Number of released fish ranged from 1,136 in 1992 to 33,824 in 1994, most of which were yearling walleyes (Table 10) and most of these were inadvertently caught by crappie anglers in May-June.

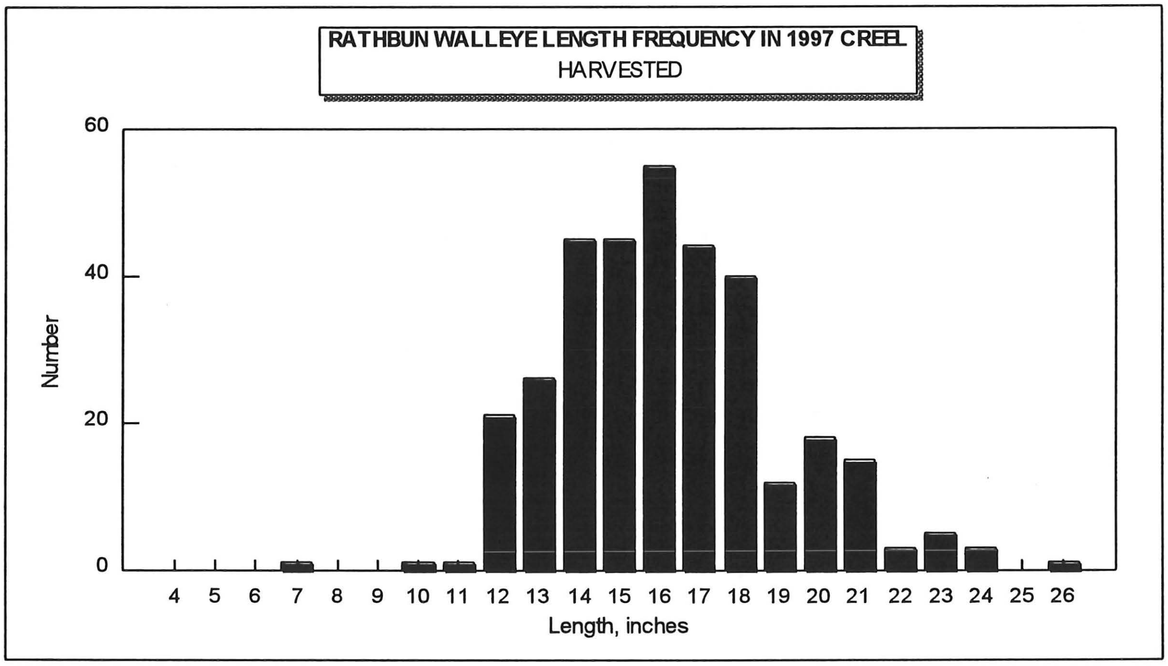

Figure 6. *Length frequency of harvested walleye at Rathbun Lake, 1997.*

Natural mortality rate of walleye greater than 18 inches was estimated from the function

$A = m + n - (m*n)$

where A is average annual mortality, males and females combined,

m is average annual fishing mortality and

n is average natural mortality.

Solving for n yielded a natural mortality rate of 29.2%.

DISCUSSION

The major cause of decreasing walleye abundance at Rathbun Lake during the early 1980's was lack of recruitment. More uniform and consistent stocking since 1984 resulted in an increase in walleye biomass (> 17 inches) from 0.94 lbs per acre in 1987 to 2.80 lbs per acre in 1989. Thus, the primary goal of tripling the walleye biomass at Rathbun Lake was attained with biomass stabilizing in 1992 at 3.77 lbs per acre.

Fry stocking was most influential in establishing strong year-classes at Rathbun Lake; these occurred in 1985, 1986, 1993 and 1995. Densities of these year classes in November were 9-27 fish per acre and fry stocking was responsible for 65-80% of the population. At the other extreme, fry stocking contributed as little as 30% to the year classes in 1984, 1988, 1990, and 1994, yielding only 2-3 young per acre in November.

An extensive 17-year fry stocking evaluation at Clear Lake by Carlander et al. (1960) and Payne (1975) showed similar year-to-year variation. Year-class abundance varied by a factor of 5 at Clear Lake as compared to the 13-fold difference found at Rathbun Lake. Although the Clear Lake study used relative abundance indices and did not estimate densities, the investigators concluded fry stocking strongly influenced year-class abundance.

Findings by Paragamian and Kingery (1992), McWilliams and Larscheid (1992) and Fielder (1992) showed low success of fry stocking; however, occasionally strong year classes were produced, similar to those produced at Rathbun Lake. Had fry not been stocked at Rathbun, the 1985, 1986, 1993 and 1995 year classes would have been sparse.

Assessment of fingerling stocked fish at Rathbun Lake focused on the differential overwinter mortality between fingerlings that originated from larval fish stocked into the lake, fish reared in tanks on dry pellet diets and fingerling fish reared in nursery lakes. Survival of tank-reared walleye was found to be superior to walleye reared in nursery lakes, 4 out of 5 years. Although some years nursery lake walleye mortality was 11 times greater than tank-reared or native (fry-stocked) walleye the average differential mortality over the course of the investigation was closer to 2:1. That is, overwinter mortality was twice as great for fingerlings raised in nursery lakes as compared to tank-reared fish. This greater mortality was probably due to the size and physiological well being of the fish at stocking. Mean length of tank-reared fish averaged 7.3 inches as opposed to an average length of 5.0 inches for conventionally reared walleye. In 1986, when differential mortality was greatest, the walleye produced in nursery lakes averaged 4.3 inches.

Another factor which may have influenced survival was pond harvest and hauling stress. Tank-reared fish required minimal handling and were stocked within an hour after being loaded on the distribution truck. Nursery lake fish, on the other hand, were seined, cribbed, loaded and hauled 300 miles. Hatchery personnel used every precaution to minimize stress, yet the harvest and transportation of these fish was probably more stressful than that experienced by tank-reared fish. Also, the physiological condition of tank-reared fish seemed to be more consistent than nursery pond fish.

Assessment of the differential success of fall- and spring-stocked fingerlings commenced in 1990. Fish in fall and spring were of identical size and stocked from the Rathbun Fish Hatchery. Six comparisons were made for the 1991-1995 and 1997 year classes. Of these comparisons, survival of fall stocked fish was better in 1992 and 1993. Survival of spring stocked fish was better in 1994, 1995 and 1997. In 1991, the hypothesis was not tested because of poor sample size. The poor performance of the 1994 fall stocking was probably due to the adverse conditions at the time of stocking. During the entire year in 1994, the water was 4-5 feet below normal conservation pool, with sparse forage available to these fingerlings at the time of stocking in October. Spring-stocked fish were released in mid-March when food would have been at its lowest during the year. However, by May, forage due to hatches of crappie and shad, would be available in large numbers. Economics of stocking walleye, in view of this differential mortality should be examined to provide direction for future walleye culture objectives. The least expensive fish to produce were sac fry at $0.40 per 1,000. Intensively reared fish cost about $410 per 1,000, while extensively reared nursery walleye averaged $280 per 1,000. Fingerling walleye produced from the fry stocking cost about $0.08 each in October, based on average mortality rates found in this study. Using the best overwinter estimates available and those generated by the GIFSIM model it was estimated that each live walleye the following spring would cost $0.22 each for fingerling originating as fry, $1.08 each for tank-reared fingerlings, and $1.50 each for nursery-reared fingerlings.

Fry stocking, if the supply were great enough, would be the most economical. However, success of walleye fry is highly variable from year-to-year and would not provide uniform year-classes if relied upon entirely. Although fingerlings raised in nursery lakes are less expensive to produce than intensively reared fish ($0.28 Vs $0.41 apiece), the higher overwinter mortality of nursery lake stock reversed the economics and by spring the price ascribed to intensively reared fish and an extensively reared fingerling walleye was $1.08 and $1.50, respectively. Production cost alone should not be the deciding factor in stocking intensively reared fish at Rathbun Lake. Such analysis, considering limitations of the hatchery system, demand for fingerlings and fry, economics and survivorship should help in guiding culture and fish management alternatives.

An important goal of this investigation was to increase walleye broodstock abundance, to produce egg quotas of 500 quarts consistently at Rathbun Hatchery. The objective of tripling the population was attained by accelerated and more uniform recruitment through stocking. This increase in available broodfish numbers has yielded an increase in spring broodfish netting success, but not proportional to population density. The quarts of eggs stripped have increased from a low of 235 in 1989 and 1990 to 594 quarts in 1998. The egg take in 1999 produced 600 quarts of eggs. This was the first time since 1986 that such a quantity of eggs were taken.

Harvest regulations on walleye at Rathbun Lake, if implemented, would provide little increase in walleye broodstock abundance or biomass. At the present level of exploitation, of about 25%, the broodstock population might be anticipated to increase by only 20% if a 14-inch minimum size limit were imposed (Mitzner 1994). This small increase would not justify regulation of the harvest.

RECOMMENDATIONS

Write a completion report for this investigation, including guidelines for walleye management with emphasis on cost:benefit of stocked walleye to the fishery and also the importance of walleye harvest to population characteristics. The report will be completed by 1 January, 2001.

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Appendix A. Mark and recapture records of 4,486 female walleye at Rathbun Lake. Fish were marked with Visual Implant Tags, 1990-98.

90	91	92	93	94	95	96	97	98	Frequency
1	1	1	0	0	0	0	0	0	4
1	1	0	1	1	1	0	0	0	2
1	1	0	1	0	0	0	0	0	7
1	1	0	0	1	0	0	0	0	1
1	1	0	0	0	1	0	0	0	1
1	1	0	0	0	0	1	1	0	1
1	1	0	0	0	0	1	0	0	2
1	1	0	0	0	0	0	0	1	1
1	1	0	0	0	0	0	0	0	48
1	0	1	1	0	0	0	0	0	2
1	0	1	0	0	0	0	0	0	10
1	0	0	1	1	0	0	0	0	1
1	0	0	1	0	0	1	0	0	1
1	0	0	1	0	0	0	0	0	6
1	0	0	0	1	1	1	0	0	1
1	0	0	0	1	0	0	1	0	1
1	0	0	0	1	0	0	0	0	4
1	0	0	0	0	1	0	1	0	1
1	0	0	0	0	0	1	0	0	1
1	0	0	0	0	0	0	0	0	337
	1	1	1	1	0	0	1	0	1
	1	1	1	0	1	0	0	0	1
	1	1	1	0	0	0	0	0	4
	1	1	0	1	0	1	0	0	2
	1	1	0	1	0	0	0	0	1
	1	1	0	0	1	1	0	0	1
	1	1	0	0	0	1	0	0	1
	1	1	0	0	0	0	0	0	34
	1	0	1	1	1	1	0	0	3
	1	0	1	1	1	0	0	0	1
	1	0	1	1	0	0	1	0	1
	1	0	1	1	0	0	0	0	7
	1	0	1	0	1	1	1	0	1
	1	0	1	0	1	0	0	0	3
	1	0	1	0	0	0	1	1	1
	1	0	1	0	0	0	0	0	24
	1	0	0	1	1	1	1	0	1
	1	0	0	1	1	1	0	0	1
	1	0	0	1	1	0	0	0	4
	1	0	0	1	0	1	0	0	3

Appendix A continued.

90	91	92	93	94	95	96	97	98	Frequency
	1	0	0	1	0	0	1	0	1
	1	0	0	1	0	0	0	0	16
	1	0	0	0	1	0	0	1	1
	1	0	0	0	1	0	0	0	5
	1	0	0	0	0	1	0	0	1
	1	0	0	0	0	0	0	0	578
		1	1	1	1	1	1	0	1
		1	1	1	1	1	0	1	1
		1	1	1	1	1	0	0	1
		1	1	1	1	0	1	1	1
		1	1	1	1	0	0	0	1
		1	1	1	0	0	0	0	4
		1	1	0	0	0	0	0	15
		1	0	1	1	1	0	0	2
		1	0	1	0	0	0	0	3
		1	0	0	1	0	0	0	4
		1	0	0	0	1	0	0	2
		1	0	0	0	0	1	0	1
		1	0	0	0	0	0	0	400
			1	1	1	1	0	0	4
			1	1	1	0	1	1	1
			1	1	1	0	1	0	2
			1	1	1	0	0	0	10
			1	1	0	1	1	1	1
			1	1	0	1	1	0	2
			1	1	0	1	0	1	1
			1	1	0	1	0	0	7
			1	1	0	0	1	1	1
			1	1	0	0	1	0	2
			1	1	0	0	0	1	5
			1	1	0	0	0	0	55
			1	0	1	1	0	1	4
			1	0	1	1	0	0	9
			1	0	1	0	1	0	2
			1	0	1	0	0	1	2
			1	0	1	0	0	0	30
			1	0	0	1	1	1	1
			1	0	0	1	1	0	7
			1	0	0	1	0	1	2
			1	0	0	1	0	0	10
			1	0	0	0	1	0	2
			1	0	0	0	0	1	3

Appendix A continued.

90	91	92	93	94	95	96	97	98	Frequency
			1	0	0	0	0	0	292
				1	1	1	1	1	2
				1	1	1	1	0	1
				1	1	1	0	1	5
				1	1	1	0	0	10
				1	1	0	1	1	1
				1	1	0	1	0	1
				1	1	0	0	1	4
				1	1	0	0	0	34
				1	0	1	1	0	4
				1	0	1	0	1	4
				1	0	1	0	0	28
				1	0	0	1	1	2
				1	0	0	1	0	5
				1	0	0	0	1	7
				1	0	0	0	0	377
					1	1	1	1	1
					1	1	1	0	6
					1	1	0	1	7
					1	1	0	0	27
					1	0	1	1	5
					1	0	1	0	7
					1	0	0	1	17
					1	0	0	0	197
						1	1	1	22
						1	1	0	41
						1	0	1	32
						1	0	0	585
							1	1	88
							1	0	455
								1	491
Total	35	24	48	54	47	45	37	30	4486

Appendix B. Mark and recapture records of 4,990 male walleye at Rathbun Lake. Fish were marked with Visual Implant Tags, 1990-98.

