IOWA CONSERVATION COMMISSION
FISHERIES SECTION

FEDERAL AID TO FISH RESTORATION

ANNUAL PERFORMANCE REPORT

MAN-MADE LAKES FISHERIES INVESTIGATIONS

PROJECT NO. F-88-R-2

Study No. 501-2: The Relationship of Cage Reared and Released Channel Catfish and Established Fish and Benthos Populations

Study No. 503-4: Life History and Dynamics of Largemouth Bass in Three Man-Made Lakes

Study No. 504-1: Evaluation of Biological Control of Nuisance Aquatic Vegetation by White Amur

PERIOD COVERED 1 JULY, 74 - 30 JUNE, 75

FEDERAL AID TO FISH RESTORATION

ANNUAL PERFORMANCE REPORT

MAN-MADE LAKES FISHERIES INVESTIGATIONS

PROJECT NO. F-88-R-2

Study No. 501-2: The Relationship of Cage Reared and Released Channel Catfish and Established Fish and Benthos Populations

Study No. 503-4: Life History and Dynamics of Largemouth Bass in Three Man-Made Lakes

Study No. 504-1: Evaluation of Biological Control of Nuisance Aquatic Vegetation by White Amur

TABLE OF CONTENTS

Page

STUDY NO.: 501-2 - The Relationship of Cage Reared and Released Channel Catfish and Established Fish and Benthos Populations

JOB NO. 1 - Vital statistics of cage reared and released channel catfish populations -------------------- 1

JOB NO. 2 - Growth and condition of native fish ------------ 8

JOB NO. 3 - Abundance, distribution and population structure of benthos ------------------------------------ 12

STUDY NO.: 503-4 - Life History and Dynamics of Largemouth Bass in Three Man-Made Lakes

JOB NO. 1 - Life history of largemouth bass at three man-made lakes in Iowa ---------------------------------- 16

JOB NO. 2 - Population dynamics of largemouth bass at three man-made lakes in Iowa ------------------------- 25

JOB NO. 3 - Contribution of stocked fingerling largemouth bass to the fishery in two man-made lakes ----------- 33

STUDY NO.: 504-1 - Evaluation of Biological Control of Nuisance Aquatic Vegetation by White Amur

JOB NO. 1 - Standing crop of vascular plants, primary productivity and water quality at Red Haw Lake -- 37

JOB NO. 2 - Vital statistics of white amur in Red Haw Lake -- 51

JOB NO. 3 - Behavioral activity patterns of white amur ------ 57

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE:	Iowa	NAME:	The Relationship of Cage Reared and Released Channel Catfish and Established Fish and Benthos Populations
PROJECT NO.:	F-88-R-2		
STUDY NO.:	501-2		
JOB NO.:	1	TITLE:	Vital statistics of cage reared and released channel catfish populations

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: *Angler catch of released channel catfish was 880 of which 821 were released in 1973. Catfish released in 1971 and 1972 contributed 48 to the catch, while catch of native catfish was 12. Success of catfishermen was .21 catfish per hour and they accounted for 94% of the harvest. Growth of channel catfish was 31 mm (1.2 in) for the fish released in 1972 followed by 28 mm (1.1 in) for those released in 1973. Growth increment for the 1971 release was 19 mm (.8 in). Body condition continued to decrease with mean K-factor of .68 for the 1973 subpopulation. Fish released in 1972 and 1971 had mean condition indices of .77 and .87, respectively. Stomach analysis showed 61% of the stomachs contained < 1 ml of food and 36% were empty. Released catfish relied almost entirely on dipteran larvae for food contributing > 80% to the diet. Chironomus was most important followed by Procladius, Cryptochironomus and Chaoborus. Numerical abundance of channel catfish was 4,594 in April, 1974, but decreased to 852 the following year. Natural mortality ranged from 37% for the 1973 release group to 85% for catfish released in 1971.*

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

STUDY OBJECTIVE

To determine the direct effects of annually stocked cage reared channel catfish at 30 kg/ha on the abundance and species structure of benthic fish food organisms and the indirect effects on growth rate and body condition on indigenous populations of channel catfish and other fish species until the released stock is reduced by natural and fishing mortality to 90 percent of the initial population density.

JOB 1 OBJECTIVE

To determine abundance, mortality rate, standing crop, food habits, growth rate and body condition of released channel catfish into Williamson Pond.

INTRODUCTION

Investigation, to determine the effects of three different groups of released channel catfish on native fish and benthos populations continued in 1974. Unlike past years channel catfish were not cage reared, but population statistics were monitored as before. Measurement of catch statistics, population density, growth, body condition and food habits were continued for each sub-population to evaluate all levels of competition in the entire fish population.

STUDY BACKGROUND

Catch statistics in 1973 showed 3,861 anglers fished 9,528 hours and caught 3,857 fish, of which 1,410 were channel catfish. Fishing success was .14 catfish per hour. Mean lengths of the 1971 and 1972 sub-populations in October, 1973 were 420 mm (16.5 in) and 327 mm (12.9 in). Cage cultured fish in 1973 were released at a mean length of 237 mm (9.3 in). Mean body condition in October for the 1971 group was .74 compared to .83 for the 1972 sub-population. Released channel catfish had mean body condition of .82. There was a general decline in body plumpness after release. By October, 1973, the estimated standing stock of released catfish was 830 kg (1,820 lbs). Food habit studies showed channel catfish consumed mainly insects with dipteran larvae most numerous in the stomach samples, but waste from cage culture was found in 30% of the stomachs. Fish remains were found in larger fish and the sample from the 1971 sub-population showed 80% of the catfish stomachs contained fish remains.

METHODS AND PROCEDURES

Fish were sampled with gill nets, fyke nets and box traps as before using the same regime. Growth and body condition were estimated by the usual age and growth techniques. Food habits methods were identical to past years.

FINDINGS

HARVEST STATISTICS

Anglers caught 2,222 fish at Williamson Pond in 1974. The most frequently caught species was bullhead with 997. Channel catfish were second in importance with 880. Bluegill, largemouth bass and crappie comprised the remaining 353 fish. The catfish harvest was dominated by fish released in 1973 with 821 of the catch. Indigenous catfish and catfish cage reared and released in 1972 each contributed 2.7% to the catch, while catfish released in 1971 comprised 1.4% of the catch. Success of anglers fishing specifically for catfish was .21 catfish per hour, while catch rate of all anglers was .16 catfish per hour. Sixty-nine percent of the anglers were catfishermen and they accounted for 94% of the catfish harvested. Best fishing success occurred in July and August when 85% of the catfish were taken.

GROWTH AND CONDITION

Growth of channel catfish at Williamson Pond in 1974 was greatest for the 1972 release group which had a mean increment of 31 mm (1.2 in) followed by the 1973 sub-population with 28 mm (1.1 in) and the 1971 group with 19 mm (.8 in) (Table 1). By October, 1974, the catfish released in 1971 had attained a mean length of 439 mm (17.2 in) with decreasing size for the 1972 sub-population of 358 mm (14.1 in) and the 1973 release group of 265 mm (10.4 in).

Table 1. Mean length, growth and body condition (K) of channel catfish at Williamson Pond in 1974.

Sub-population	Mean length (mm)	Growth increment (mm)	Body condition
1971 release	439	19	.87
1972 release	358	31	.77
1973 release	265	28	.68

Body condition (K) ranged from .87 for the 1972 sub-population in April to .68 for the 1973 release in September. Catfish released in 1971 increased slightly in body condition. In April mean K was .84, but by September it was .87. The 1972 and 1973 groups decreased in body condition. Condition of the 1972 group went from .87 in April to .77 in September, while condition factors for the 1973 release decreased from .83 to .68.

FOOD HABITS

Eighty catfish stomachs were examined, of which 29 were empty and 20 more contained < 1 ml of volume. Stomachs containing > 1 ml of food material accounted for 39% of the sample, while 7.5% had a volume of > 5 ml.