90	91	92	93	94	95	96	97	98	Frequency
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	1	0	0	0	3
1	1	1	1	1	0	1	1	1	1
1	1	1	1	1	0	0	0	0	4
1	1	1	1	0	0	0	0	0	10
1	1	1	0	1	1	1	1	0	1
1	1	1	0	1	1	0	0	1	1
1	1	1	0	1	1	0	0	0	1
1	1	1	0	1	0	0	0	0	1
1	1	1	0	0	0	0	0	0	14
1	1	0	1	1	1	1	0	0	1
1	1	0	1	1	1	0	0	0	1
1	1	0	1	1	0	0	0	0	2
1	1	0	1	0	1	1	1	0	1
1	1	0	1	0	1	0	0	0	1
1	1	0	1	0	0	0	0	0	3
1	1	0	0	1	1	1	1	1	1
1	1	0	0	1	1	0	1	1	1
1	1	0	0	1	1	0	0	0	1
1	1	0	0	0	0	0	0	0	31
1	0	1	1	0	0	0	0	0	2
1	0	1	0	1	1	1	0	0	1
1	0	1	0	1	0	0	0	0	2
1	0	0	1	1	0	1	0	1	1
1	0	0	1	1	0	0	0	0	1
1	0	0	0	0	0	0	0	0	218
	1	1	1	1	1	1	1	1	3
	1	1	1	1	1	1	1	0	5
	1	1	1	1	1	1	0	0	6
	1	1	1	1	1	0	1	0	3
	1	1	1	1	1	0	0	1	1
	1	1	1	1	1	0	0	0	10
	1	1	1	1	0	1	1	1	1
	1	1	1	1	0	1	0	0	2
	1	1	1	1	0	0	0	0	14
	1	1	1	0	1	1	0	0	2
	1	1	1	0	1	0	0	0	1
	1	1	1	0	0	0	0	0	31
	1	1	0	1	1	0	0	1	1
	1	1	0	1	0	0	1	1	1

Appendix B continued.

90	91	92	93	94	95	96	97	98	Frequency
	1	1	0	1	0	0	0	0	7
	1	1	0	0	1	0	0	0	1
	1	1	0	0	0	0	0	0	90
	1	0	1	1	1	1	1	1	1
	1	0	1	1	1	1	1	0	1
	1	0	1	1	1	1	0	1	1
	1	0	1	1	1	1	0	0	4
	1	0	1	1	1	0	0	0	5
	1	0	1	1	0	1	1	0	1
	1	0	1	1	0	0	0	1	1
	1	0	1	1	0	0	0	0	7
	1	0	1	0	1	1	0	0	1
	1	0	1	0	0	0	0	0	11
	1	0	0	1	1	1	1	0	2
	1	0	0	1	1	1	0	0	1
	1	0	0	1	0	0	0	0	3
	1	0	0	0	1	1	0	0	2
	1	0	0	0	0	0	0	0	345
		1	1	1	1	1	1	1	3
		1	1	1	1	1	1	0	2
		1	1	1	1	1	0	1	2
		1	1	1	1	1	0	0	5
		1	1	1	1	0	1	0	1
		1	1	1	1	0	0	0	8
		1	1	1	0	1	1	0	2
		1	1	1	0	1	0	0	3
		1	1	1	0	0	1	1	1
		1	1	1	0	0	1	0	1
		1	1	1	0	0	0	0	24
		1	1	0	1	1	0	1	1
		1	1	0	1	0	0	1	1
		1	1	0	1	0	0	0	1
		1	1	0	0	1	0	0	1
		1	1	0	0	0	0	0	37
		1	0	1	1	1	0	0	1
		1	0	1	1	0	0	0	2
		1	0	1	0	1	0	0	3
		1	0	1	0	0	0	0	13
		1	0	0	1	1	0	1	1
		1	0	0	1	0	0	0	2
		1	0	0	0	1	0	0	4
		1	0	0	0	0	1	1	1

Appendix B continued.

90	91	92	93	94	95	96	97	98	Frequency
		1	0	0	0	0	0	0	374
			1	1	1	1	1	1	9
			1	1	1	1	1	0	4
			1	1	1	1	0	0	5
			1	1	1	0	1	1	3
			1	1	1	0	1	0	3
			1	1	1	0	0	1	3
			1	1	1	0	0	0	42
			1	1	0	1	1	0	2
			1	1	0	1	0	1	1
			1	1	0	1	0	0	2
			1	1	0	0	0	1	3
			1	1	0	0	0	0	91
			1	0	1	1	1	1	3
			1	0	1	1	1	0	1
			1	0	1	1	0	1	1
			1	0	1	1	0	0	5
			1	0	1	0	1	1	1
			1	0	1	0	1	0	1
			1	0	1	0	0	1	2
			1	0	1	0	0	0	19
			1	0	0	1	1	1	1
			1	0	0	1	0	0	7
			1	0	0	0	1	1	3
			1	0	0	0	1	0	1
			1	0	0	0	0	1	1
			1	0	0	0	0	0	317
				1	1	1	1	1	9
				1	1	1	1	0	9
				1	1	1	0	1	5
				1	1	1	0	0	17
				1	1	0	1	1	1
				1	1	0	1	0	5
				1	1	0	0	1	2
				1	1	0	0	0	31
				1	0	1	1	1	1
				1	0	1	1	0	1
				1	0	1	0	1	3
				1	0	1	0	0	5
				1	0	0	1	0	9
				1	0	0	0	1	2
				1	0	0	0	0	276

Appendix B continued.

90	91	92	93	94	95	96	97	98	Frequency
					1	1	1	1	14
					1	1	1	0	26
					1	1	0	1	4
					1	1	0	0	35
					1	0	1	1	10
					1	0	1	0	12
					1	0	0	1	5
					1	0	0	0	203
						1	1	1	85
						1	1	0	129
						1	0	1	35
						1	0	0	621
							1	1	244
							1	0	704
								1	592
Total	143	147	171	177	171	158	146	146	4990

STUDY 7008

Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations

OBJECTIVE

To determine the importance of lake watershed, lake basin morphology, water quality, predator populations and angling upon the well-being of crappie and bluegill populations in man-made impoundments < 500 acres.

JOB 1

Population characteristics of bluegill, crappie and largemouth bass

OBJECTIVE

To measure density, size structure, growth, body condition, harvest and exploitation rates of bluegill, crappie and largemouth bass at selected Iowa man-made lakes.

JOB 2

Physical and chemical components of the ecosystem that may affect bluegill and crappie populations

OBJECTIVE

To determine the impact of watershed, lake morphology and water quality upon bluegill and crappie density, size structure, growth rate and body condition.

JOB 3

Impact of angler harvest and largemouth bass predation on bluegill and crappie populations

OBJECTIVE

To determine the impact of angler exploitation and largemouth bass density and size structure upon bluegill and crappie density, size structure, growth rate and body condition.

JOB 4

Statewide database statistics on bluegill and crappie

OBJECTIVE

To enter findings from study lakes of this investigation into the statewide database of fisheries statistics.

ANNUAL REPORT
RESEARCH PROJECT SEGMENT

STATE: Iowa **TITLE:** Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations

JOB NO.: 1, 2, 3, and 4

ABSTRACT

Quality crappie and bluegill populations at 21 study lakes were related to populations of predator fish, lake morphometry, water quality, angler harvest and watershed size, land use and nutrient loading. This was accomplished by measuring those factors most responsible for creating quality panfish angling in Iowa man-made lakes. Indices of well-being were developed for bluegill, largemouth bass and crappie and were based upon body condition, growth and size structure. Analytical comparisons by multivariate statistics showed the quality of largemouth bass populations were not significantly related to quality of bluegill or crappie populations. Lake shape was, however, closely related to the well-being of bluegill populations. Deep lakes with high mean basin slopes were associated with bluegill populations characterized by above average growth, body condition and good size distribution. These bluegill characteristics were also associated with small watershed:lake area ratios. Correlation showed 51% of the variability in bluegill well-being indices were accounted for by lake shape. Crappie well-being indices were positively associated with small watershed to lake area ratio, phosphorous concentration, and water clarity, large, deep lakes and small watershed to lake area ratios. Water quality, as measured by Carlson's Trophic State Index, was adversely impacted by watershed size and watershed:lake area ratios. Correlation showed 12% of the variability in water quality was accounted for by watershed characteristics. The most important parameters affecting water quality, however, were high mean basin slope and mean depth which accounted for 67% of the variability in water quality. Analysis of angler harvest and effort showed largemouth bass population characteristics were impacted by anglers; however, the quality of bluegill and crappie populations were not affected by angling. Agricultural Nonpoint Source Pollution (AGNPS) modeling showed fish well-being indices with the lowest rankings had the highest watershed sediment and nutrient loading coefficients.

INTRODUCTION

Crappie and bluegill are the most often caught fish in Iowa and comprised 46% of the 1994 statewide harvest as estimated by a telephone survey (University Northern Iowa 1995). Popularity of these panfish also ranked high, outranked only by channel catfish, largemouth bass and walleye. Statewide, 20% of the licensed Iowa anglers preferred catching bluegill or crappie. Estimated harvest in 1994 was nearly 19 million fish, and panfish comprised about 50% of the harvest in southern Iowa. It is common for crappie or bluegill to comprise 85% of the fish harvested by anglers from man-made lakes (Mitzner, 1978 and 1981).

The great popularity of panfish, and dominance of crappie and bluegill in the sportfish harvest are largely due to the health and vigor of these populations in Iowa's waters. Some lakes produce quality angling with very little cost and effort, while other lakes produce fish lacking angler appeal, regardless of liberal and costly application of traditional fisheries management techniques. The purpose of this investigation is to identify and delineate those factors responsible for such disparity in panfish populations, measure the magnitude of these influences, and provide information necessary to predict the quality of bluegill and crappie fishing provided by a variety of Iowa lakes. The study is also designed to assess and predict impacts of a variety of management strategies on the quality of these fisheries.

Previous investigations provided the impetus for this investigation; foremost of these was work done by Hill (1991). He found lakes, which contained the most angler acceptable fish, were steep-sided and subjected to very little siltation. Buck (1956), Gardener (1981) and Mitzner (1991) also delineated the impact of physical factors upon the well being of bluegill and crappie populations. Factors described by these authors included water level, temperature, turbidity, wind and substrate.

Biotic factors affecting bluegill and crappie populations as reported in the literature include available food supply and density of predator fish. Control of overabundant panfish populations by stocking predators was reported by Snow (1968), Jahn et al. (1987), Gablehouse (1984a), Boxrucker (1987), Savino and Stein (1982), and Hill (1981). Mechanical removal of bluegills and crappies to reduce densities and improve growth of remaining fish was marginally successful, but at least 50% of the population biomass must be removed, and results were short-lived Beyerle and Williams (1972) and Houser and Grinstead (1961). Rutledge and Baron (1972) provided a comprehensive bibliography on the subject of fish removal along with a case history study on white crappies.

Another biotic factor addressed by Coble (1988) is the impact of angling on bluegill populations. He reported that exploitation rates in excess of 27% would substantially alter the total mortality rate and size structure of bluegill populations. Colvin (1985) outlined the Missouri crappie management program of harvest restrictions, using both size and take limits. Other authors, however, showed harvest restrictions on bluegills and crappies were not needed or were counter-productive, Snow (1982), Schneider (1973) and Partriarche (1968).

The problem of slow growing and unappealing bluegill and crappie populations in Iowa lakes is a major concern of anglers and resource managers. A major focus of this investigation will be the physical shape of the lake basin, water quality and lake watershed characteristics. These factors, along with influences of anglers and predator populations, will be related to the well being of bluegill and crappie populations. The information obtained will expand our efforts beyond traditional fisheries management activities and help managers address important ecological factors that limit angling opportunity for quality bluegill and crappie.

METHODS

This research follows several lines of investigation. First, a minimum of 20 lakes will be studied, 1990-1998. Lakes included in the sample will represent the range of ecological conditions found associated with Iowa's man-made lakes. The physical, chemical and biological characteristics of each study lake and lake watershed will be examined, particularly the relationships between fish well being, lake watersheds, lake morphology, angler harvest and water quality. Nine district managers provided basic fisheries information from 11 lakes. These included Viking, Slip Bluff, Mariposa, Hawthorn, Lacey-Keosauqua, Pollmiller, Iowa, Yellow Smoke, Smith, Union Grove, and Pahoja. Research staff obtained fisheries information for the following lakes: Ahquabi, Anita, Miami, Nine Eagles, Red Haw, Bob White, Green Valley, Keomah, Prairie Rose, Williamson Pond, and Swan.

Fish Populations

Population density and biomass of bluegill, crappie, and largemouth bass were estimated by sequential mark and recapture efforts conducted May through June. The exception was Swan, Anita, Nine Eagles, Ahquabi and Prairie Rose Lakes, where crappie abundance was estimated in September. Fish were sampled, finclipped, and released for subsequent recapture. A combination of electrofishing gear and fyke nets was used to sample fish.

Age, growth, size structure, and weight-length statistics were derived from monthly samples. Otoliths were taken from fish at lakes with stunted or slow-growing populations while scale samples were taken from fish at the remaining lakes. Growth calculations were performed with DisBcal (Frie 1982), while relative weight was based on standards by Newmann and Murphy (1992). Size structure was described by the relative stock density (RSD) incremental method (Gablehouse 1984b). The three size categories used in this investigation included stock, quality and preferred, and each category was a percent of the whole sample. The method required that the three categories equal 100%.

Harvest statistics were estimated from stratified random creel survey methods conducted mid April through mid October. Effort was a function of hourly instantaneous counts, length of fishing day, and number of days per month. Total sportfish harvest was estimated as the product of catch per hour and total effort during the period. The anglers sampled in the surveys were stratified by weekend/weekday and boat/shore. Further, the fishing day was divided equally into two parts, early and late, with independent expansion for each segment.

Lake Morphology and Water Quality

Lake basin shapes and other physical characteristics of the lakes were derived from measurements and calculations made by Bachmann et al. (1994). Characteristics included area, length of shoreline, maximum depth, mean depth, volume, shoreline development, watershed/lake area ratio, mean basin slope, and volume development. Equations to calculate these indices were given by Hutchinson (1975).

Lake water quality was measured at each lake 3 times during the summer, May through August. Parameters determined for the upper 10 feet of the water column included field measurement of turbidity (Secchi disc depth), temperature, and dissolved oxygen, and laboratory analysis of chlorophyll *a*, total suspended solids, total phosphorous, and total nitrogen according to APHA, AWNA, WPCF, (1976) standards.

Watershed Characteristics

Watersheds are being assessed with a PC-based Agricultural Nonpoint Source Pollution (AGNPS) Model, which requires the following information:

curve number
slope shape factor
field slope length
channel slope
channel sideslope
soil erodibility factor
cover and management factor
support practice factor
surface condition constant
aspect, direction of drainage
soil texture
fertilization level
fertilization availability factor
point source level
gully source level
chemical oxygen demand factor
impoundment factor
channel indicator

Each watershed was divided into 10-acre or 40-acre units and the above parameters were described for each of the units. Information was obtained and digitized from soil maps, USGS maps, and SCS photos. Ground observations were also used to obtain additional information needed in our assessment.

STUDY AREAS

Each of the study lakes contained the following target species: bluegill, crappie, and largemouth bass. These lakes also contained channel catfish, green sunfish, and bullhead. In addition, some of the lakes contained common carp and/or grass carp. Table 1 shows the locations and characteristics of each lake examined through 1998.

Table 1. Physical characteristics of 22 study lakes.

Lake	Area Acres	Maximum depth (ft)	Mean depth (ft)	Mean Basin Slope	Volume ac-ft	Shoreline Development	Volume Development	Watershed Lake area ratio
Ahquabi	109	17.5	8.2	2.5	889	9.221	1.42	30.6
Anita	182	28	12	5.7	2,227	4.05	1.31	13.2
Bob White	89	14	5	2.7	444	2.97	1.07	38.2
Green Valley	337	24	10	3.4	3,574	3.73	1.38	12.5
Hawthorn[1]	172	32	12	5.4	2,267	3.4	1.13	19.4
Iowa[1]	86	32	12	4.3	987	2.12	1.12	15.5
Keomah	84	22	10	4.0	846	2.91	1.37	22.1
Lacey-Keo[1]	21	28	12	11.3	258	1.98	1.26	34.4
Mariposa[1]	18	16	7	5.2	135	1.53	1.35	31
Miami	135	24	10	5.5	1,336	3.29	1.19	28.9
Nine Eagles	63	32	14	7.6	863	2.3	1.29	19
Pahoja[1]	63	30	11	2.5	673	2.98	1.04	62.5
Pollmiller[1]	18	30	12	8	213	2.63	1.19	13.1
Prairie Rose	219	24	10	5.1	2,083	3.04	0.82	21
Red Haw	64	40	14	10	948	3.48	1.08	14
Slip Bluff[1]	16	24	12	12.4	198	2.29	1.55	14.4
Smith[1]	59	10	5	2.3	315	1.82	1.6	18.6
Swan	112	14	6	2.2	643	1.78	1.19	6.1
Union Grove[1]	105	16	8	2.3	788	1.92	1.6	63.2
Viking[1]	137	48	15	8.6	2,059	3.51	0.94	15.6
Williamson Pond	30	18	8	5.5	237	2.06	1.37	46.8
Yellow Smoke[1]	39	26	11	6.2	325	3.56	1.3	39.9

[1] sampled by Fisheries Management personnel.

FINDINGS

Fish Populations

<u>Abundance and Biomass</u> Population estimates were completed at 11 study lakes since 1990. The highest density of bluegills was found at Lake Ahquabi, 1998, with an estimated 2,391 fish per acre. The greatest biomass occurred at Ahquabi, estimated at 354 lbs per acre in 1997 (Table 2). Lowest bluegill abundance was measured at Green Valley, 1996, at 27 per acre. Low biomass estimates occurred at Green Valley (1996), Red Haw, Keomah, and Williamson with values < 40 lbs per acre. Average density and biomass estimates for the study lakes were 640 fish per acre and 106 lbs per acre.

Table 2. Population and biomass estimates of bluegills (≥4 in), crappies (≥5 in) and largemouth bass (≥8 in) at 11 study lakes.

Lake	Year	Bluegill N/ac	 lbs/ac	Crappies N/ac	 lbs/ac	Largemouth Bass N/ac	 lbs/ac
Ahquabi	1997	2,373	354	102	22	148	110
Ahquabi	1998	2,391	317	51	27	21	9
Anita	1992	356	86	71	20	35	42
Bobwhite	1992	679	129	--	--	27	22
Green Valley	1993	257	62	63	23	14	25
Green Valley	1996	27	6	318	71	11	28
Keomah	1994	106	31	--	--	38	22
Miami	1991	589	129	359	94	19	14
Miami	1995	224	71	93	37	20	12
Nine Eagles	1992	209	70	217	23	55	58
Prairie Rose	1994	496	72	1,105	293	17	17
Red Haw	1990	75	39	--	--	58	32
Red Haw	1997	71	32	11	9	42	36
Swan	1990	758	153	79	36	54	68
Swan	1991	1,164	122	30	12	49	55
Swan	1992	1,083	88	9	2	22	53
Swan	1993	799	91	2,557	297	40	58
Swan	1994	575	103	1,847	312	17	29
Swan	1995	466	119	1,792	360	15	21
Swan	1996	802	98	1,053	326	9	8
Williamson	1991	180	37	372	73	8	3
Williamson	1997	391	114	550	175	22	16
Average		640	106	562	116	34	34

Crappie density was greatest at Swan Lake during 1993, 1994, 1995, and 1996 with an estimated 1,053 to 2,557 per acre. Crappie were nearly nonexistent at Red Haw (1990), Keomah and Bobwhite Lakes. Biomass estimates were near 300 lbs per acre at Swan during 1993, 1994, 1995, 1996, and Prairie Rose during 1994. Average density and biomass estimates were 590 fish per acre and 102 lbs of crappie per acre.

Largemouth bass density was about 50 per acre at Red Haw Lake (1990), Nine Eagles Lake (1992) and Swan Lake, (1990 and 1991). Greatest density occurred at Ahquabi Lake in 1997 at 148 per acre. Lowest density was 8 per acre, estimated at Williamson Pond. Greatest largemouth bass biomass was 110 lbs per acre and occurred at Lake Ahquabi during 1997, while lowest biomass of 3 lbs per acre occurred at Williamson Pond. Average largemouth bass density and biomass for the study lakes was 34 fish per acre and 34 lbs per acre.

Growth Bluegill, largemouth bass and crappie growth statistics were described using the Walford plot as shown in Figure 1. Length at age t was plotted against length at age t + 1. The example in Figure 1 is for Lacey-Keosauqua bluegill with mean back-calculated lengths for age 1-7 of 2.60, 4.17, 5.28, 6.18, 7.40, 8.11 and 8.58 inches. Slope of the Walford line was 0.83 with an intercept of 1.95 inches and an R^2-value of 0.98. From this information the L (MAX)-value was calculated at 11.5 inches. This value is where the growth equation intersects the Y=X line.

This process was used to calculate growth statistics for the target species at all the study lakes (Table 3). Slope of growth curves for bluegills ranged from 0.44 at Williamson Pond to 0.83 at Lacey-Keosauqua. Length at maximum growth (L (MAX)) for bluegills ranged from 6.4 inches at Williamson Pond to 11.5 inches at Lacey-Keosauqua. Average for 21 study lakes was 8.7.

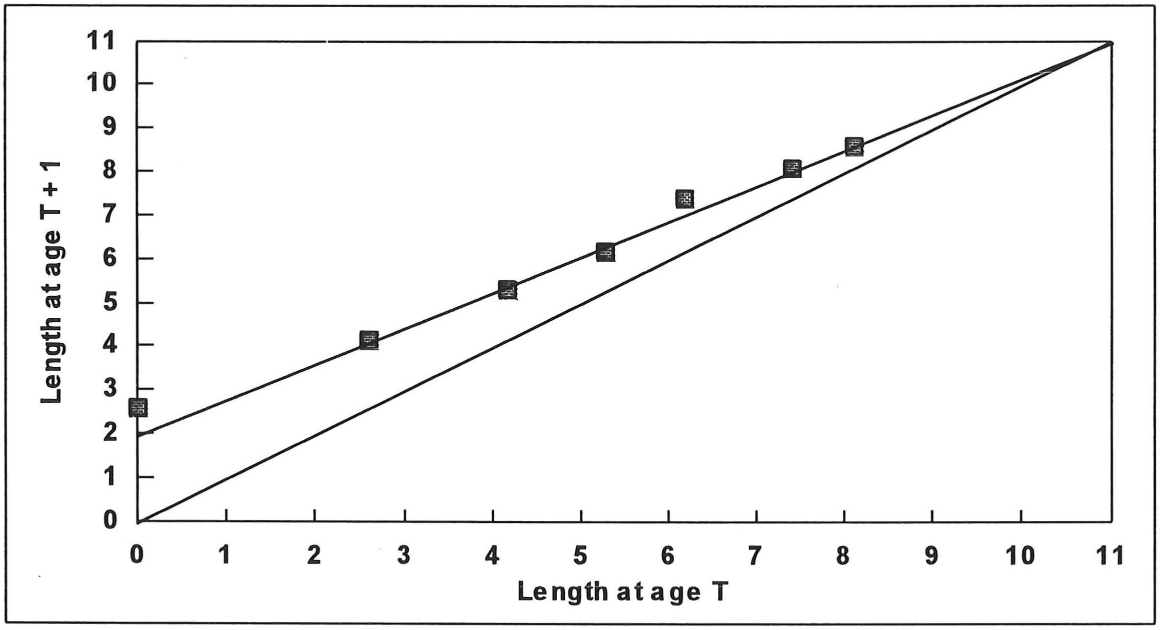

Figure 1. *Walford graph of bluegill growth at Lacey-Keosauqua Lake.*

Table 3. Walford growth statistics for bluegills, largemouth bass and crappie where B is slope of the Walford graph and L (MAX) is the average asymptotic length, in inches, fish can attain.

	Bluegills		Largemouth Bass		Black Crappies		White Crappies	
Lake	B	L(MAX)	B	L(MAX)	B	L(MAX)	B	L(MAX)
Anita	0.69	10	0.82	24.4	0.81	22.7	--	--
Bobwhite	0.69	7.8	0.73	17	--	--	--	--
Green Valley	0.55	7.9	0.83	25.2	0.59	9.5	--	--
Hawthorn	0.77	9.2	0.72	17.5	0.47	10.9	--	--
Iowa	0.64	8.2	0.77	21.9	--	--	0.59	10.6
Keomah	0.56	8.3	0.85	21.3	--	--	--	--
Lacey-Keosauqua	0.83	11.5	0.65	14.4	--	--	--	--
Mariposa	0.81	10.1	0.86	27.4	0.75	15.4	--	--
Miami	0.68	8.2	0.80	19.1	0.67	11.9	0.69	13.7
Nine Eagles	0.65	8.2	0.69	14.8	0.69	11.3	--	--
Pahoja	0.68	8.5	0.73	18.3	a	a	--	--
Pollmiller	0.74	11.2	0.82	17.2	--	--	--	--
Prairie Rose	0.59	8.2	0.81	22.8	0.67	10.5	--	--
Red Haw	0.7	9.8	0.73	15.5	0.62	11.4	--	--
Slip Bluff	0.56	6.5	0.65	15.1	0.63	8.3	0.86	24.5
Smith	0.6	8.1	0.82	24.4	--	--	a	a
Swan 1991	0.74	10	0.92	24.3	0.55	11.2	--	--
Swan 1995	0.55	7.3	0.86	27.9				
Union Grove	0.74	8.9	0.84	22.5	0.52	8.6	--	--
Viking	0.7	7.9	0.76	20.9	a	a	--	--
Williamson Pond	0.44	6.4	0.72	22.7	0.48	8.8	a	a
Yellow Smoke	0.54	9.6	0.50	13.5	--	--	--	--

[a]inadequate sample size.

Slope of growth curves for largemouth bass ranged from 0.50 at Yellow Smoke Lake to $\geq$0.85 at Keomah, Swan and Mariposa Lakes. The growth parameter, L (MAX), ranged from 13.5 inches at Yellow Smoke Lake to > 25.2 inches at Green Valley, Mariposa, and Swan Lakes. Average L (MAX) for largemouth bass at the study lakes was 19.4 inches.

Black crappie growth characteristics yielded slopes that ranged from 0.47 at Hawthorn Lake to 0.81 at Lake Anita, the average was 0.59. Length at maximum growth (L (MAX)) ranged from 8.3 inches at Slip Bluff Lake to 22.7 inches at Lake Anita; average was 11.2 inches. Growth statistics were represented by only 3 white crappie populations (Table 3).

Condition Body condition was determined for bluegill and largemouth bass at 22 study lakes, and crappie at 19 study lakes (Appendix A). Average W_r-values for bluegills ranged from 81 at Mariposa Lake in 1996 to 125 at Yellow Smoke Lake in 1995. Standard deviations were about 15, but ranged from 8 to 22, while the average relative weight for bluegill was 100.

Body condition of largemouth bass ranged from 80 at Red Haw Lake in 1994 to 119 at Yellow Smoke in 1998. Average relative weight for largemouth bass was 99 with a standard deviation of 7 to 13.

Relative weight (W_r) of black crappie ranged from 81 at Keomah, 1995, Nine Eagles Lake, 1989 and 1995, Slip Bluff Lake, 1994, and Williamson Pond, 1991, to 115 at Smith in 1995. Standard deviations of relative weight ranged from 5-16 with a median of 10. White crappie W_r's ranged from 74 at Lake Ahquabi in 1997, to 116 at Smith Lake in 1997. Average W_r for black and white crappies was 95 and 92.

Size structures Size structures of bluegill populations are shown in Appendix B. Relative stock density (RSD-stock 3-6 inches) ranged from 0% at Red Haw Lake 1995, to 100% at Yellow Smoke Lake, 1996. The average was 51% and standard deviation was 24%. Quality sized bluegills (6-8 inches) ranged from 0% at Yellow Smoke Lake, 1996, to 90% at Miami Lake, 1991. Average quality size was 42% with a standard deviation of 24%. Larger bluegills in the preferred category (8-10 inches) ranged from an RSD of 0% at many lakes to 87% at Red Haw, 1995. Relative stock density, preferred, was 6% for 21 study lakes.

Size structure of largemouth bass populations was more variable than that of bluegill populations. For example, RSD-stock (8-12 inches) ranged from 4% at Swan Lake, 1990, to 96% at Hawthorn Lake, 1994, and Lacey-Keosauqua Lake, 1993 (Appendix C). Overall average for this size class was 48% with a standard deviation of 24%. Intermediate largemouth bass, RSD-Quality (12-15 inches), ranged from 1% at Williamson Pond, 1991, to 90% at Yellow Smoke Lake, 1997. The average RSD values for these bass were 39% with a standard deviation of 20%. Bass larger than 15 inches had an RSD-preferred range of 0% for 16 populations to 48% for the population at Smith Lake, 1993. The average RSD-preferred for all lakes was 14% with a standard deviation of 13%.

Crappie size structure is shown in Appendix D. The RSD-stock (5-8 inches) ranged from 0% at Swan Lake, 1990, and Red Haw, 1995 to 100% at the Swan Lake, 1993 and Mariposa, 1996. The average for this size group was 49% with a standard deviation of 27%. RSD-quality (8-10 inch) crappie ranged from 0% at Swan, 1993, Hawthorn, 1994, Smith Lake, 1992 and Mariposa, 1996 to 100% at Williamson Pond, 1997. The average RSD-quality was 41% with a standard deviation of 28%. Larger crappie in the RSD-preferred range (10-12 inches) were nonexistent in 57 samples to 96% at Red Haw Lake, 1995. Average and standard deviation for this length group of crappies were 9%.