The most predominant food group consumed by catfish was insects, of which dipteran larvae contributed > 80% to the diet. *Chironomus* was the most frequent item in the stomachs and comprised 56% of the numerical sample. The second most numerous taxa were *Procladius* with 8% and *Cryptochironomus* with 7%. Less important dipterans were *Chaoborus*, *Tanypodinae*, and *Ceratopogonidae*. The most important non-dipteran food groups were *Annelida* and *Ephemaridae*, each contributing approximately 2% to the diet. Fish scales were found in 17% of the stomachs and all those were consumed by the 1973 sub-population. Older fish contained no fish remains in the stomach samples.

Selection of *Chironomus* for food by catfish depended on the period in which the sample was collected. In April, May, mid-July and September electivity indices were positive ranging from +.68 to +.38, but in June and August indices were negative with a mean of -.70. *Procladius*, *Tanypodinae* and *Ephemaridae* had negative electivity indices with means of -.60, -.49 and .27, repectively.

POPULATION ESTIMATES

Numerical abundance of channel catfish was estimated from 24 April-19 June, 1974, and in 1975 from 4-28 April. In 1974, the final cumulative estimate was 4,594 with 95% confidence limits of 3,946-5,498. The estimate a year later showed the population was reduced to 852 with 95% confidence of 583-1,584 (Table 2).

The composition of the population in 1974 was dominated almost entirely by catfish released in 1974 with 4,337. The 1972 release accounted for 152 catfish and the 1971 release, 74. The indigenous population was estimated at 32 fish.

In April, 1975, the composition was approximately the same, but abundance of the sub-population was much less. The 1973 group made up 812 of the population followed by 29 from the 1972 group and 5 each from the 1971 release and native catfish.

SURVIVAL

Overall survival of catfish was computed by dividing the number of catfish in the population in April, 1975 by the total number of catfish stocked. The population of released catfish was 8,291 and the number remaining was 852 yielding an overall survival of slightly over 10%. Annual survival of each release group

Table 2. Population estimates of channel catfish in Williamson Pond in April, 1974 and 1975 with confidence interval at the 95% level.

Date	N captured	Cumulative N marked	Cumulative N recaptured	Population estimate	Confidence interval
1974					
24 April	14	0	0	---	---
26 April	72	14	0	---	---
29 April	269	86	1	24,142	---
2 May	70	354	2	24,461	±14,184
6 May	48	423	8	8,653	± 3,533
8 May	122	457	17	7,351	± 2,367
10 May	173	569	35	6,383	± 1,587
13 May	85	724	47	6,063	± 1,347
15 May	51	796	56	5,813	± 1,206
17 May	41	837	67	5,371	± 1,037
20 May	21	867	69	5,479	± 1,045
21 May	25	884	74	5,408	± 1,003
23 May	59	893	85	5,328	± 933
2 June	108	941	114	4,864	± 753
3 June	78	941	126	4,983	± 740
19 June	26	941	142	4,594	± 648
1975					
9 April	13	0	0	---	---
10 April	16	13	0	---	---
11 April	1	29	0	---	---
15 April	23	30	0	---	---
18 April	23	53	2	1,073	± 623
21 April	43	76	6	888	± 394
24 April	28	119	10	849	± 324
28 April	34	153	17	773	± 249
20 May	16	169	18	852	± 269

was computed by the same procedure ranging from 15% for the 1971 sub-population in 1973 to 52% for the 1973 group (Table 3).

Sources of total mortality were partitioned to annual fishing and natural mortality. Fishing mortality was high for the 1971 release group with 73% and 85% during the first two years after release (Table 3). After that, fishing mortality decreased for all release groups when approximately 17% of available catfish were harvested.

Table 3. Annual fishing (m), natural (n) and total mortality of channel catfish released during three seasons at Williamson Pond.

	1971			1972			1973		
Period	m	n	a	m	n	a	m	n	a
October, 1971-Sept, 1972	.73	0	.73	---	---	---	---	---	---
October, 1972-Sept, 1973	.85	0	.85	.48	.29	.63	---	---	---
October, 1973-Sept, 1974	.16	.39	.49	.16	.76	.80	.18	.37	.48
October, 1974-April, 1975	0	.85	.85	0	.63	.63	0	.63	.63

Natural mortality was low in 1971 and 1972 when harvest was high, but during the summer of 1974 and the winter of 1974-1975 natural mortality accelerated. During 1974 the average natural mortality was 59% and from October, 1974 to April, 1975, 70% of the released catfish succumbed to natural causes.

STANDING STOCK

Standing stock of channel catfish at Williamson Pond in April, 1974 was 921 kg (2,030 lbs) with a density of 80 kg/ha (72 lbs/ac). The 1973 group contributed the greatest with 746 kg (1,645 lbs) followed by the 1972 and 1973 releases with 67 kg (148 lbs) and 55 kg (121 lbs). Standing stock of indigenous channel catfish was 53 kg (117 lbs).

By April, 1975, standing stock declined from 921 kg (2,030 lbs) to 153 kg (338 lbs). The decrease was of the same magnitude for each sub-population with standing stock of 131 kg (289 lbs) for the 1973 release followed by 10 kg (22 lbs) for the 1972 release and 3 kg (7 lbs) for the 1971 release. Native catfish contributed 9 kg (20 lbs) to the standing stock.

DISCUSSION OF FINDINGS

Population statistics strongly indicated biomass of channel catfish cage reared and stocked in Williamson Pond were over carrying capacity. The most extreme change was the increase in natural mortality for the 1972 release group from 29% in 1973 to 76% in 1973 and 63% in the fall and winter of 1974-1975. Other groups showed a similar trend of increased natural mortality.

Body condition and growth rate also decreased as catfish biomass increased. When catfish were released the K-factor was near 1.0, but by October, 1974, mean condition was .77. Body condition of native catfish in 1971 before catfish were released was .92, but in 1974 increased slightly to .98. Growth increment of released catfish was 64% less than indigenous catfish.

Food items in stomach samples were similar during the investigation, but occurrence of empty stomachs increased each year. In 1972, 17% were empty compared to 22% in 1973. Channel catfish with empty stomachs accounted for 36% of the sample in 1974. Also, in 1973 there was a greater occurrence of released catfish consuming food and waste from the cage area. In 1972, 3% of the samples contained catfish food while in 1973, 30% of the fish were eating catfish food and waste near the feeding site.

Maximum standing stock of channel catfish at Williamson Pond was during October, 1973 through April, 1974. At that time natural mortality was greatest and body condition and growth rate were lowest. Food habit studies also showed overall food intake was less and catfish became more dependent on waste from the cage culture program. All biological indicators showed maximum carrying capacity of channel catfish in Williamson Pond was reached prior to October, 1973 probably slightly before the final stocking of catfish.

RECOMMENDATIONS

The investigation will be terminated because the objective was achieved. A study completion report will be prepared.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

PROJECT NO.: F-88-R-2

STUDY NO.: 501-2

JOB NO.: 2

NAME: The Relationship of Cage Reared and Released Channel Catfish and Established Fish Populations

TITLE: Growth and condition of native fish

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: *Growth indices of bluegill and crappie were -46% and 0, respectively. Mean body condition of bluegill was 1.73 and ranged from 1.49-2.15. Condition of crappie was 1.15 with a range of 1.07-1.28. Indigenous channel catfish had a condition index of .98. Growth and body condition of bluegill, crappie and channel catfish since 1971 showed inter- and intra-specific competition was more intense each year after 1,146 kg (2,525 lbs) of cage reared channel catfish were released.*

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

JOB 2 OBJECTIVE

To determine the growth rate and body condition of native channel catfish, bluegill and crappie in Williamson Pond.

INTRODUCTION

During 1971-73, 8,291 channel catfish weighing 1,146 kg (2,525 lbs) were released at Williamson Pond resulting in an increase of the indigenous catfish biomass by 33 kg/ha (30 lbs/ac) each year. Ensuing competition with indigenous fish populations was entirely dependent on the magnitude of exploitation, natural mortality and growth rate of released channel catfish. When exploitation of released fish was high, competition was less intense; but with low exploitation and rapid growth, competition became more intense.

Growth rate and body condition of fish are indicators of population stability with slow growth and low condition factors indicating high levels of competition for life requirements. Growth and body condition of bluegill, crappie and channel catfish were determined in 1974 to assess the competitive effect of an annual stocking of cage reared channel catfish at Williamson Pond.