Well-being Index and Model Development An index of fish population well-being was developed and based upon three parameters, growth, body condition, and size structure. These indices were developed for bluegills, largemouth bass, and crappie. Each species was rated according to the following criteria:

Growth: L(MAX) - values (inches)

Bluegill		Largemouth Bass		Crappie	
Value	Points	Value	Points	Value	Points
6-6.9	1	13-14.9	1	8-9.9	1
7-7.9	2	15-16.9	2	10-11.9	2
8-8.9	3	17-18.9	3	12-13.9	3
9-9.9	4	19-20.9	4	14-15.9	4
≥10	5	≥21	5	≥16	5

Body Condition: W_r-values

Bluegill		Largemouth Bass		Crappie	
Value	Points	Value	Points	Value	Points
<93	1	<93	1	<85	1
93-95	2	93-95	2	96-95	2
96-99	3	96-99	3	96-100	3
100-109	4	100-109	4	101-110	4
>109	5	>109	5	>110	5

Bluegills, size structure, RSD-values

Stock (3-6)	Points	Quality (6-8)	Points	Preferred (8-10)	Points
<10	0	≤5	1	0	0
11-20	1	6-15	3	1	1
21-30	3	16-25	5	2	3
31-40	5	26-35	7	3	5
41-50	7	36-45	10	4	7
51-60	10	46-55	7	≥5	10
61-70	7	56-75	5		
71-80	5	76-95	3		
81-90	3	96-100	1		
91-100	1				

LM bass size structure, RSD-values

Stock (8-12)	Points	Quality (12-15)	Points	Preferred (15-20)	Points
0-15	0	0-5	1	0	0
16-25	1	6-15	3	1	1
26-35	3	16-25	5	2	3
36-45	5	26-35	7	3	5
46-55	7	36-45	10	4	7
56-65	10	46-55	7	≥5	10
66-75	7	56-75	5		
76-85	5	76-95	3		
86-95	3	96-100	1		
96-100	1				

Crappie size structure, RSD-values

Stock (5-8)	Points	Quality (8-10)	Points	Preferred (10+)	Points
0-10	0	1-10	0	0-2	0
11-20	1	11-20	1	3-4	1
21-30	3	21-30	3	5-6	3
31-40	5	31-40	5	7-8	5
41-50	7	41-50	7	9-10	7
51-60	10	51-60	10	≥11	10
61-70	7	61-70	7		
71-80	5	71-80	5		
81-90	3	81-90	3		
91-100	1	91-100	1		

Points for size structure were summed and divided by 3, so that maximum points awarded for size structure was 10. Maximum points for growth and body condition was 5 for each category. Scores for each of the parameters (size, growth and condition) were then summed, and the maximum possible point value was 20. This raw score was then divided by 4 to yield a final rating score of 1-5, one being poorest and five being best.

An example of the mechanics of this system is provided by the 1992 data for Lake Anita bluegills. Average body condition was 94, thus 2 points were given. Measurement of growth in terms of L (MAX) was 10 inches; thus, 5 points were given. RSD-values for stock, quality, and preferred categories were 64, 22, and 14; thus, points awarded were 7, 5 and 10 and the average was 7.33. Adding the later to growth and body condition points yielded 14.33 points. The final rating was obtained by dividing the score by 4. Therefore, the well-being index of bluegills at Lake Anita in 1992 was 3.6, somewhat above average.

This system was then used to award points and ratings for all the populations at all the lakes (Appendix E). Bluegill populations which were consistently over the mean of a 3.0 rating were Anita, Hawthorn, Lacey-Keosauqua, Nine Eagles, Prairie Rose, Red Haw, Swan, Union Grove and Viking Lakes.

Largemouth bass populations with ratings consistently over 3.0 were Ahquabi, Anita, Green Valley, Iowa, Keomah, Mariposa, Pahoja, Prairie Rose, Smith, Swan, Union Grove and Viking Lakes. One method of comparing these lakes was the graphic representation of the bluegill and largemouth bass ratings shown in Figure 2. Lake Anita rankings for bass and bluegill fell in the upper right quadrant, while Red Haw rankings were in the lower right quadrant. Bluegill populations ranked low for Green Valley and Slip Bluff; however, bass populations were above average at Green Valley, but low at Slip Bluff. The remaining 16 study lake ratings for bass and bluegill were less well defined, with values plotted in at least two quadrants.

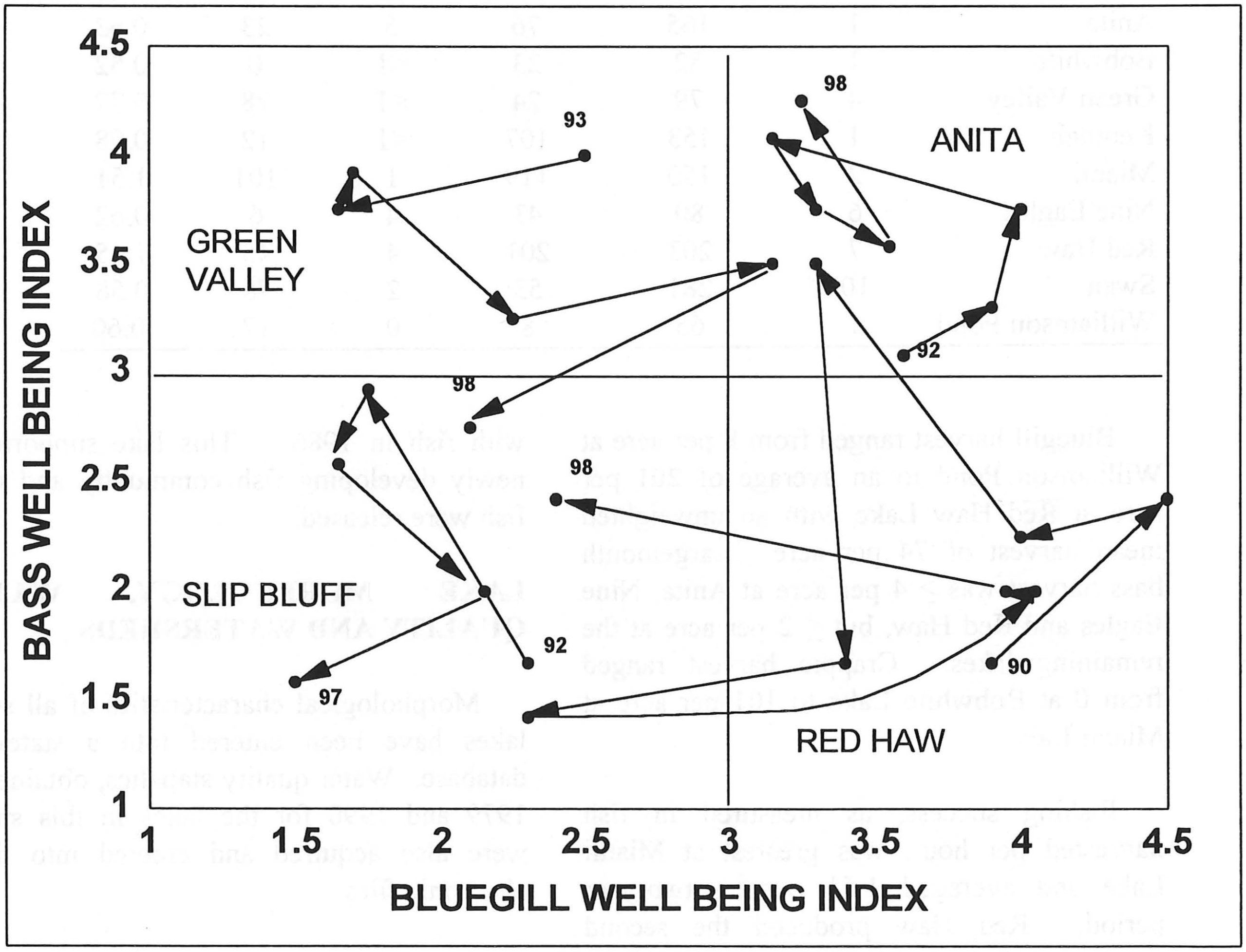

Figure 2. *Annual relationships between bluegill and largemouth bass well-being indices at 4 study lakes. A rating of one indicates a poor quality fishery and a rating of five suggests the fishery is in excellent condition.*

Crappie population ratings were much more variable than those were for bass and bluegill. Crappie ratings ranged from 0.83 at Green Valley Lake, 1994, Miami Lake, 1994, and Hawthorn Lake, 1994 to 3.67 at Lake Anita, 1993. Average black crappie rating was 1.9, while average white crappie rating was 2.1.

Sportfish Harvest Harvest statistics were available from 34 creel surveys conducted on 10 study lakes (Table 4). Annual fishing effort ranged from 52 hours/acre at Bobwhite Lake to an average of 281 hours/acre at Swan Lake, while the average angling effort for the 10 study lakes was 146 hours/acre.

Table 4. A summary of sportfish harvest surveys conducted at 10 study lakes.

Lake	Number Surveys	Average Effort Hrs/Ac	Bluegill N/Ac	Bass N/Ac	Crappie N/Ac	Harvest Fish/Hr
Ahquabi	2	238	76	0	17	0.45
Anita	1	165	76	5	23	0.63
Bobwhite	1	52	23	<1	0	0.52
Green Valley	4	79	24	<1	28	0.77
Keomah	1	153	107	<1	12	0.98
Miami	2	150	119	1	101	1.51
Nine Eagles	6	80	43	4	6	0.62
Red Haw	7	203	201	4	45	1.45
Swan	10	281	53	2	75	0.58
Williamson Pond	1	65	8	0	17	0.60

Bluegill harvest ranged from 8 per acre at Williamson Pond to an average of 201 per acre at Red Haw Lake with an unweighted mean harvest of 74 per acre. Largemouth bass harvest was ≥ 4 per acre at Anita, Nine Eagles and Red Haw, but ≤ 2 per acre at the remaining lakes. Crappie harvest ranged from 0 at Bobwhite Lake to 101 per acre at Miami Lake.

Fishing success, as measured in fish harvested per hour, was greatest at Miami Lake and averaged 1.51 over a two-year period. Red Haw produced the second greatest angling success at 1.45 fish per hour over a seven-year period. The number of fish harvested per hour of angling was lowest at Lake Ahquabi, a lake renovated and stocked with fish in 1986. This lake supported a newly developing fish community and most fish were released.

LAKE MORPHOLOGY, WATER QUALITY AND WATERSHEDS

Morphological characteristics of all study lakes have been entered into a statewide database. Water quality statistics, obtained in 1979 and 1990 for the lakes in this study, were also acquired and entered into these electronic files.

Water quality parameters including Secchi disk depth, chlorophyll *a* and total phosphorous have been incorporated into the Carlson Trophic State Index (TSI) (Carlson

1977). The relative importance of these values and those of other parameters in the database will be determined by multivariate analysis (Appendix F).

Secchi disk depths ranged from 0.3 ft at Bobwhite and Williamson Lakes in 1990 to 12.1 ft at Red Haw Lake in 1990. Median Secchi disk depth for all lakes and years was 3.0 feet. Chlorophyll *a* concentration ranged from 3 mg/m^3 at Red Haw Lake and Williamson Pond in 1990 to 151 mg/m^3 at Smith Lake in 1990. Median chlorophyll *a* concentration for the data set was 90.0. Total phosphorus concentration ranged from 16 mg/m^3 at Slip Bluff, 1979, to 483 mg/m^3 at Lake Pahoja, 1990. Median phosphorus concentration for the data set was 90 mg/m^3.

Carlson's TSI ranged from 47.6 at Red Haw Lake in 1990 to the more eutrophic value of 72.8 at Bob White Lake in 1990. Median and standard deviation for Carlson's TSI values were 62.1 and 5.7.

Watershed data were collected and entered into the AGNPS database for Red Haw, Williamson Pond, Miami Lake, Bobwhite Lake, Swan Lake, Union Grove Lake, and Lake Ahquabi. Watershed analysis utilized the AGNPS model to assess the quality of runoff water and estimate sediment and nutrient yield to the lake for a series of rain events (Table 5). Bobwhite Lake received the greatest sediment load of those lakes studied. Sedimentation of Bobwhite Lake ranged from 6.7 tons per lake surface acre, the result of a 0.5-inch rain, to 146.3 tons per lake acre, after a 3.5-inch rain. The Miami and Red Haw Lake watersheds yielded considerably less sediment. Practically no sediment entered these lakes as the result of a 0.5-inch rainfall event. Lake Sedimentation increased to 9.5 tons per lake acre, at Miami; and 2.5 tons per lake acre, at Red Haw, after a 3.5-inch rain.

Table 5. Estimated sediment delivery to six lakes as determined by Agricultural Nonpoint Source Pollution Model (AGNPS). Values are expressed as tons per lake surface area, in acres.

	Inches of rain in watershed						
	0.5	1.0	1.5	2.0	2.5	3.0	3.5
Ahquabi ‘85	1.1	3.6	5.0	6.9	7.8	8.4	8.9
Ahquabi ‘98	0.9	2.1	3.3	3.9	4.3	4.6	4.8
Bobwhite	6.7	23.9	46.1	71.8	93.9	124.3	146.3
Miami	0.1	0.7	1.8	3.5	5.2	7.2	9.5
Red Haw	0.1	0.4	0.9	1.5	1.9	2.4	2.5
Union Grove	0.7	4.8	14.3	30.0	47.6	69.3	95.0
Swan	0.2	1.2	3.5	7.2	11.7	17.5	24.6
Williamson	1.0	4.7	12.2	24.3	34.1	55.3	76.1

ANALYTICAL COMPARISONS AND DISCUSSION

The primary objective of the investigation was to define and delineate factors responsible for the well being of two important panfish in Iowa -- bluegill and crappie. Factors examined were lake morphometry, lake water quality, watershed characteristics, angling and predation. Correlation-regression was used to examine these complex data sets. Each of the statistical methods provided a unique analysis of the data sets. Final analysis was through regression, which yielded a predictive endpoint.

Panfish vs. Largemouth bass predation

Correlation showed bluegill well being indices were positively associated with largemouth bass body condition and well being indices (Table 6). However, size structure and growth of bass were not associated with bluegill well being indices. Lakes with greater proportions of large bluegill (>8 inches) showed significant negative correlations with largemouth bass L (MAX) and RSD-P (P = 15-20 inches). Bluegill populations which tended to have fish > 8 inches were associated with bass populations lacking fish in the 15-20 inch range (Table 6). Similarly, bass populations with slower growth were associated with populations with large bluegill. Lakes with largemouth bass populations conducive to bluegill populations of high RSD-P values are shown in Table 7. Lakes with consistent bass parameters associated with bluegill of high RSD-P (> 8 inches) were Red Haw, Lacey-Keosauqua, Nine Eagles and Slip Bluff.

Table 6. Correlation coefficients (r) of bluegill well being indices and bluegill RSD-preferred Vs largemouth bass population statistics.

	Largemouth Bass Parameters					
	WR	RSD-S	RSD-Q	RSD-P	LMAX	WBI
Bluegill WBI	0.665*	-0.004	-0.005	0.013	0.032	0.614*
Bluegill RSD-P	-0.061	0.125	0.011	-0.238*	-0.217*	-0.178
Crappie WBI	0.127	-0.416*	0.341*	0.245*	0.260*	0.107
Crappie RSD-P	-0.019	-0.242*	0.318*	-0.033	0.003	-0.091

* Significant at the 0.01 level

Table 7. Lakes with largemouth bass characteristics associated with bluegill having high RSD-P (> 8 inches)

Low bass RSD-P	Low bass growth (Lmax)	Low bass well being index
Lacey-Keosauqua	Yellow Smoke	Lacey-Keosauqua
Red Haw	Lacey-Keosauqua	Nine Eagles
Nine Eagles	Nine Eagles	Red Haw
Slip Bluff	Slip Bluff	Slip Bluff
Keomah	Red Haw	Yellow Smoke

Correlations between crappie and largemouth bass population parameters are shown in Table 6. There were positive correlations between crappie well being indices and bass of quality and preferred size. However, there was a significant, but negative relationship between crappie well being and largemouth bass of stock size. On the other hand there was a positive relationship between bass growth and crappie well being indices.

Lake Morphometry and Watershed

Bluegill well being indices were negatively and significantly correlated with lake area to watershed ratio. Larger watershed ratios yielded bluegill populations with lower well being indices (Table 8). Other lake morphometrics were not related to bluegill well being. However, lakes which had a large proportion of large bluegill (RSD-P) (those greater than 8 inches), had positive, significant correlations with mean and maximum depths. The correlation with mean basin slope was also significant. The greater proportion of larger bluegills were found in the lakes with the steeper lake basin slopes.

A list of the lakes which had characteristics conducive to high bluegill well being indices and high RSD-P values for bluegill are listed in Table 9. Lakes that were listed most often were Viking, Red Haw, Nine Eagles and Lacey-Keosauqua and were characterized by high mean depth, high maximum depth, high mean basin slope, and low volume development. Lakes with lowest watershed area to lake area ratio were Swan, Green Valley, Anita, Pollmiller and Red Haw.

Table 8. Correlation coefficients (r) between bluegill, crappie and largemouth bass well being indices (WBI), relative stock density-preferred (RSD-P) and lake morphometry and watershed characteristics. ACRE is lake size in acres, MND is mean depth in feet, MXD is maximum depth in feet, VOLD is volume development, MBS is mean basin slope, WSR is watershed area to lake area ratio and WSS is watershed size in acres.

	ACRE	MND	MXD	VOLD	MBS	WSR	WSS
BLG WBI	0.062	0.077	0.096	0.025	0.092	-0.213*	-0.065
BLG RSD-P	-0.032	0.224*	0.250*	-0.145	0.197*	-0.095	-0.052
CRA WBI	0.228*	0.087	0.096	-0.127	-0.143	-0.260*	-0.007
CRA RSD-P	0.023	0.145	0.139	-0.036	0.082	-0.076	-0.001
LMB WBI	0.232*	-0.249*	-0.207*	0.117	-0.289*	-0.114	0.142
LMB-RSD-P	0.359*	-0.391*	-0.322*	0.175*	-0.450*	-0.041	0.209*

*Significant at the 0.05 level

Table 9. Lakes with physical characteristics associated with high bluegill well being indices and high RSD-P values.

Highest Mean Depth	Greatest Maximum Depth	Lowest Volume Development	Highest Mean Basin Slope
Viking	Viking	Viking	Slip Bluff
Red Haw	Red Haw	Pahoja	Lacey-Keosauqua
Nine Eagles	Nine Eagles	Red Haw	Red Haw
Anita	Hawthorn	Bob White	Viking
Lacey-Keosauqua	Iowa	Prairie Rose	Nine Eagles

A significant, positive correlation was found between crappie well being indices and lake size, in acres. The correlation coefficient of this relationship was +0.23 (Table 8). Study lakes with largest area were Green Valley, Prairie Rose, Anita, Hawthorn and Viking Lakes. There was a significant, negative relationship between crappie well being indices and lake area to watershed area ratio and the correlation coefficient of -0.26. Largemouth bass well being indices were significantly and positively associated with lake size, but negatively correlated with mean depth, maximum depth and mean basin slope (Table 8). Largemouth bass populations with proportionately more fish over 15 inches (RSD-P) were also negatively correlated with mean depth, maximum depth and mean basin slope but were positively correlated with volume development. Shallow lakes with a concave basin shape tended to have bass populations with proportionally more bass greater than 15 inches. These lakes included Smith, Union Grove, Slip Bluff, Green Valley, and Keomah Lakes.

Water Quality

Bluegills were adversely affected by eutrophic conditions at the study lakes. For example, a significant, negative correlation existed between Carlson's Secchi trophic index and bluegill well being indices. The coefficient was -0.12. Likewise, there was a significant, negative correlation with Carlson's phosphorus trophic index of -0.24. Bluegill of proportionately large size (>8 inches) were also adversely affected by eutrophication. Correlation coefficients between RSD-P and Secchi disc depths, and RSD-P and phosphorus indices were -0.24 and -0.21.

Lakes with better water quality in terms of lower turbidity included Red Haw, Nine Eagles, Yellow Smoke, Pahoja, and Lacey-Keosauqua Lakes. Lowest phosphorus concentrations were found at Yellow Smoke, Slip Bluff, Nine Eagles, Red Haw, and Lacey-Keosauqua Lakes.

Crappie populations were also adversely affected by turbidity where the significant correlation coefficient was -0.28. Crappie well being indices were positively correlated to chlorophyll *a* concentrations with an r-value of +0.31. The five lakes with highest chlorophyll *a* levels were Swan, Viking, Green Valley, Hawthorn and Anita Lakes.

Largemouth bass well being indices were positively associated with more eutrophic conditions. Likewise, lakes with higher proportions of bass larger than 15 inches (RSD-P) were more eutrophic. For example, correlation coefficients between bass well being indices were +0.24, +0.30, and +0.13 for Secchi disc depth, chlorophyll *a* and phosphorus, respectively. R-values for RSD-P were +0.26, +0.36, and +0.45 when correlated to the same water quality parameters.

Multiple Regression

Lakes with a preponderance of large bluegill (> 8 inches) were best described by the multiple regression model:

BLGRSD-P=10.706 -
0.149*LMBRSD-P + 0.155*MXD –
0.150*SECCHI + 0.038*PHOS

where the dependent variable BLGRSD-P was the proportion of bluegill greater than 8 inches, and the independent variables were

LMBRSD-P = proportional stock density of bass >15 inches
MXD = maximum depth in feet
SECCHI = Carlson's trophic state index of Secchi values
PHOS = Carlson's trophic state index of total phosphorus concentration.

This model had an r-value of 0.099; thus, these variables accounted for only 1% of the variability in the proportion of large bluegill found in the various populations. The lack of large bass was most influential in this model. Deeper lakes with high water transparency and lower phosphorus levels were conducive to large bluegill.

The same method was followed for bluegill well being indices. The following regression model was

BLGWBI = -0.789
+ 0.071*LMBWR
– 0.002*SECCHI
– 0.044*PHOS
– 0.017*WSRATIO

where the dependent variable BLGWBI was bluegill well being index and the independent variables were

LMBWR = body condition of largemouth bass
SECCHI = as above
PHOS = as above
WSRATIO = lake area to watershed area ratio

The model was highly significant with an r-value of 0.723. Over 50% of the variability in bluegill well being was attributed to the model variables. Lakes having bass with above average body condition, clear water, low phosphorus concentrations and low lake to watershed ratios contributed to bluegill populations with high well being indices.

Lakes with a greater proportion of large crappie, those greater than 8 inches (RSD-P) were best characterized by

CRARSD-P = 2.667
– 0.122*SECCHI
+ 0.751*BLGRSD-P
+ 0.245*LMBRSD-Q

where the dependent variable CRARSD-P was the proportion of crappie greater than 8 inches, and the independent variables were

SECCHI = as above
BLGRSD-P = as above and
LMBRSD-Q = proportional stock density of 12-15 inch largemouth bass.

The multiple regression model had a significant r-value of 0.609, so 37% of the variability in crappie RSD-P was accounted for. Lakes with large crappie were characterized by large bluegill, many intermediate-sized bass and high water clarity.

Crappie well being indices were best described by

CRAWBI = -1.667

+ 0.0007*ACRE
–0.008*WSRATIO
+ 0.0208*BLGWR
+0.2104*BLGMAX
where the dependent variable, CRAWBI, was crappie well being index and the independent variables were
ACRE = lake size in acres
WSRATIO = as above
BLGWR = bluegill body condition, relative weight and
BLGMAX = bluegill growth factor, maximum estimated growth.

AGNPS and Water Quality

Bluegill and crappie populations were adversely impacted by eutrophic conditions at the study lakes, as shown above. Furthermore, watershed size and lake area to watershed area ratio showed adverse affects upon bluegill and crappie populations. The regimented study of the watershed using the Agricultural Nonpoint Source (AGNPS) model better described the relationships between watersheds and water quality, and thus water quality and bluegill, crappie populations.

Significant correlations were found to exist between water quality measurements taken by Bachmann and the predicted nutrient loading as estimated by the AGNPS model. These correlations are given in Table 10, and all were significant at the 0.05 level of probability. Estimated sediment, Nitrogen and Phosphorus loading were all positively correlated to watershed size, watershed ratio, Secchi disk depths and Phosphorus concentrations found in lakes. Conversely, the AGNPS loading estimates were negatively correlated to primary production as measured by Chlorophyll (*a*). It is readily apparent that watershed size, ratio of lake area to watershed area, land use, slope and ground cover are vitally important to nutrient loading, which is important to lake water quality, which in turn is related to the well being of bluegill and crappie populations.

Table 10. Correlation coefficients between AGNPS loading predictions and water quality as measured by Bachmann (1980), (1991).

	Bachmann's water quality measurements				
AGNPS parameters	Watershed size	Watershed/Lake ratio	Secchi	Chlorophyll (a)	Phosphorus
Sediment tons/acre	+0.37	+0.51	+0.71	-0.56	+0.42
Sediment N lbs/acre	+0.53	+0.73	+0.64	-0.65	+0.35
Sediment P lbs/acre	+0.53	+0.73	+0.64	-0.66	+0.35

Angler Harvest

The impact of largemouth bass harvest on well being indices for bass was negative and accounted for 14.4% of the variability in size structure, growth and body condition. The greater number of bass harvested per acre yielded lower well-being indices for bass, and indicated anglers can have a negative impact upon bass populations.

Greater bluegill and crappie harvests, however, were associated with higher well-being indices of these species. Conversely, low panfish harvest was associated with lower well-being indices. Bluegill harvest accounted for 35% of the variability in bluegill well being; whereas, crappie harvest accounted for 6% of the variability in crappie well being. These correlations were probably not cause-and-effect related and the following two questions remain: 1. Is low harvest the result of unappealing fish populations as viewed by the angler? or 2. Are fish populations unappealing because anglers have over-harvested the species? The important fact is panfish populations were not over-exploited in the study lakes, and higher harvests were associated with higher well-being indices. A good example was at Red Haw Lake where an average of 203 hrs/acre were expended by anglers, and mainly on bluegill, yet well being indices for bluegill were in the top 25% of all lakes studied. The opposite was true at Williamson Pond where 65 hrs/acre of effort were expended and bluegill well being indices were among the lowest at 1.50.

Major factors influencing panfish populations included lake basin shape, watershed characteristics, lake water quality and, to a much lesser degree, predation by largemouth bass and angler harvest. It appears that high angler exploitation can have a negative impact on size of largemouth bass. Preliminary findings show lake basin shape is the most important factor in establishing the goodness or poorness of bass and panfish populations. Watershed characteristics are also important because lake morphology and water quality are greatly influenced by watershed. This investigation has shown predation of bass on panfish, and harvest of panfish by anglers has a relatively small role in the well being of crappie and bluegill populations.

RECOMMENDATIONS AND CONCLUSIONS

1. Lakes with proportionately larger bluegill were associated with bass populations dominated by fish smaller than 15 inches. Well being of bluegill populations was also positively correlated with largemouth bass well being indices and body condition. This indicated bass minimum size limits, although required to protect large bass, are not justified as a tool to enhance bluegill populations. Other factors have a much greater influence on quality and relative size of bluegill populations.

2. The relationship between anglers and bass populations showed high harvest was correlated with poor size structure. Largemouth bass harvest regulations are justified if the objective is to provide fishing for larger bass.

3. The relationship between anglers and bluegill or crappie populations showed a positive relationship between angler harvest and panfish well-being indices. Lakes that produced the highest bluegill harvest were those lakes with the highest quality bluegill populations. This indicated panfish harvest regulations, either by size or number are not justified. In fact, panfish harvest should be encouraged, particularly at lakes with poor panfish size structure, growth and body condition.

4. Watershed characteristics and lake basin shape are important to angling and influences the quality of the fish community. Lake site selection will

determine the quality of angling a lake produces. Bluegill, the most important fish in man-made lakes, is positively influenced by small watershed area:lake area ratio and large mean basin slope values. Mean depth and maximum depth are also positively correlated to quality of bluegill populations. Preliminary AGNPS investigations showed sediment and nutrient loading was vitally important to the well being of panfish populations. The lower the sediment and nutrient runoff from the watershed the better the panfish angling; therefore, these parameters should be examined carefully in developing alternatives during lake site selection.

5. Lakes that have already been constructed can benefit from lake deepening and reduction of soil and nutrient erosion in the watershed. Technology is available to predict the reduction in sediment and nutrient loading from watershed erosion control work and implementation of best management practices on land in the lake watershed. These benefits should be compared to the cost required to implement these practices and improve the lake. These costs and associated benefits should then be considered during prioritization of lake improvement efforts. Even if lakes are not candidates for rehabilitation, the well being of fish populations can be assessed relative to physical characteristics of the lake and its watershed. Lakes containing undesirable panfish populations should be examined to determine potential for improvement. Fish management can then target those species best adapted to the habitat offered by the lake and its watershed.