STUDY BACKGROUND

Mean length of bluegill at age 5 in 1972 was 180 mm (7.1 in) with mean body condition of 2.33. Crappie were 218 mm (8.6 in) at 5 years with mean body condition of 1.41. Native channel catfish growth in 1971 before cage cultured fish were released was 370 mm (14.6 in) for age 5 fish. Mean body condition was .92. Growth indices for preceding years showed 1968 and 1969 below normal, and 1967, 1970 and 1971 above normal.

METHODS AND PROCEDURES

Scales, spines and length-weight measurements were collected as in 1972 with the usual age and growth methods used to estimate growth rate and body condition. Gill nets and box traps were used to capture catfish, while fyke nets were used to sample bluegill and crappie populations.

FINDINGS

Slowest growth for bluegill was during the first year of life with an increment of 42 mm (1.6 in). At ages 2, 3 and 4 mean calculated lengths were 97 mm (3.8 in), 133 mm (5.2 in), and 156 mm (6.1 in) (Table 4). Mean length at age 5 was 182 mm (7.2 in). Deviation from average growth for bluegill in 1974 was 47% below the 8 year average, while body condition was 1.73, ranging from 1.49-2.15.

Table 4. Body condition, growth and mean length of crappie, bluegill and the native sub-population of channel catfish at Williamson Pond in 1974.

	K-factor	Deviation from average growth	$\overline{X}$ length
Bluegill	1.73	-47%	154 (6.1 in)
Crappie	1.15	0	182 (7.2 in)
Channel catfish	.98	[a]	544 (21 in)

[a]Channel catfish not sampled in autumn, 1974.

Mean calculated length of white crappie at age 1 was 59 mm (2.3 in), while age 2 crappie had mean length of 115 mm (4.5 in). Lengths at ages 3-7 were 152 mm (6.0 in), 173 mm (6.8 in), 195 mm (7.7 in), 209 mm (8.2 in) and 228 mm (9 in). Deviation from average growth was 0 in 1974, but condition factor was lower than previous years with 1.15 and a range of 1.07-1.28.

Computation of growth for native channel catfish showed total length was 527 mm (21 in) after 11 years of growth. Slowest growth was during the first year of life with 68 mm (2.7 in). Calculated total length for ages 2-10 were 170 mm (6.7 in), 251 mm (9.9 in), 314 mm (12.4 in), 375 mm (14.8 in), 430 mm (16.9 in), 464 mm (18.2 in), 493 mm (19.4 in), 503 mm (19.8 in) and 524 mm (20.6 in). Mean body condition was .98.

DISCUSSION OF FINDINGS

Population statistics of released channel catfish showed the population biomass of catfish at Williamson Pond was over carrying capacity following a three year cage rearing program. Likewise, indigenous crappie, bluegill and channel catfish populations showed signs of intensified competition since 1971.

Bluegill was most affected with the average body condition decreasing significantly ($P < .05$) from 2.33 in 1972 to 1.73 in 1974. Growth index declined from 0 in 1971 to -47% from mean growth in 1974.

Growth of crappie declined since 1971, but was less than for bluegill. In 1971, growth index was +26% decreasing to -20% in 1972 and then increasing gradually to normal growth in 1974. Body condition declined significantly ($P < .05$) from 1.41 in 1972 to 1.15 in 1974.

Growth of large native catfish was not adversely affected by stocking cage reared catfish. Indigenous channel catfish were above mean growth index with +27%, +6% and +20% for 1971-1973. Likewise, body condition was greater after cage reared catfish were stocked. In 1971, mean K-factor was .92, while in 1974 mean body condition was .98.

Intra-specific competition caused by introducing 1,146 kg (2,525 lbs) of cage reared channel catfish during three years was most apparent for the 1973 release group causing retarded growth, decreased body condition, change in food habits and increased natural mortality. Results of this study segment indicated competition with bluegill was quite severe and further stocking would result in a lowered bluegill density and a smaller fish. Crappie growth and body condition was also reduced. Native channel catfish were not adversely affected since the population was made up of large sized fish which did not compete for food with the stocked fish.

RECOMMENDATIONS

The study was terminated because the objective was achieved. A study completion report will be prepared.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

PROJECT NO.: F-88-R-2

STUDY NO.: 501-2

JOB NO.: 3

NAME: The Relationship of Cage Reared and Released Channel Catfish and Established Fish Populations

TITLE: Abundance, distribution and population structure of benthos

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: *Benthic samples at Williamson Pond were dominated by Chaoborus with 26%, followed by Chironomus with 22% and Procladius with 16%. Thermal stratification in July caused 70% of the benthos to become unavailable to channel catfish. Standing stock of benthos above the thermocline in July was 18 kg/ha (16 lbs/ac) compared to the yearly mean of 39 kg/ha (35 lbs/ac). Evaluation of benthic standing stock and intensity of thermal stratification showed cropping by fish population were a major factor in depleting benthos populations significantly since 1972.*

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

JOB 3 OBJECTIVE

To measure the abundance, distribution and species composition of benthic invertebrate populations used for food by channel catfish.

INTRODUCTION

Benthic invertebrates are the single most important food of cage reared and released channel catfish at Williamson Pond. Catfish were released at 250 mm (10 in) and they fed primarily on immature dipteran larvae for two years. Benthos populations were systematically monitored at Williamson Pond to determine the impact of stocking 1,146 kg (2,525 lbs) of catfish on benthic populations. Water temperature and oxygen profiles were recorded and the distribution and availability of benthos related to catfish food consumption.

STUDY BACKGROUND

Standing stock of benthos above the thermocline was greatest in 1972 with 83 kg/ha (74 lbs/ac) followed by 1971 with 67 kg/ha (60 lbs/ac) and 1973 with 53 kg/ha (47 lbs/ac). Spcies composition of the invertebrates was always dominated by *Chaoborus* with 39% in 1971, 46% in 1972 and 48% in 1973. The next most abundant dipteran was Chironominae contributing about 20% to the samples. Tanypodinae and Annelida each contributed 7-20%, while Ephemaridae, Odonata, Ceratopogonidae and Mullusca comprised the remaining 16-29%.

Thermal stratification was important to the distribution of benthos and in July, 1973, 34% of the substrate was above the thermocline while in August, 1972, 35% of the benthos was above thermocline. In 1971, > 60% of the substrate was available for benthic production.

METHODS AND PROCEDURES

Benthic invertebrates were sampled bimonthly from April-October as before with a core sampler at the 14 locations. The substrate was seived through a No. 30 screen and preserved in 5% formalin for separation and enumeration of invertebrates.

FINDINGS

Benthic samples at Williamson Pond were comprised of 2,651 organisms, of which immature dipterans accounted for 68%. The most numerous dipteran larvae was *Chaoborus* with 26%, while *Chironomus* was second most abundant with 22%. *Procladius* contributed 16% to the samples. Other orders of insects were Ephemeroptera and Odonata, but comprised < 5% of the sample. Annelida and Mollusca contributed 20% and 6% to the sample, respectively.

Thermal stratification influenced the availability of benthos as food for channel catfish. The thermocline developed in mid-May and by mid-June thermocline depth was 1.5 m (5 ft). About 30% of the benthos were available to channel catfish. During ten days in mid-July the thermocline was 1-1.5 m (3-5 ft) with 23% of the substrate above the thermcoline, but during August 53-55% of the substrate was above the thermocline and by October, 94% was above the thermocline.

Vertical distribution of semi-anaerobic dipterans showed they were mainly unavailable to channel catfish. *Chaoborus* and *Chironomus* were most abundant below the thermocline, while Annelida and Mollusca were found almost entirely above the thermocline. *Procladius* and Ephemeroptera were found exclusively above the thermocline. Greater than 80% of the anaerobes were unavailable to catfish, while 44% of the annelids and molluscs occurred below the thermocline.

When available substrate was decreased by shallow stratification the available standing stock of benthos decreased proportionately. Invertebrate biomass above the thermocline decreased from the previous years with a mean of 39 kg/ha (35 lbs/ac) (Table 5). Greatest biomass was 73 kg/ha (65 lbs/ac) in early August, while lowest standing stock was 18 kg/ha (16 lbs/ac) in mid-June.

Table 5. Standing stock of benthic invertebrates in kg/ha above the thermocline at Williamson Pond.

Date	1971	1972	1973	1974
1 June	53	91	67	53
15 June	83	21	55	18
1 July	18	102	2	35
15 July	32	122	43	18
1 August	206	96	61	73
15 August	65	65	38	37
1 September	49	42	56	31
15 September	61	106	72	40
1 October	19	66	79	43
15 October	86	123	58	47
Mean	67	83	53	39

DISCUSSION OF FINDINGS

Available benthos abundance at Williamson Pond was greatly affected by depth of the thermocline, total benthic biomass and intensity of cropping by fish. The former factors were similar during the investigation and analysis of variance showed total benthic biomass and substrate area above the thermocline were not significantly different ($P > .05$).

The greatest change in benthic biomass occurred above the thermocline. Benthos availability in 1974 was significantly less ($P < .05$) than in previous years. Standing stock above the thermocline was greatest in 1972 with 83 kg/ha (74 lbs/ac), but decreased systematically to 53 kg/ha in 1973 and 39 kg/ha (35 lbs/ac) in 1974.

Reduction in benthic standing stock by fish was substantiated by food habit studies of released channel catfish. They were wholly dependent on benthos for food. Later, catfish became omnivorous and the volume of food in the stomachs decreased steadily each year. In 1972, empty stomachs accounted for 17% of the sample, while in the two successive years the value increased to 22% and 36%. In 1974, 61% of the stomachs contained < 1 ml of food. Indigenous fish populations that also competed for benthic food showed significantly lower body condition and growth, particularly bluegill and crappie. Annual stocking of channel catfish at 33 kg/ha (30 lbs/ac) had an adverse affect on the benthic population causing intense competition which, in the long term, affected both released catfish and native fish populations.

RECOMMENDATIONS

The investigation will be terminated because the study objective was achieved. A study completion report will be prepared.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

NAME: Life History and Dynamics of Largemouth Bass in Three Man-Made Lakes

PROJECT NO.: F-88-R-2

STUDY NO.: 503-4

TITLE: Life history of largemouth bass at three man-made lakes in Iowa

JOB NO.: 1

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: *Length-weight regressions for largemouth bass at Red Haw and Bobwhite Lakes were described. At Red Haw Lake the regression coefficient was 3.1043, while at Bobwhite Lake the value was 3.1900. Regression analysis showed there was no difference in coefficients between populations. Mean condition factor (K) of bass at Red Haw Lake was 1.52 and ranged from 1.25-1.67, while body condition for bass at Bobwhite was 1.44 with a range of 1.24-1.68. Body condition of bass at Bobwhite Lake remained unchanged since 1971, while condition factor of Red Haw bass gradually increased. Growth rate was greatest at Bobwhite Lake; mean length was 354 mm (14 in) at age 5. Red Haw Lake bass had a mean length of 321 mm (12.5 in). Density of largemouth bass was greatest at Red Haw, but bass grew slower and body condition was poorer.*

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

STUDY OBJECTIVE

To compare growth rate, body condition, length-weight relationship, age structure, natural mortality rate, exploitation rate and standing crop of adult largemouth bass populations and compare the contribution of stocked fingerling bass to the fishery at Red Haw Lake, Green Valley Lake and Bobwhite Lake which are characteristic of three distinct lake types, each having unique physical, chemical and biological characteristics.

JOB 1 OBJECTIVE

To determine the difference in life history statistics of largemouth bass including growth rate, body condition and length-weight relationship in three man-made lakes with different physical, chemical and biological characteristics.

INTRODUCTION

Largemouth bass provide a dual function in man-made impoundments. They are the most important piscivorous predator and provide many hours of angling recreation. Intensive management and hatchery efforts are required to maintain populations at levels adequate for the sport fishery, and yet maintain an effective predator stock. Management of largemouth bass is predicted on an accurate knowledge of life history and population statistics. The main emphasis of management is stocking new and renovated lakes with advanced fry, imposing size limits on new and renovated lakes, statewide catch regulations and to a lesser degree supplemental stocking of fingerling bass in established populations. Regardless of the techniques used to manage bass populations vital statistics are an integral part of the management decision to assure success.

Management of bass populations are based on accurate statistics, but most important they must be applicable to specific populations. These statistics might be compiled for each lake, but with more than 100 lakes under management agreement the logistics become unrealistic. The premise of this investigation was to determine largemouth bass population statistics at different lake types based on physical and chemical characteristics which included area development, volume development, basin slope and thermal stratification. Lakes in this investigation were selected from three basic classification types.

Measurement of population statistics for largemouth bass was continued in 1974, but the study at Green Valley Lake was terminated because the water level was reduced for spillway repair and the fish populations killed with Fintrol.

STUDY BACKGROUND

Length-weight relationships, condition factors, age structure and growth rates were determining at Red Haw, Green Valley and Bobwhite Lakes in 1971-1973. Length-weight relationships were similar between populations and years, but condition factors (K) were significantly different ($P < .05$) and varied from a mean of 1.39 for bass at Red Haw in 1971 to 1.75 at Green Valley in 1973. Mean condition at Red Haw in 1972 and 1973 was 1.43 and 1.48. Condition factors at Bobwhite Lake were intermediate with means of 1.52, 1.54 and 1.56 in 1971-1973.

Growth rate at Red Haw was slower, while bass at Green Valley grew faster. Weight of bass at age 4 for Red Haw Lake was 457 g, while mean weight of age 4 bass at Green Valley Lake was 679 g and bass at Bobwhite Lake were intermediate at 515 g.

METHODS AND PROCEDURES

Fish populations were sampled using procedures identical to those in 1971-1973. Age, growth, condition factors and length-weight regressions were computed as before by standard age and growth techniques.

FINDINGS

RED HAW LAKE

Length-weight regression of largemouth bass at Red Haw Lake was

$$\log_{10}W = -5.0754 + 3.1043 \log_{10}TL$$

where W was weight in g and TL was total length in mm. Correlation coefficient of the relationship was .98.

Condition factors (K) were determined for 90 largemouth bass in 14 size groups. Indices ranged from 1.25 for the 136-161 mm size class to 1.67 for the 486-511 size class (Table 1). Mean condition index was 1.52 with one standard error of $\pm$ .01.

Body-scale regression used to estimate lengths during previous years of growth was

$$TL = -.08 + 2.54\ ScR$$

where TL was total body length in mm and ScR was scale radius in mm magnified 27 times.

Growth rate was greatest during the first year of life with a mean of 96 mm (3.8 in) (Table 2). Growth rate progressively decreased after age 1. Age 2 mean length was 163 mm (6.4 in), followed by 221 mm (8.7 in), 275 mm (10.8 in), 321 mm (12.6 in), 365 mm (14.3 in), 414 mm (16.3 in), 444 mm (17.4 in) and 468 mm (18.4 in) for ages 3-9 (Figure 1).

Table 1. Condition factors of largemouth bass at Red Haw Lake, 1971-74.

Class interval (mm)	1971	1972	1973	1974
111-136	1.21	[a]	1.67	[a]
136-161	1.25	.82	1.50	1.25
161-186	1.37	1.25	1.67	1.55
186-211	1.45	1.57	1.63	1.51
211-236	1.45	1.83	1.46	1.52
236-261	1.51	[a]	1.48	1.54
261-286	1.52	[a]	1.43	1.54
286-311	1.42	1.32	1.42	1.57
311-336	1.46	1.47	1.41	1.48
336-361	[a]	1.49	1.36	1.37
361-386	1.54	1.40	1.48	1.59
386-411	[a]	1.45	1.43	[a]
411-436	[a]	[a]	1.46	1.52
436-461	[a]	[a]	1.27	1.64
461-486	1.25	[a]	1.60	1.58
486-511	1.29	[a]	1.49	1.67
511-536	[a]	[a]	1.65	[a]
536-561	[a]	1.65	1.28	[a]

[a]No fish captured in class interval.

Table 2. Estimated total length (mm) and weight (g) of largemouth bass at the end of each year of life at Red Haw Lake.