6. This investigation should be extended to expand the data sets and provide greater confidence in defining those factors that influence the quality of bluegill and crappie populations and the sportfisheries they support. The number of study lakes will remain the same; however, the well being indices will be tested at other lakes with long-term management history, such as at Lake Geode. Emphasis should be placed on economically expanding the data available on important lakes and watersheds of the state. Analysis by AGNPS is time consuming and expensive. Greater use of Geographical Information System (GIS) should be made in conjunction with satellite imagery and recently developed watershed based models to analyze for Nonpoint sediment and nutrient loading.

6. A completion report will be written and completed by July 1, 2001.

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Appendix A. Average W_r-values and standard deviations for bluegills, largemouth bass, and crappies at 22 study lakes.

		Bluegill		Largemouth Bass		Black Crappie		White Crappie	
Lake	Year	W_r	SD	W_r	SD	W_r	SD	W_r	SD
Ahquabi	1997	99	7	84	11			74	8
Ahquabi	1998	95	15	95	15			91	7
Anita	1992	94	16	93	12	98	10	91	7
Anita	1993	105	15	97	10	88	8		
Anita	1994	110	12	105	12	105	12		
Anita	1995	109	15	99	11	94	13		
Anita	1996	106	15	102	12	91	13		
Anita	1997	105	15	101	12	94	10	95	7
Anita	1998	104	15	81	118	101	14		
Bobwhite	1992	86	8	104	10				
Bobwhite	1993	95	15	102	8				
Bobwhite	1994	104	10	103	10			98	6
Bobwhite	1995	98	8	98	7				
Bobwhite	1996	86	9	90	10			86	9
Bobwhite	1997	97	12	91	10				
Bobwhite	1998	90	14	95	8			84	11
Green Valley	1993	121	15	112	10	98	8		
Green Valley	1994	96	19	107	13	89	12		
Green Valley	1995	86	11	101	13	97	8	97	11
Green Valley	1996	99	8	92	11	97	8	93	6
Green Valley	1997	101	10	100	9	97	9	95	10
Green Valley	1998	110	16	106	10	99	9	94	11
Hawthorn	1992	107	11	102	9	97	8		
Hawthorn	1993	109	10	97	10				
Hawthorn	1994	108	12	107	8	91	4	75	29
Hawthorn	1995	111	14	117	14	107	10		
Hawthorn	1996	101	6	97	9	93	4		
Hawthorn	1997	105	12	97	8	92	4		
Hawthorn	1998	104	11	97	9	98	9	101	11
Iowa	1992	107	15	105	11	99	11	100	11
Iowa	1993	98	9	100	9	96	7		
Iowa	1994	95	9	104	8	93	10		
Iowa	1995	100	11	101	11	98	8	96	8
Iowa	1996	99	14	98	9	94	9		
Iowa	1997	96	10	95	7	92	8		
Iowa	1998	105	11	107	8	99	7		
Keomah	1993	102	10	94	9				
Keomah	1994	95	10	98	8	97	12		
Keomah	1995	104	10	103	11	81	7	94	3
Keomah	1996	94	8	95	6	88	14		
Keomah	1997	95	6	101	8				
Keomah	1998	103	14	98	9	85	4		
Lacey-Keosauqua	1992	98	9	89	8				
Lacey-Keosauqua	1993	112	12	89	6				
Lacey-Keosauqua	1994	107	6	89	7				
Lacey-Keosauqua	1995	100	9	90	6				
Mariposa	1992	113	13	110	9				
Mariposa	1993	96	13	99	9				
Mariposa	1994			95	13	104	23	100	21
Mariposa	1995	99	25	104	11	90	16		
Mariposa	1996	81	24	95	12	58	25		
Mariposa	1997	88	11	87	12	88	8		
Mariposa	1998	83	20	105	20	79	6		
Miami	1990	99	13	96	10	94	9	92	8
Miami	1991	91	10	99	11	93	9	88	10
Miami	1992	91	12	100	11	98	9	94	11
Miami	1993	92	16	90	10	90	5	84	7
Miami	1994	105	13	93	9				
Miami	1995	99	11	114	9	91	9	94	10
Miami	1996	93	9	94	8	96	8	87	4
Miami	1997	97	10	93	7	95	6	95	7
Miami	1998	105	11	94	8	101	13	97	8
Nine Eagles	1989	94	10	91	10	81	13		

Appendix A continued

		Bluegill		Largemouth Bass		Black Crappie		White Crappie	
Lake	Year	W_r	SD	W_r	SD	W_r	SD	W_r	SD
Nine Eagles	1990	89	15	91	10	86	10		
Nine Eagles	1991	84	8	93	9	89	12		
Nine Eagles	1993	102	13	94	12	89	10		
Nine Eagles	1994			87	7				
Nine Eagles	1995	92	12	84	10	81	7	83	20
Nine Eagles	1996	93	9	87	8	87	7		
Nine Eagles	1997	93	10	89	10				
Nine Eagles	1998	91	15	90	12	95	12		
Pahoja	1992	111	9	112	15	104	5		
Pahoja	1993	115	8	115	11	108	8		
Pahoja	1994	104	6	109	10	108	5		
Polmiller	1992	97	13	101	6				
Polmiller	1993	95	12	97	7				
Polmiller	1994	91	13	98	8				
Polmiller	1995	100	12	98	8				
Polmiller	1996	103	18	100	15				
Polmiller	1997	94	9	99	8				
Prairie Rose	1994	106	16	103	10	90	10		
Prairie Rose	1996	107	15	108	14	101	9		
Prairie Rose	1997	103	14	107	7	96	10		
Prairie Rose	1998	90	12	96	8	88	7		
Red Haw	1990	106	14	94	11				
Red Haw	1991	111	12	86	8				
Red Haw	1992	108	11	94	11	104	16		
Red Haw	1993	102	13	98	8	103	9		
Red Haw	1994	100	11	80	9				
Red Haw	1995								
Red Haw	1996	104	11	86	10				
Red Haw	1997	106	14	85	8	88	10		
Red Haw	1998	94	13	94	8	97	6		
Slipbluff	1992	94	14	92	8	100	10	89	12
Slipbluff	1993	94	12	93	10	84	6	77	7
Slipbluff	1994	90	9	92	11	81	7	87	12
Slipbluff	1996	86	9	90	10	85	6	80	9
Slipbluff	1997	89	11	94	12	90	7		
Smith	1992	120	10	104	12			97	10
Smith	1993	104	7	103	10			94	6
Smith	1994	109	12	107	7				
Smith	1995	113	15	111	8	114	13	109	14
Smith	1996	109	15	108	12			97	5
Smith	1997	112	17	106	6	115	11	116	11
Smith	1998	120	9	102	8	101	8	96	7
Swan	1989	102	14	92	15	114	13		
Swan	1990	95	13	93	13	108	9		
Swan	1991	107	15	109	15	108	14		
Swan	1992	92	16	108	14	89	11		
Swan	1993	103	17	104	17	99	16		
Swan	1994	114	19	96	14	91	9		
Swan	1995	106	15	91	15	105	13		
Swan	1996	110	15	110	11				
Union Grove	1993	101	10	107	8	105	6		
Union Grove	1994	98	10	103	8	94	6		
Union Grove	1995	110	17	114	12	99	19		
Union Grove	1996	115	15	111	11			105	8
Union Grove	1997	102	14	114	8	102	6		
Union Grove	1998	114	14	109	9	97	8		
Viking	1992	112	21	100	9	98	13	108	20
Viking	1993	115	22	100	12	98	10		
Viking	1994	106	19	94	8	85	8		
Viking	1995	113	14	106	10			105	11
Viking	1996	103	16	98	12	92	12		
Viking	1997	114	12	108	10			98	12
Viking	1998	88	10	95	6	83	8		

Appendix A continued

		Bluegill		Largemouth Bass		Black Crappie		White Crappie	
Lake	Year	W_r	SD	W_r	SD	W_r	SD	W_r	SD
Williamson Pond	1991	93	10	87	12	81	10	84	10
Williamson Pond	1992	103	10	91	7	94	10	91	8
Williamson Pond	1994	106	19	103	14			85	9
Williamson Pond	1995	92	10	97	12	85	12	82	6
Williamson Pond	1996	96	9	97	9	94	5	87	5
Williamson Pond	1997	98	15	97	8	88	23	87	5
Williamson Pond	1998	99	14			100	15		
Yellow Smoke	1992	106	13	106	14				
Yellow Smoke	1993	93	20	104	6				
Yellow Smoke	1994	102	17	114	14				
Yellow Smoke	1995	125	18	117	15				
Yellow Smoke	1996	114	22	101	11				
Yellow Smoke	1997	100	9	109	8				
Yellow Smoke	1998	115	11	119	13				

Appendix B. Size structure of bluegills at 22 lakes using three Relative stock density (RSD) classes, 3-6, 6-8, and 8-10 inches.

Lake	Year	RSD-Stock (3-6)	RSD-Quality (6-8)	RSD-Preferred (8-10)
Ahquabi	1997	44	44	12
Ahquabi	1998	72	26	0
Anita	1992	64	22	14
Anita	1993	73	20	8
Anita	1994	80	14	6
Anita	1995	26	72	2
Anita	1996	80	18	2
Anita	1997	81	13	6
Anita	1998	64	22	14
Bobwhite	1992	25	75	0
Bobwhite	1993	47	53	0
Bobwhite	1994	39	61	0
Bobwhite	1995	36	61	3
Bobwhite	1996	29	70	1
Bobwhite	1997	60	40	0
Bobqhite	1998	42	57	1
Green Valley	1993	41	59	0
Green Valley	1994	14	85	1
Green Valley	1995	37	62	1
Green Valley	1996	41	59	0
Green Valley	1997	56	44	0
Green Valley	1998	36	62	2
Hawthorn	1992	52	45	3
Hawthorn	1993	54	41	5
Hawthorn	1994	20	24	56
Hawthorn	1995	66	10	24
Hawthorn	1996	41	54	5
Hawthorn	1997	31	63	6
Hawthorn	1998	40	54	6
Iowa	1992	51	44	5
Iowa	1993	45	55	0
Iowa	1994	60	36	4
Iowa	1995	22	65	14
Iowa	1996	49	45	6
Iowa	1997	33	64	2
Iowa	1998	78	22	0
Keomah	1993	57	38	6
Keomah	1994	9	51	40
Keomah	1995	92	4	4
Keomah	1996	68	31	1
Keomah	1997	26	74	0
Keomah	1998	13	87	0
Lacey-Keosauqua	1992	53	38	9
Lacey-Keosauqua	1993	72	15	13
Lacey-Keosauqua	1994	69	31	0
Lacey-Keosauqua	1995	76	31	0
Mariposa	1992	64	36	0
Mariposa	1993	33	67	0
Mariposa	1994	80	20	0
Mariposa	1995	25	74	1
Mariposa	1996	43	57	0
Mariposa	1997	53	47	0
Mariposa	1998	60	40	0
Miami	1990	27	71	2
Miami	1991	6	90	4
Miami	1992	39	59	2
Miami	1993	78	22	0
Miami	1994	67	33	0
Miami	1995	10	76	14
Miami	1996	93	7	0
Miami	1997	100	0	0
Miami	1998	75	25	0
Nine Eagles	1989	37	33	30
Nine Eagles	1990	59	18	23

Appendix B continued.

Lake	Year	RSD-Stock (3-6)	RSD-Quality (6-8)	RSD-Preferred (8-10)
Nine Eagles	1991	68	28	4
Nine Eagles	1993	56	19	25
Nine Eagles	1995	71	26	3
Nine Eagles	1996	72	28	0
Nine Eagles	1997	81	19	0
Nine Eagles	1998	25	69	6
Pahoja	1992	62	38	0
Pahoja	1993	32	58	10
Pahoja	1994	91	9	0
Pahoja	1997	74	26	0
Polmiller	1994	89	11	0
Polmiller	1995	64	34	2
Polmiller	1996	92	5	3
Polmiller	1997	94	6	0
Prairie Rose	1994	59	39	2
Prairie Rose	1996	61	39	0
Prairie Rose	1997	55	45	0
Prairie Rose	1998	64	36	0
Red Haw	1990	54	7	39
Red Haw	1991	47	37	16
Red Haw	1992	41	48	11
Red Haw	1993	88	8	5
Red Haw	1994	72	24	4
Red Haw	1995	0	12	87
Red Haw	1996	61	28	11
Red Haw	1997	98	2	0
Red Haw	1998	85	14	1
Slipbluff	1992	43	54	3
Slipbluff	1993	41	59	0
Slipbluff	1994	48	52	0
Slipbluff	1996	57	43	0
Slipbluff	1997	45	55	0
Smith	1992	82	18	0
Smith	1993	43	57	0
Smith	1994	17	83	0
Smith	1995	71	29	0
Smith	1996	48	48	3
Smith	1997	58	38	4
Smith	1998	35	65	0
Swan	1989	33	66	1
Swan	1990	49	46	5
Swan	1991	54	30	16
Swan	1992	46	37	18
Swan	1993	59	35	6
Swan	1994	64	36	0
Swan	1995	26	72	2
Swan	1996	37	60	3
Union Grove	1993	57	43	0
Union Grove	1994	17	80	3
Union Grove	1995	39	44	17
Union Grove	1996	53	28	20
Union Grove	1997	44	41	15
Union Grove	1998	48	6	9
Viking	1992	67	38	0
Viking	1993	46	52	2
Viking	1994	64	32	4
Viking	1995	40	56	4
Viking	1996	72	22	6
Viking	1997	59	39	2
Viking	1998	38	0	8
Williamson Pond	1991	17	83	0
Williamson Pond	1992	35	65	0
Williamson Pond	1994	51	47	2
Williamson Pond	1995	14	80	6

Appendix B continued.

Lake	Year	RSD-Stock (3-6)	RSD-Quality (6-8)	RSD-Preferred (8-10)
Williamson Pond	1996	9	86	5
Williamson Pond	1997	51	42	8
Williamson Pond	1998	25	3	6
Yellow Smoke	1992	56	34	10
Yellow Smoke	1993	84	10	6
Yellow Smoke	1994	82	18	0
Yellow Smoke	1995	92	8	0
Yellow Smoke	1996	100	0	0
Yellow Smoke	1997	80	17	3
Yellow Smoke	1998	98	2	0

Appendix C. Size structure of largemouth bass at 22study lakes using three Relative stock density (RSD) classes, 8-12, 12-15, and 15-20 inches.

Lake	Year	RSD-Stock (8-12	RSD-Quality (12-15	RSD-Preferred (15-20
Ahquabi	1997	77	15	8
Ahquabi	1998	78	17	5
Anita	1992	20	60	20
Anita	1993	11	73	16
Anita	1994	24	51	25
Anita	1995	35	34	30
Anita	1996	22	50	28
Anita	1997	22	61	17
Anita	1998	46	39	15
Bobwhite	1992	59	33	8
Bobwhite	1993	43	53	4
Bobwhite	1994	30	59	11
Bobwhite	1995	18	64	18
Bobwhite	1996	18	56	26
Bobwhite	1997	27	54	20
Bobwhite	1998	17	62	22
Green Valley	1993	18	54	28
Green Valley	1994	22	48	30
Green Valley	1995	29	46	26
Green Valley	1996	22	41	38
Green Valley	1997	4	69	27
Green Valley	1998	6	54	39
Hawthorn	1992	66	23	11
Hawthorn	1993	53	34	13
Hawthorn	1994	96	4	0
Hawthorn	1995	78	20	2
Hawthorn	1996	89	8	3
Hawthorn	1997	81	9	11
Hawthorn	1998	44	52	3
Iowa	1992	48	12	40
Iowa	1993	63	25	12
Iowa	1994	65	30	5
Iowa	1995	22	46	32
Iowa	1996	53	26	22
Iowa	1997	59	40	1
Iowa	1998	54	43	4
Keomah	1993	31	49	21
Keomah	1994	39	50	11
Keomah	1995	78	16	6
Keomah	1996	77	19	4
Keomah	1997	82	18	0
Keomah	1998	13	87	0
Lacey-Keosauqua	1992	82	18	0
Lacey-Keosauqua	1993	96	4	0
Lacey-Keosauqua	1994	63	37	0
Lacey-Keosauqua	1995	57	43	0
Mariposa	1992	87	9	4
Mariposa	1993	27	47	26
Mariposa	1994	20	69	11
Mariposa	1995	24	30	46
Mariposa	1996	30	33	38
Mariposa	1997	46	26	29
Mariposa	1998	36	25	39
Miami	1990	77	10	13
Miami	1991	73	24	3

Appendix C continued.

Lake	Year	RSD-Stock (8-12	RSD-Quality (12-15	RSD-Preferred (15-20
Miami	1992	70	28	2
Miami	1993	81	18	1
Miami	1994	71	26	3
Miami	1995	35	57	8
Miami	1996	46	48	6
Miami	1997	62	30	8
Miami	1998	38	52	10
Nine Eagles	1989	46	52	2
Nine Eagles	1990	61	39	0
Nine Eagles	1991	45	50	5
Nine Eagles	1996	43	57	0
Nine Eagles	1997	59	38	3
Nine Eagles	1998	79	21	0
Pahoja	1992	38	40	22
Pahoja	1993	55	25	21
Pahoja	1994	75	23	2
Pahoja	1997	48	49	4
Polmiller	1992	59	41	0
Polmiller	1993	46	52	2
Polmiller	1994	43	55	2
Polmiller	1995	43	55	2
Polmiller	1996	69	30	2
Polmiller	1997	46	54	0
Prairie Rose	1994	67	14	18
Prairie Rose	1996	34	43	23
Prairie Rose	1997	15	48	37
Prairie Rose	1998	60	14	27
Red Haw	1990	85	15	0
Red Haw	1991	57	43	0
Red Haw	1992	52	47	1
Red Haw	1993	57	39	4
Red Haw	1994	42	57	1
Red Haw	1995	30	70	0
Red Haw	1996	51	47	2
Red Haw	1997	65	33	2
Red Haw	1998	24	37	39
Slipbluff	1992	35	63	2
Slipbluff	1993	57	41	2
Slipbluff	1994	72	22	6
Slipbluff	1996	74	24	2
Slipbluff	1997	87	12	1
Smith	1992	15	43	37
Smith	1993	30	23	48
Smith	1994	35	26	39
Smith	1995	66	28	6
Smith	1996	67	33	0
Smith	1997	54	43	4
Smith	1998	52	26	22
Swan	1989	13	67	20
Swan	1990	4	72	24
Swan	1991	38	39	23
Swan	1992	17	55	28
Swan	1993	36	35	29
Swan	1994	22	52	25
Swan	1995	17	44	40
Swan	1996	63	17	20

Appendix C continued.

Lake	Year	RSD-Stock (8-12)	RSD-Quality (12-15)	RSD-Preferred (15-20)
Union Grove	1993	30	35	35
Union Grove	1994	33	51	16
Union Grove	1995	42	53	5
Union Grove	1996	68	29	3
Union Grove	1997	20	58	22
Union Grove	1998	13	59	28
Viking	1992	43	48	9
Viking	1993	56	38	7
Viking	1994	23	71	6
Viking	1995	21	64	16
Viking	1996	24	62	13
Viking	1997	47	26	28
Viking	1998	75	6	20
Williamson Pond	1991	83	1	16
Williamson Pond	1992	78	15	7
Williamson Pond	1994	27	62	11
Williamson Pond	1995	61	11	28
Williamson Pond	1996	77	8	15
Williamson Pond	1997	87	10	3
Williamson Pond	1998	79	13	8
Yellow Smoke	1992	34	64	2
Yellow Smoke	1993	18	80	2
Yellow Smoke	1994	67	22	11
Yellow Smoke	1995	66	14	20
Yellow Smoke	1996	46	42	12
Yellow Smoke	1997	6	90	4
Yellow Smoke	1998	45	32	23

Appendix D. Size structure of crappies at 13 study lakes using three Relative stock density (RSD) classes, 5-8, 8-10, and 10-12 inches.

Lake	Year	RSD-Stock (5-8)	RSD-Quality (8-10)	RSD-Preferred (10-12)
BLACK CRAPPIE				
Anita	1992	7	65	27
Anita	1993	23	54	23
Anita	1994	71	6	23
Anita	1995	58	37	5
Anita	1996	2	61	37
Anita	1997	3	3	95
Anita	1998	47	20	33
Green Valley	1993	36	45	19
Green Valley	1994	94	5	1
Green Valley	1995	53	44	3
Green Valley	1996	71	24	6
Green Valley	1997	33	67	0
Green Valley	1998	53	57	0
Hawthorn	1994	28	66	6
Hawthorn	1995	67	29	5
Hawthorn	1996	90	10	0
Hawthorn	1997	36	64	0
Hawthorn	1998	69	31	0
Iowa	1992	65	32	3
Iowa	1993	24	74	2
Iowa	1994	50	35	15
Iowa	1995	16	70	14
Iowa	1996	13	78	9
Iowa	1997	40	60	0
Iowa	1998	26	56	18
Keomah	1994	13	62	25
Keomah	1995	98	2	0
Keomah	1996	96	4	0
Keomah	1998	3	90	8
Mariposa	1994	56	42	2
Mariposa	1995	37	49	14
Mariposa	1996	100	0	0
Mariposa	1997	90	8	3
Mariposa	1998	66	32	2
Miami	1990	30	70	0
Miami	1991	26	72	2
Miami	1992	74	20	4
Miami	1993	36	64	0
Miami	1995	28	58	14
Miami	1996	76	24	0
Miami	1997	17	83	0
Miami	1998	68	29	3
Nine Eagles	1989	74	21	5
Nine Eagles	1990	65	20	14
Nine Eagles	1991	50	17	33
Nine Eagles	1993	10	80	10
Nine Eagles	1995	39	56	6
Nine Eagles	1996	78	22	0
Nine Eagles	1998	87	13	0
Pahoja	1992	94	6	0
Pahoja	1993	14	86	0
Pahoja	1994	71	22	7
Pahoja	1996	9	92	0
Pahoja	1997	42	57	1
Prairie Rose	1994	53	46	1
Prairie Rose	1996	9	91	0
Prairie Rose	1997	48	52	0
Prairie Rose	1998	78	22	0
Red Haw	1992	25	67	8
Red Haw	1993	78	22	0
Red Haw	1995	0	4	96
Red Haw	1997	15	5	80
Red Haw	1998	50	50	0

Appendix D continued.

Lake	Year	RSD-Stock (5-8)	RSD-Quality (8-10)	RSD-Preferred (10-12)
Smith	1998	43	57	0
Slipbluff	1992	81	18	1
Slipbluff	1993	20	76	4
Slipbluff	1994	27	69	4
Slipbluff	1995	96	4	0
Slipbluff	1996	72	28	0
Slipbluff	1997	28	72	0
Swan	1989	62	37	1
Swan	1990	0	86	14
Swan	1991	12	44	44
Swan	1995	57	43	0
Swan	1996	36	64	0
Union Grove	1993	49	51	0
Union Grove	1994	79	21	0
Union Grove	1995	58	6	36
Union Grove	1996	77	23	0
Union Grove	1997	2	97	1
Union Grove	1998	17	11	71
Viking	1992	87	7	6
Viking	1993	27	73	0
Viking	1994	56	42	2
Viking	1996	72	22	7
Viking	1998	88	13	0
Williamson Pond	1991	42	57	1
Williamson Pond	1992	18	82	0
Williamson Pond	1995	26	74	0
Williamson Pond	1996	33	67	0
Williamson Pond	1997	38	50	13
Williamson Pond	1998	63	38	0
WHITE CRAPPIE				
Ahquabi	1997	50	42	8
Ahquabi	1998	13	88	0
Bobwhite	1994	83	17	0
Bobwhite	1996	64	19	17
Bobwhite	1997	15	78	7
Bobwhite	1998	39	53	8
Green Valley	1994	34	66	0
Green Valley	1995	0	42	58
Green Valley	1996	17	83	0
Green Valley	1997	38	54	9
Green Valley	1998	35	58	7
Hawthorn	1994	100	0	0
Hawthorn	1998	59	24	17
Iowa	1992	55	35	10
Iowa	1994	39	56	5
Iowa	1995	29	47	24
Keomah	1995	22	78	0
Mariposa	1994	27	73	0
Miami	1990	19	79	2
Miami	1991	15	73	12
Miami	1992	74	20	4
Miami	1993	8	72	20
Miami	1995	30	46	24
Miami	1996	75	16	9
Miami	1997	97	3	0
Miami	1998	35	65	0
Nine Eagles	1995	43	43	14
Slipbluff	1992	14	63	6
Slipbluff	1993	9	69	22
Slipbluff	1994	89	7	4
Slipbluff	1996	33	66	2
Smith	1992	100	0	0
Smith	1993	85	15	0
Smith	1995	84	14	2
Smith	1996	82	19	0

Appendix D continued.

Lake	Year	RSD-Stock (5-8)	RSD-Quality (8-10)	RSD-Preferred (10-12)
Smith	1997	94	6	0
Smith	1998	63	37	0
Viking	1992	92	8	0
Viking	1995	2	74	24
Viking	1997	93	6	2
Williamson Pond	1991	62	38	0
Williamson Pond	1992	10	90	0
Williamson Pond	1994	65	31	4
Williamson Pond	1995	24	76	0
Williamson Pond	1996	18	82	0
Williamson Pond	1997	0	100	0

Appendix E. Index of population of well-being based upon growth, body condition, and size structure for bluegills, largemouth bass and crappies at 21 study lakes, one being "poorest" and five being "best".

Lake	Year	Bluegill	Largemouth Bass	Black Crappie	White Crappie
Ahquabi	1998	2.25	3.67	1.33	
Anita	1992	3.60	3.08	3.42	
Anita	1993	3.90	3.30	3.67	
Anita	1994	4.00	3.75	3.50	
Anita	1995	3.17	4.08	3.25	
Anita	1996	3.33	3.75	3.17	
Anita	1997	3.58	3.58	2.58	
Anita	1998	3.25	4.25		3.92
Bobwhite	1992	1.40	4.00		
Bobwhite	1993	2.20	3.30		
Bobwhite	1994	2.33	3.30		
Bobwhite	1995	2.33	2.83		
Bobwhite	1996	1.50	2.33		
Bobwhite	1997	2.92	2.67		1.92
Bobwhite	1998	1.83	2.58	2.17	
Green Valley	1993	2.50	4.00	2.83	
Green Valley	1994	1.67	3.75	0.83	1.75
Green Valley	1995	1.67	3.92	2.67	2.50
Green Valley	1996	2.25	3.25	1.92	1.52
Green Valley	1997	3.17	3.50	2	2.83
Green Valley	1998	2.42	2.42	2.42	2.42
Hawthorn	1992	4.10	3.58		
Hawthorn	1993	4.50	3.50		
Hawthorn	1994	3.33	1.92	2.08	0.83
Hawthorn	1995	3.92	3.08	2.58	
Hawthorn	1996	4.00	2.42	1.25	
Hawthorn	1997	3.67	3	2	
Hawthorn	1998	3.83	2.92	3.42	2.25
Iowa	1992	4.25	3.92	2.33	3.08
Iowa	1993	2.67	4.33	1.92	
Iowa	1994	3.50	4.50	2.83	2.75
Iowa	1995	3.25	3.75	2.58	2.67
Iowa	1996	3.50	4.00	2.08	
Iowa	1997	2.58	3.75	2.25	
Iowa	1998	2.58	4.08		3.17
Keomah	1993	4.25	3.42		
Keomah	1994	2.67	3.83		
Keomah	1995	2.50	3.92	0.83	1.67
Keomah	1996	2.42	3.00	1.33	
Keomah	1997	2.17	3.08		
Keomah	1998	2.17	4.08		1.92
Lacey-Keosauqua	1992	4.50	1.33		
Lacey-Keosauqua	1993	4.00	0.67		
Lacey-Keosauqua	1994	3.42	2.17		
Lacey-Keosauqua	1995	3.75	2.17		
Lacey-Keosauqua	1997				
Mariposa	1992	3.40	3.33		
Mariposa	1993	2.33	3.42		

Appendix E continued.