		Year of life								
Year class	Number	1	2	3	4	5	6	7	8	9
1973	19	137								
1972	19	96	224							
1971	12	92	170	246						
1970	20	90	147	224	296					
1969	7	97	154	221	278	322				
1968	4	107	158	215	267	313	347			
1967	3	78	162	224	279	340	383	412		
1966	4	81	143	202	269	329	375	416	442	
1965	2	85	146	216	260	301	355	416	446	468
Mean length		96	163	221	275	321	365	414	444	468
Mean length increment		96	67	58	54	46	44	49	30	24
Mean weight		12	62	159	313	509	755	1,120	1,388	1,620

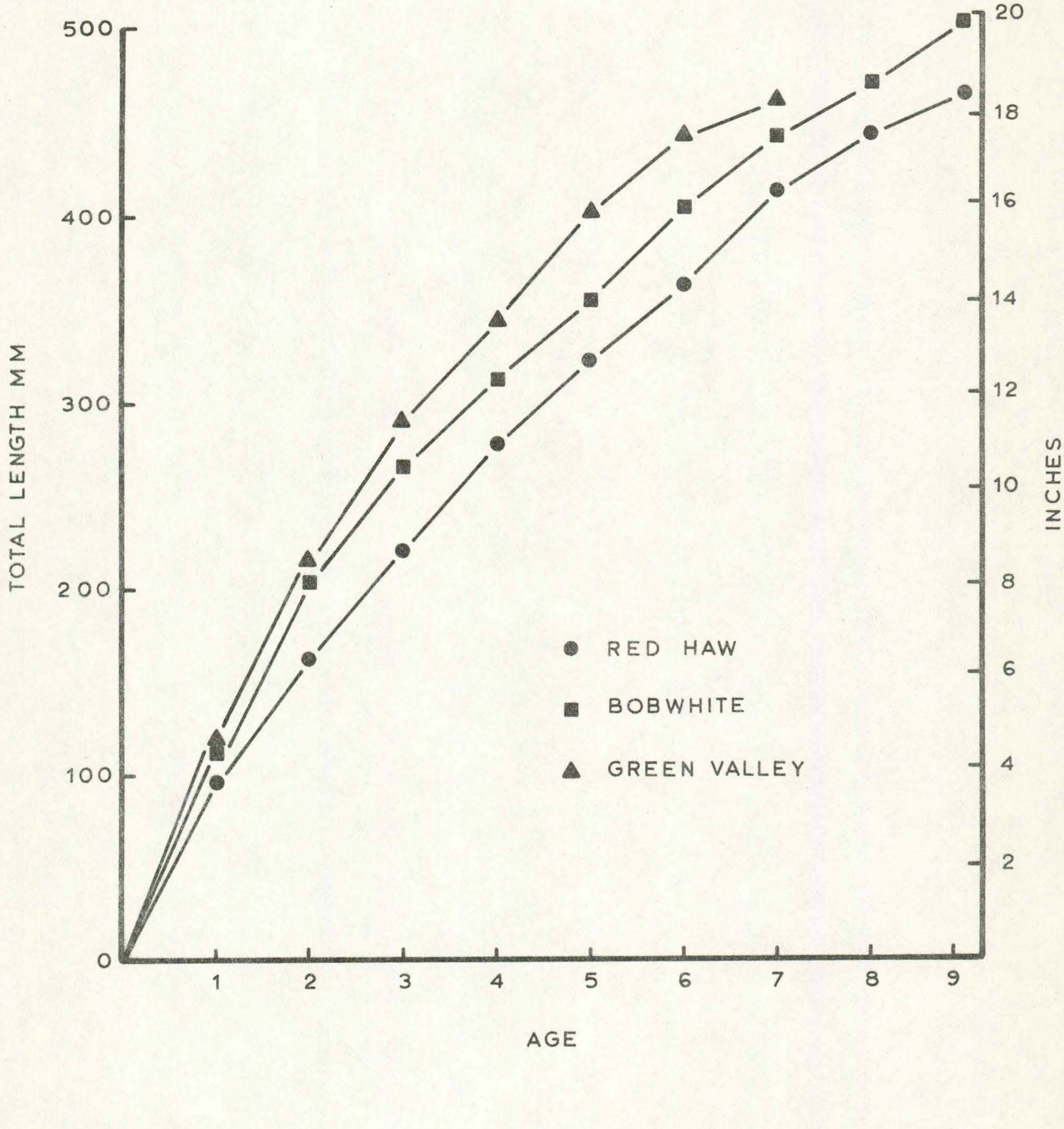

Figure 1. Growth in length of largemouth bass at three Iowa lakes.

Growth in weight was greatest during the seventh year of life when mean increment was 365 g (.81 lbs) (Figure 2). Growth in weight was slowest during the first year at 12 g (.03 lbs). Growth increased to 62 g (.14 lbs) by age 2 followed by 159 g (.35 lbs), 313 g (.69 lbs), 509 g (1.12 lbs), 755 g (1.66 lbs), 1,120 g (2.47 lbs), 1,388 g (3.06 lbs) and 1,620 g (3.57 lbs) for ages 2-9 (Table 2).

BOBWHITE LAKE

Length-weight regression for bass at Bobwhite Lake was

$$\log_{10}W = -5.3193 + 3.1900 \log_{10}TL$$

where the measurement units were the same as before. Coefficient of correlation for the regression was .98.

Condition factors (K) were measured for 92 largemouth bass grouped by 25 mm (1 in) class intervals. Poorest body condition was 1.24 for the smallest class, while greatest condition index was 1.68 for the largest class (Table 3). Mean condition factor was 1.44. As bass increased in length condition factor was generally larger.

Table 3. Condition factors of largemouth bass at Bobwhite Lake, 1971-74.

Class interval (mm)	1971	1972	1973	1974
111-136	1.27	a	a	a
161-186	1.75	1.70	a	a
186-211	1.52	a	a	1.24
211-236	1.55	1.48	1.43	1.47
236-261	1.23	1.43	1.41	1.40
261-286	1.64	1.52	1.42	1.31
286-311	1.53	1.59	1.50	1.34
311-336	1.50	1.52	1.48	1.44
336-361	1.59	1.52	1.58	1.48
361-386	1.46	1.56	1.50	1.37
386-411	1.45	1.50	1.53	1.44
411-436	1.48	1.53	1.52	1.56
436-461	1.46	1.50	1.62	1.48
461-486	1.55	1.48	1.67	1.57
486-511	1.74	1.56	1.70	1.68
511-536	1.59	1.67	1.63	a
536-671	a	1.57	1.81	a

[a]No fish captured in class interval.

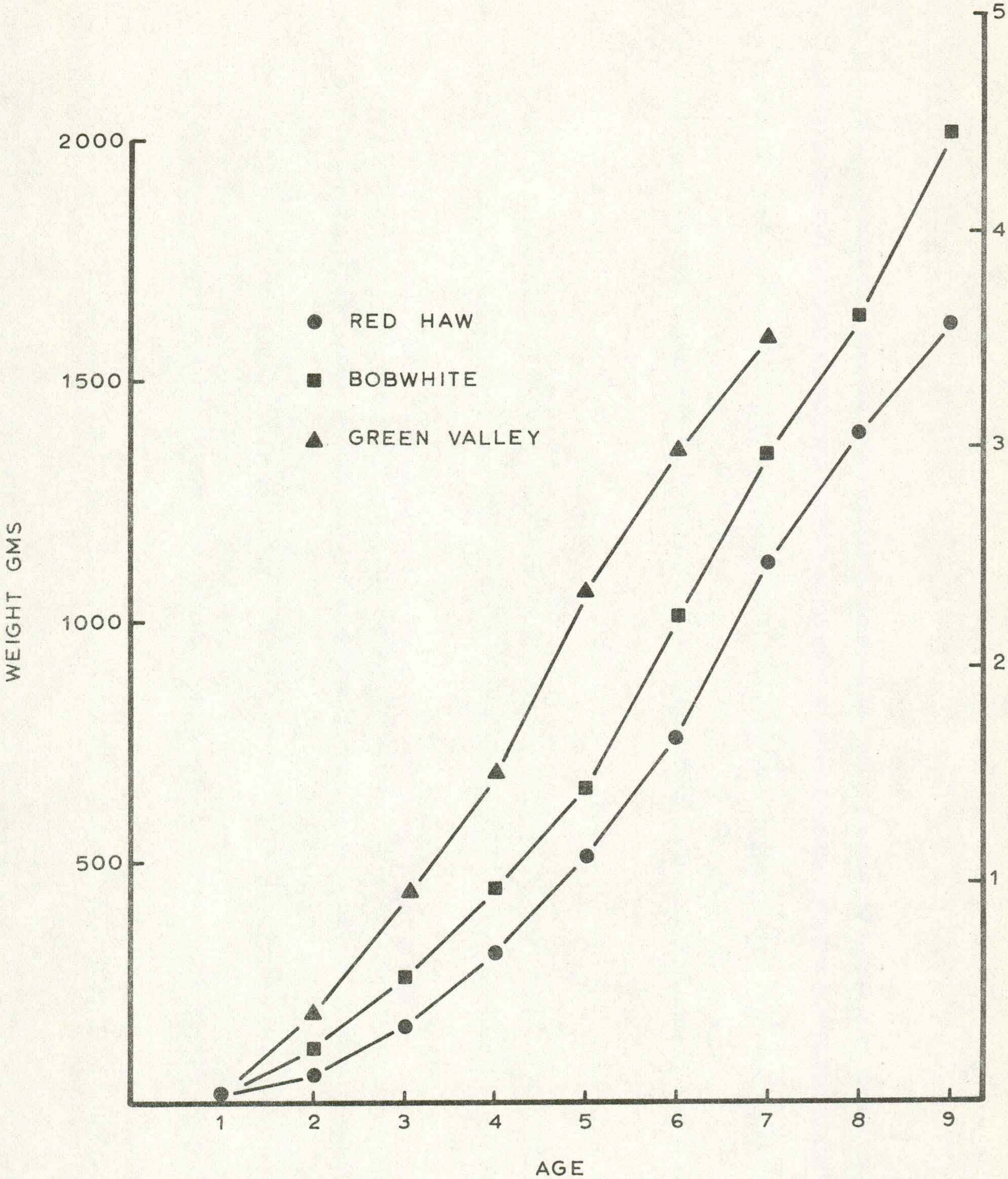

Figure 2. Growth in weight of largemouth bass at three Iowa lakes.

Growth rate of bass at Bobwhite Lake was greatest during the first year of life and then declined rapidly. Age 1 bass were 123 mm (4.8 in) compared to an increment of 85 mm (3.3 in) the second year (Table 4). By age 3 bass attained 269 mm (10.6 in) followed by 314 mm (12.4 in), 354 mm (13.9 in), 407 mm (16.0 in), 445 mm (17.5 in), 472 mm (18.5 in), and 505 mm (19.9 in) for ages 4-9 (Figure 1).

Table 4. Estimated total length (mm) and weight (g) of largemouth bass at the end of each year of life at Bobwhite Lake.

		Year of life								
Year class	Number	1	2	3	4	5	6	7	8	9
1972	31	118	216							
1971	7	110	210	289						
1970	7	118	205	262	308					
1969	22	119	189	244	295	325				
1968	16	125	199	261	305	340	379			
1967	4	126	217	273	321	365	403	429		
1966	1	122	199	256	302	344	398	428	455	
1965	4	145	232	297	351	398	450	477	490	505
Mean length		123	208	269	314	354	407	445	472	505
Mean length increment		123	85	61	45	40	53	38	27	33
Mean weight		22	120	266	445	652	1,018	1,352	1,631	2,023

Weight increased most during the seventh and eighth years of life when increments were 366 g (.81 lbs) and 334 g (.74 lbs), respectively. Slowest growth was during age 1 with 22 g (.05 lbs) (Figure 2). At age 2 bass at Bobwhite Lake were 120 g (.26 lbs) followed by 266 g (.59 lbs), 445 g (.98 lbs), 652 g (1.44 lbs), 1,018 g (2.24 lbs), 1,352 (2.99 lbs), 1,631 g (3.61 lbs) and 2,023 g (4.47 lbs) for ages 3-9.

DISCUSSION OF FINDINGS

Length-weight regression coefficients of largemouth bass were compared by regression analysis. At Red Haw Lake the length-weight regression coefficient increased significantly ($P < .05$) from 2.9117 in 1973 to 3.1043 in 1974, but was not significantly different ($P > .05$) from regression coefficients of bass at Bobwhite Lake. The only years Red Haw and Bobwhite were different ($P < .05$) were in 1971 and 1972. Length-weight regression coefficient of bass at Red Haw in 1971 was 3.2159, while for bass at Bobwhite in 1971 and 1972 the constants were 3.0190 and 3.0101.

Body condition of bass at Red Haw continued to increase, while bass at Bobwhite decreased slightly in body plumpness. For the first time since 1971 bass at Red Haw Lake had better body condition than bass at Bobwhite Lake, but the difference was not significant ($P > .05$).

Growth rate was greatest at Bobwhite Lake. After seven years of growth mean length and weight of bass at Bobwhite Lake was 445 mm at 1,352 g. Bass of the same age at Red Haw were 414 mm at 1,120 g. Maximum difference in weight occurred at age 5 when bass at Bobwhite Lake were 22% heavier than the same age bass at Red Haw Lake.

Findings of this investigation showed growth rates differed greatly between the study lakes. Growth potential of largemouth bass was limited by physical and chemical characteristics, but was also related to the density of largemouth bass as discussed in the following study segment. Growth rate was slowest where density was greatest. Ultimately physical and chemical factors are of primary importance because they also control density of bass by affecting reproduction and survival of young.

Body condition and length-weight relationships were different between lakes, but the magnitude of difference was much less compared to growth. There was a trend of better body condition for bass at Red Haw Lake and surpassed the mean K-factor of bass at Bobwhite Lake in 1974. Condition of bass at Bobwhite Lake was fairly stable.

RECOMMENDATIONS

This study segment will be continued one additional year.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

PROJECT NO.: F-88-R-2

STUDY NO.: 503-4

JOB NO.: 2

NAME: Life History and Dynamics of Largemouth Bass in Three Man-Made Lakes

TITLE: Population dynamics of largemouth bass at three man-made lakes in Iowa

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: *Angler harvest of bass at Red Haw Lake was 1,521 fish weighing 567 kg (1,251 lbs) compared to 20 bass weighing 7.6 kg (17 lbs) at Bobwhite Lake. Population density at Red Haw was greater than at Bobwhite, but turbidity was high at Bobwhite causing low catch success. Success at Red Haw was .32 bass per hour, while catch at Bobwhite was .20 bass per hour. Total annual mortality of Red Haw Lake bass was 45% compared to 40% for Bobwhite bass. Natural mortality of Bobwhite bass was 38%, while the value for Red Haw was < 15%. The population at Bobwhite Lake had a fast growth rate, good body condition, low exploitation and low density; the opposite was true of the bass population at Red Haw Lake.*

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

JOB 2 OBJECTIVE

Determine the difference in population dynamics of largemouth bass including population size, standing crop, age structure and exploitation of largemouth bass in three man-made lakes with different physical, chemical and biological characteristics.

INTRODUCTION

Measurement of population statistics for largemouth bass were continued in 1974. Catch statistics were added to the project at Red Haw and Bobwhite Lakes. Population estimates, age distribution, annual survival, fishing mortality, natural mortality, and standing stock were determined as before at Bobwhite Lake. Population estimates and related statistics at Red Haw Lake were not completed. Other population statistics were measured as before except at Green Valley Lake where the fish population was killed as explained in the previous study segment.

STUDY BACKGROUND

Numerical abundance of largemouth bass at Red Haw Lake in 1974 was 57 per ha (23 per ac), while abundance at Bobwhite and Green Valley Lakes was 9.4 per ha (3.8 per ac) and < 1 per ha (< .5 per ac). Survival at Red Haw Lake was 61%, while at Bobwhite it was 68%. Total catch of bass at Red Haw in 1971 was 1,251 with an exploitation of 54%. Standing stock at Red Haw was dominated by age 4 bass in 1973 and contriubted 19.5 kg/ha (17.7 lbs/ac) to the total biomass which was 26.7 kg/ha (24.2 lbs/ac). At Bobwhite Lake standing stock was 8.2 kg/ha (7.5 lbs/ac) with ages 7 and 8 contributing most to biomass.