Lake	Year	Bluegill	Largemouth Bass	Black Crappie	White Crappie
Mariposa	1994	2.83	3.33	2.92	2.75
Mariposa	1995	2.67	3.75	3.33	
Mariposa	1996	2.50	3.42	1.33	
Mariposa	1997	2.92	3.50	1.83	
Mariposa	1998	3.20	3.90	2.33	
Miami	1990	2.17	2.50	1.58	1.50
Miami	1991	1.58	2.42	1.42	2.33
Miami	1992	1.83	2.67	1.58	1.58
Miami	1993	1.58	1.42	1.75	2.00
Miami	1997	1.67	3.75	1.08	1.92
Miami	1998	2.42	3.08	2.58	2.08
Nine Eagles	1989	3.08	1.92	1.67	
Nine Eagles	1990	3.08	2.16	2.50	
Nine Eagles	1991	2.75	2.58	2.50	
Nine Eagles	1993	3.82	2.17	2.00	
Nine Eagles	1994	--	1.33		
Nine Eagles	1995	2.25	0.83	2.25	2.75
Nine Eagles	1996	2.00	1.33	1.67	
Nine Eagles	1997	1.92	2.42		
Nine Eagles	1998	2.5	1.33		1.33
Pahoja	1992	3.40	4.00	1.83	
Pahoja	1993	3.17	3.83	2.08	
Pahoja	1994	2.08	3.00	2.58	
Polmiller	1993	2.83	2.92		
Polmiller	1994	2.00	2.75		
Polmiller	1995	3.67	2.42		
Polmiller	1996	2.83	3.00		
Polmiller	1997	2.08	2.92		
Prairie Rose	1994	3.33	3.42	2.42	
Prairie Rose	1996	3.17	4.17	1.33	
Prairie Rose	1997	3.17	3.75	2.42	
Prairie Rose	1998	2.42	3.92		1.67
Red Haw	1990	3.92	1.67		
Red Haw	1991	4.50	2.42		
Red Haw	1992	4.00	2.25	2.92	
Red Haw	1993	3.33	3.50	2.17	
Red Haw	1994	3.42	1.67	1.83	
Red Haw	1995	2.33	1.42	1.83	
Red Haw	1996	4.00	2.00		
Red Haw	1997	3.92	2.00	1.92	
Red Haw	1998	2.08	2.75		2.42
Slipbluff	1992	2.33	1.67	1.33	2.67
Slipbluff	1993	1.75	2.92	1.08	2.92
Slipbluff	1994	1.67	2.58		2.00
Slipbluff	1996	2.17	2.00	1.17	2.50
Slipbluff	1997	1.5	1.58	1.42	
Smith	1992	2.67	3.92		
Smith	1993	2.75	3.75		
Smith	1994	2.08	3.92		

Appendix E continued.

Lake	Year	Bluegill	Largemouth Bass	Black Crappie	White Crappie
Smith	1995	3.00	4.50	1.83	1.83
Smith	1996	3.33	3.42		1.83
Smith	1997	4.25	4.08	1.83	1.83
Smith	1998	2.83	4.25		2.67
Swan	1989	3.17	2.75	2.75	
Swan	1990	3.75	3.00	2.58	
Swan	1991	4.50	4.33	3.00	
Swan	1992	3.25	3.25	1.58	
Swan	1993	4.00	3.58	1.33	
Swan	1994	3.92	3.50	1.08	
Swan	1995	2.17	3.25	2.92	
Swan	1996	2.58	4.33	2.25	
Swan	1997				
Union Grove	1995	4.08	4.33	2.67	
Union Grove	1996	4.25	4.08	1.92	2.92
Union Grove	1997	4	3.83	1.33	
Union Grove	1998	4	3.5		2
Viking	1992	3.17	3.83	1.75	
Viking	1993	3.17	4.50	1.92	
Viking	1994	3.25	3.08	3.17	
Viking	1995	3.17	3.33		2.75
Viking	1996	3.17	3.08	2.08	
Viking	1997	3.5	4.00		1.33
Viking	1998	2.17	3.42		1.08
Williamson Pond	1991	1.08	2.83	1.92	1.50
Williamson Pond	1992	2.08	3.00	1.08	1.00
Williamson Pond	1994	2.50	3.75		1.83
Williamson Pond	1995	1.67	3.92	1.17	1.42
Williamson Pond	1996	2.08	3.50	1.75	
Williamson Pond	1997	3.5	3.00	2.58	1.08
Williamson Pond	1998	2.17	3.42		1.08
Yellow Smoke	1992	4.25	2.17		
Yellow Smoke	1993	2.83	1.83		
Yellow Smoke	1994	2.67	3.33		
Yellow Smoke	1995	2.58	3.17		
Yellow Smoke	1996	2.67	3.50		
Yellow Smoke	1997	2.67	3.50		
Yellow Smoke	1998	2.42	3.33		

Appendix F. Water quality of 22 study lakes including turbidity, chlorophyll a and phosphorus. Carlson's Trophic State Index (TSI) is an index of these parameters where larger numbers indicate greater eutrophication.

Lake	Year	Secchi Disk Depth (feet)	Chlorophyll a mg/m^3	Phosphorus mg/m^3	Carlson's TSI
Ahquabi	1979	2.9	20	52	59.3
Ahquabi	1990	1.6	42	191	67.4
Anita	1979	2.3	47	56	62.8
Anita	1990	6.2	44	71	58.4
Bobwhite	1979	0.7	13	167	68.4
Bobwhite	1990	0.3	7	474	72.8
Green Valley	1979	3.0	68	193	63.6
Green Valley	1990	3.3	38	136	62.8
Hawthorn	1979	3.0	--	90	62.3
Hawthorn	1992	3.0	43	80	62.2
Iowa	1979	1.6	90	66	66.5
Iowa	1990	4.3	19	106	59.2
Keomah	1979	2.0	66	86	60.7
Keomah	1990	3.3	22	93	60.5
Lacey-Keosauqua	1979	7.2	11	30	52.0
Lacey-Keosauqua	1990	3.3	22	93	60.5
Mariposa	1979	2.3	65	169	66.4
Mariposa	1990	2.0	26	234	65.8
Miami	1979	2.6	43	57	62.0
Miami	1990	2.0	38	125	65.0
Nine Eagles	1979	6.9	16	26	52.8
Nine Eagles	1990	4.3	25	49	57.9
Pahoja	1979	4.9	18	744	63.4
Pahoja	1990	4.9	50	483	64.8
Polmiller	1979	3.0	21	37	58.5
Polmiller	1990	4.6	28	90	59.4
Prairie Rose	1979	2.0	39	95	59.5
Prairie Rose	1990	3.0	74	90	62.9
Red Haw	1979	3.0	55	38	61.0
Red Haw	1990	12.1	3	46	47.6
Slip Bluff	1979	7.9	5	16	48.0
Slip Bluff	1990	2.3	9	74	59.4
Smith	1979	1.6	92	110	67.8
Smith	1990	1.6	151	236	71.0
Swan	1979	1.6	47	205	67.7
Swan	1990	2.3	120	360	69.9
Union Grove	1979	1.6	9	119	55.5
Union Grove	1990	2.6	53	115	64.3
Viking	1979	2.6	56	55	62.5
Viking	1990	4.9	63	90	61.1
Williamson Pond	1979	2.6	21	56	60.1
Williamson Pond	1990	0.3	3	386	70.2
Yellow Smoke	1979	4.9	--	39	55.3
Yellow Smoke	1992	4.9	11	28	53.6

STUDY 7009

Microcomputer Technical Training and Support

OBJECTIVE

To provide computer-oriented technical assistance to field personnel by developing, modifying, installing and maintaining a statewide database and other software and hardware for fisheries applications, training in the use of software and hardware, and updating and maintaining systems.

JOB 1

Statewide database and other software development

OBJECTIVE

To develop and maintain a statewide database and develop other software as needed.

JOB 2

Personnel training and system maintenance

OBJECTIVE

To provide training to field personnel and install and maintain software and hardware.

INTRODUCTION

Sound fisheries research and management is based on the ability to collect, store, and interpret large data sets. The ability to access, sort and analyze these data sets is essential. During the last decade the computer has become an important tool for this work.

During the mid 1960's through the mid 1980's, the Fisheries Bureau used a main frame computer at Iowa State University to analyze large data sets, but the development of inexpensive, powerful desktop computers ended the Bureau's dependence on Iowa State University. Since 1982, the Fisheries Bureau has purchased a few microcomputers each year. Today, computers have been placed on of each biologist's desk and all technicians have access to one. Software is purchased or designed in-house and placed on computers to meet the needs of the particular station. Many of these programs are customized for use in a variety of applications.

Newly Developed Databases

Annual Fish Stocking Request

Several advantages are associated with the use of computers in development of annual stocking requests. The electronic stocking request system provides a quick and accurate tabulation of fish needs that can be easily transferred to hatcheries for production and distribution. It also eliminates the need to retype and retabulate requests. If stocking cuts need to be made due to insufficient production or production facilities, the use of the database provides biologists a more scientific and selective way of making cuts. Instead of making an across-the-board percentage cut, individual stockings can easily be cut. Also putting the requests into a database provides a total tracking system for a request even if a request is rejected or changed. The database also provides historical information relative to fish stocking.

A stocking request database was developed and partially implemented during the past year. This database consists of one main table for data storage (Table 1). Also, look-up tables were developed to describe water-body, species, management unit, and county. These look-up tables are part of the statewide database.

Data entry, review and reporting are done at five different levels or locations. These levels are; field biologist, district supervisor, bureau chief, hatchery supervisor, and hatchery manager.

Different forms for data entry, viewing and editing were developed for each level. At no time are all fields visible, only the fields needed by an individual users level are shown. This was done to decrease confusion.

Initial requests are entered by the field biologist into the database. Different data entry forms are use for entering lake requests and stream requests. Lakes are selected from a pop-up, look-up table, while streams are selected using a county by county graphical display. Also, for lakes the user enters the number of fish per acre; the total number requested is calculated, but for streams the total number requested is directly entered. If the lake's area is present in the statewide database this figure is automatically used for calculating stocking numbers, otherwise it is entered by the user. Once all requests are entered the data is sent via e-mail to the district supervisor.

Table 1. Field names and description of field content in stocking database.

Field Name	Description of Content	Key Field
Unit	Unit Code from Mgmt-unit table	Yes
WaterCode	Assigned code for waterbody	Yes
SpecieCode	Species code from Species Code table	Yes
SizeReq	Size requested for stocking	Yes
MoReq	Month requested for stocking	Yes
YrReq	Year requested for stocking	Yes
Waterbody	Waterbody name	Yes
Waterbody Type	Waterbody type - Lake, Stream or Trout stream	Yes
County	County number	Yes
NumberReq	Number requested for stocking	No
Reason	Reason or justification for stocking	No
DelveryLocation	Delivery location	No
Survey	Last year waterbody was surveyed	No
Comments	Comments and remarks about stocking needs	No
ApprovedDS	Approved by district supervisor - Yes/No	No
ChangDS	Changed by district supervisor - Yes/No	No
InitalDS	District Supervisor's Initials	No
ApprovedCh	Approved by bureau chief - Yes/No	No
ChangCh	Changed by bureau chief - Yes/No	No
InitalCh	Bureau chief's initials	No
NumberApp	Number approved for stocking	No
SizeApp	Size approved for stocking	No
MoApp	Month approved for stocking	No
YrApp	Year approved for stocking	No
Hatchery	Hatchery assigned for production	No
StockDate	Date stocked	No
StockNumber	Number stocked	No
StockSize	Size stocked	No
StockCondition	Condition of fish at time of stocking	No
StockComment	Additional comments at stocking time	No

The district supervisor reviews each request and has the opportunity to approve, disapprove or change the number, and size of fish requested

The requests are then forwarded to the bureau chief for his approval. At this level, all requests are combined into a single database and sent to the hatchery supervisor.

Requests are automatically assigned a hatchery for production, but the hatchery supervisor can overwrite this assignment. The program automatically summarizes the number requested by species, size, month and hatchery. At this time, the requests are sent to the assigned hatcheries for production. Also, at this time the annual stocking request report is automatically generated.

When the fish are stocked the hatchery personnel enter the date, number and condition of fish stocked into the database. This information is then transmitted to the management biologist by e-mail and automatically entered into the statewide database.

Except for the post stocking hatchery data entry, all other facets of the database were distributed and used for submitting this year's stocking requests. Several bugs were found and other improvements were suggested. These changes will be made during this next year. Also, additional help menus and documentation will be completed.

Fishing Tournament

The tournament database was designed to keep track of fishing tournament permits and reports. In the past, fisheries managers used a fishing tournament permit database created in the DOS environment of Paradox. This database is now being moved to the Windows environment.

As reported by Mitzner (1998), most of the necessary tables, data entry forms and data management routines for the lakes section were completed last year. The forms and tables for streams were completed this year. Also, a routine for sending the database to a central repository via e-mail or on disk has been developed.

The Windows version of the tournament database underwent extensive Beta testing. This testing revealed a number of problems and improvements needed before this version could be released for general use. Most of the bugs appeared when the operator miss-keyed or performed an operation out of order. All known major problems are fixed. A major improvement that still needs to be done is an extensive contact help system. This does not effect the use of the database but greatly improves its user friendliness.

Unfortunately, the Beta testing and improvements were not completed in time for distribution and use of this version during this tournament season. This version will be in place for next season.

Statewide Network

No new post offices were added to the Fisheries Bureau's wide area network this past year, but Bellevue Research Station, Chariton Research Station, Fairport Hatchery and Rathbun Hatchery expanded the number of users on their locale area networks and relocated some of their computers. This required additional wiring to the hub and computer setup. The remaining network assistance was mainly administrative in nature, such as changing user names, removing users from the system, installing users on different computers and moving remote mail users to new locations.

Technical Assistance

Direct technical assistance was provided to field personnel during forty-eight (48) trips to field stations. Seventeen (17) trips involved the installation and instruction for use of the stocking database. Fourteen (14) trips involved network and e-mail maintenance. The remaining field assistance consisted of:

- Minor changes for the commercial fishing database.
- Minor change to the Down Home Monitoring Database.
- Beta testing of the tournament database.
- New hardware, software, macros and database installations.
- Instruction of personnel in the use of hardware and software.
- Recovery of erased files.
- Reinstallation of erased or damaged systems.
- Repair of inoperable hardware.
- Routine maintenance of computers, hard disks, and printers.

Further assistance was provided through a hot line at Chariton to answer questions dealing with computers and computer programs. A total of seventy-three calls were answered during the 1998-1999 period, almost doubling last years thirty-nine (39) calls. Twenty-two (22) calls involved the network and e-mail and thirteen (13) calls where questions about the new stocking database. Also recommendations for new hardware and software were provided via e-mail and phone.

RECOMMENDATIONS:

- Continue development and maintenance of the statewide database.
- Complete the contact help system for the tournament database by October 1999.
- Make suggested changes and improvements to the stocking database by April 2000.
- Provide technical assistance to field personnel by doing the following:
- Maintain a hot line for questions concerning the use of computer software and hardware.
- Provide training on the use of the statewide database.
- Provide training on the use of the stocking request database.
- Provide training on the use of the tournament database.
- Provide training on the use of other databases as needed.
- Provide training on the use of other software as needed.
- Provide training in the use of the network.
- Provide training in the use of Paradox for Windows.

Literature Cited

Mitzner, L. 1998. Microcomputer Training and Support. Federal Aid Performance Report, F-160-R, Des Moines, IA.