METHODS AND PROCEDURES

Sampling methods remained the same as before. Catch statistics in 1974 were estimated from creel survey information and were identical to the procedure used in 1971.

FINDINGS

RED HAW LAKE

Population estimates at Red Haw Lake commenced on 2 April and continued through 12 June. Electrofishing was discontinued in June because white amur failed to recover after being shocked. During the period 86 bass were captured, 66 were marked and one marked fish was recaptured. No valid population estimate was made for the year.

Angler harvest at Red Haw Lake from 15 April-29 September was 1,521 largemouth bass weighing 567 kg (1,251 lbs). Fishing use at the lake in 1974 was 5,708 anglers with an effort of 11,902 hours. Anglers fishing specifically for bass caught 55% of the bass, but accounted for 18% of the people and 17% of the fishing effort. Catch success of bass fishermen was .32 bass per hour. Mean length of the bass caught was 295 mm (11.6 in) with mean weight of 373 g (.82 lbs). Highest catches were in mid-May, late June and late August accounting for 46% of the bass that were caught. Lowest success was in mid-July and September when 4% of the bass were harvested.

Age structure of largemouth bass at Red Haw Lake was dominated by age 1, 2 and 4 bass. Combined age groups contributed 64.4% to the electrofishing sample (Table 5). Age 3 bass were next most abundant and comprised 13.3% of the sample followed by age 5 with 7.7%, ages 6 and 8 with 4.4%, age 7 with 3.3% and age 9 with 2.2%.

Table 5. Age distribution of largemouth bass at Red Haw Lake for 1971-1974.

Year class	Sample year 1974	1973	1972	1971
1973	19			
1972	19	9		
1971	12	25	14	
1970	20	23	8	76
1969	7	283	9	29
1968	4	17	2	12
1967	3	8	0	7
1966	4	9	0	1
1965	2	3	1	0
1964				0
1963				2

Age distribution in 1974 was combined with other sample years by the virtual population method and survival computed from age frequency. Regression of the descending limb of the curve from age 2-9 was

$$\log_e Y = 4.333 - 0.588\ X$$

where Y was the transformed frequency of largemouth bass and X was age of the fish (Figure 3). Total instantaneous mortality rate was .59 with total annual mortality of 45%.

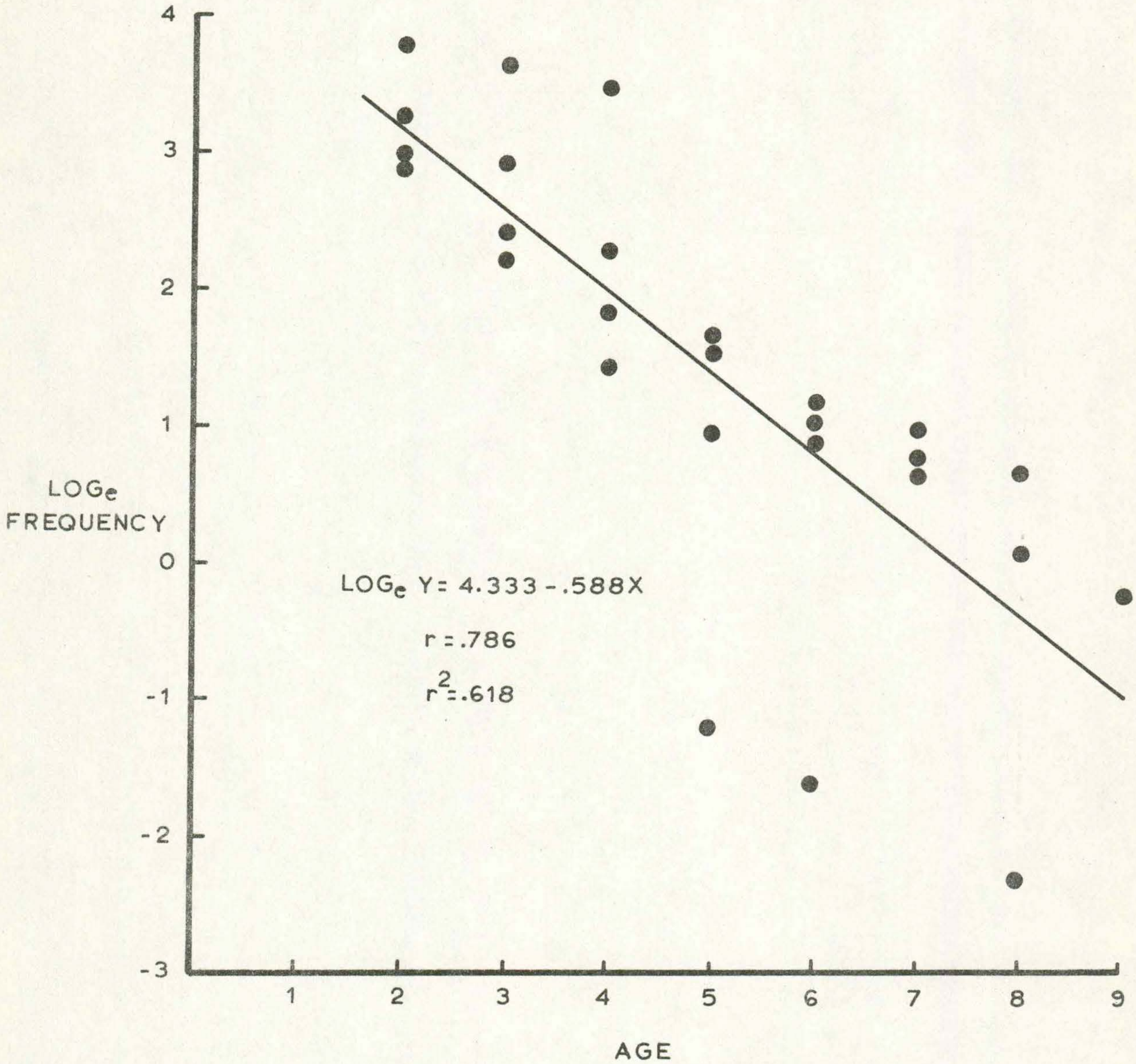

Figure 3. Catch curve of largemouth bass at Red Haw Lake from age structure in 1971-1974.

Fishing mortality was not computed because it was a function of the population estimate which was not completed. Natural mortality could not be computed because of its relationship to fishing mortality.

Standing stock of largemouth bass at Red Haw was computed as a relative biomass distribution of the stock and was estimated by the product of age composition and mean weight for each age. For example, 100 bass at Red Haw weighed 19.8 kg (44 lbs) with age 3 and 4 bass contributing most to the stock with 2.9 kg (6.4 lbs) and 3.1 kg (6.9 lbs). Distribution of standing stock for age 1 bass was .4 kg (.9 lbs); age 2, 1.6 kg (3.5 lbs); age 5, 2.7 kg (6 lbs); age 6, 2.5 kg (5.5 lbs); age 7, 2.5 kg (5.5 lbs); age 8, 2.8 kg (6.2 lbs) and age 9, 1.3 kg (2.9 lbs).

BOBWHITE LAKE

Population estimates of largemouth bass at Bobwhite Lake started on 22 April and continued through 18 September. Eighty-two bass were marked, 111 were examined, of which 6 were marked. The cummulative population estimate was 746 with 95% confidence limits of 530-1,261.

Harvest at Bobwhite Lake during the same period was 20 bass weighing 7.6 kg (17 lbs). Angler use at Bobwhite Lake was 1,697 trips with effort of 1,574 hours. Bass fishermen made 105 trips to the lake and fished 65 hours catching 10% of the bass. Catch success for bass fishermen was .20 fish per hour and mean length of the catch was 292 mm (11.5 in) at 380 g (.84 lbs). Fishing mortality of bass was computed as the total catch divided by numerical abundance or 2.7%.

Age 2 and 5 bass were most numerous in the sample at Bobwhite Lake with 34% and 24% of the sample, respectively (Table 6). Age 6 was next most numerous followed by ages 3, 4, 7, 9 and 8.

Table 6. Age distribution of largemouth bass at Bobwhite Lake in 1971-1974.

Year class	Sample year			
	1974	1973	1972	1971
1972	31			
1971	7	11	2	
1970	7	15	14	8
1969	22	24	12	2
1968	16	17	11	23
1967	4	13	23	12
1966	1	16	12	9
1965	4	14	7	8
1964		5	10	5
1963		2	1	5
1962				2

Survival of bass at Bobwhite Lake was computed identical to the Red Haw Lake method with a regression equation of

$$\log_e Y = 5.277 - 0.520\ X$$

from ages 3-9 for variables as before (Figure 4). Total instantaneous mortality rate was .52 and annual mortality was 40%.

Natural mortality of bass at Bobwhite Lake was computed by solving for n in the equation

$$a = m + n - mn$$

where a is total annual mortality, m is fishing mortality and n is natural mortality.

$$n = \frac{.400 - .027}{1 - .027} = .38 \text{ or } 38\%$$

Standing stock of largemouth bass at Bobwhite Lake was estimated as the product of numerical abundance and mean weight of age groups 2-9. Age group 6 contributed most to the standing stock with 132 kg (290 lbs) followed in order by age 5 with 116 kg (256 lbs); age 9, 65 kg (143 lbs); age 7, 43 kg (95 lbs); age 2, 30 kg (66 lbs); age 4, 25 kg (55 lbs); age 3, 15 kg (33 lbs); and age 8, 13 kg (29 lbs). Standing stock of combined age groups was 441 kg (975 lbs) or 10.7 kg/ha (9.8 lbs/ac).

DISCUSSION OF FINDINGS

Differences in population statistics between Bobwhite and Red Haw Lakes were far greater than differences in growth and body condition. The greatest contrast between the lakes were catch statistics. Angler harvest of bass at Red Haw was 76 times greater than at Bobwhite. The most obvious reason for the disparity in total catch was the difference in density of bass between Red Haw and Bobwhite. At Bobwhite Lake standing stock was 18 bass/ha (7.5/ac), while at Red Haw Lake the stock was probably near the 1973 level at 57 bass/ha (23/ac).

Differences in density were great, but not of the magnitude to account for the difference in catch and fishing pressure between lakes. More apparent was the high turbidity and lack of fishing success at Bobwhite Lake. Success was so poor at Bobwhite Lake bass anglers required 5 hours to catch one fish. Chronic turbidity was an important factor contributing to the low success. Poor success was undoubtedly responsible for lack of interest in bass fishing at Bobwhite Lake. Consequently, total effort at the lake was much lower. At Red Haw Lake 2,023 hours of effort were expended wholly on bass fishing compared to 64 hours of bass fishing effort at Bobwhite Lake.

Total annual survival of bass populations at the study lakes were similar, but natural mortality of bass at Bobwhite Lake was much higher than at Red Haw. Annual natural mortality at Bobwhite was 38% with total mortality of 40%. Natural mortality at Red Haw Lake was low as shown by the estimates in 1973 when angler

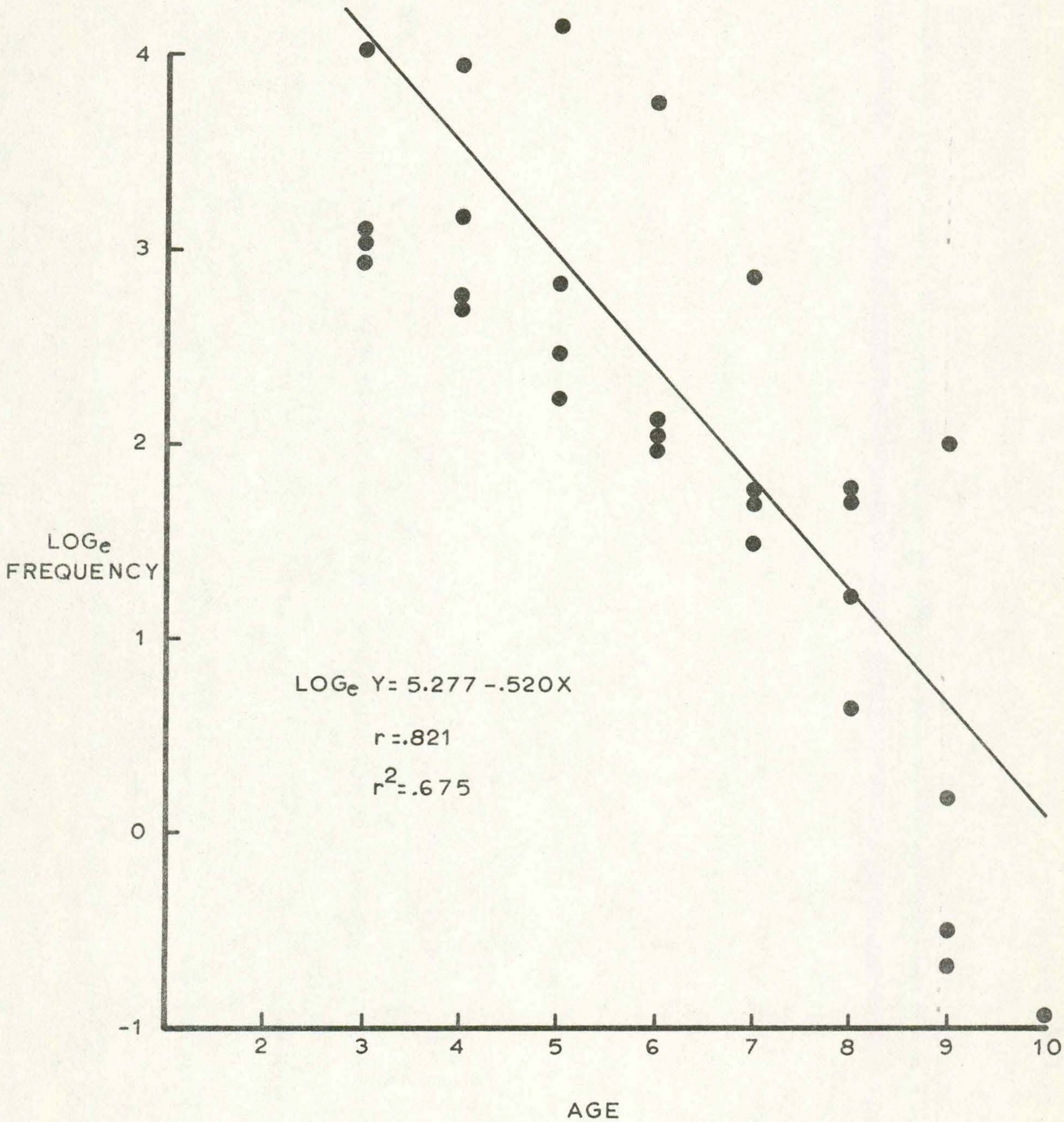

Figure 4. Catch curve of largemouth bass at Bobwhite Lake from age structure in 1971-1974.

catch was greater than population estimates. Natural mortality was negligible even when the catch was adjusted to exclude small bass which weren't marked in the population estimate.

Partitioning of total annual mortality showed largemouth bass at Bobwhite Lake had low exploitation and high natural mortality compared to the bass population at Red Haw with high exploitation and low natural mortality. Overall, total annual mortality at both lakes was similar with 40% at Bobwhite and 45% at Red Haw.

RECOMMENDATIONS

This study segment will continue one additional year.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

PROJECT NO.: F-88-R-2

STUDY NO.: 503-4

JOB NO.: 3

NAME: Life History and Dynamics of Largemouth Bass in Three Man-Made Lakes

TITLE: Contribution of stocked fingerling largemouth bass to the fishery in two man-made lakes

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: *Catch effort of age 0 largemouth bass in seine hauls at Red Haw Lake was 4.7 fish per haul (F/H). Lowest catch was in August with 3.5 F/H and highest catch was 5.8 F/H in September. At Bobwhite Lake catch effort ranged from 0 F/H in July to 5.8 F/H in August. Previous to the August sample 5,270 marked largemouth were stocked at Bobwhite Lake. The high catches in August were significantly greater than other periods and were due entirely to stocked fingerlings. Results of three experimental stockings showed catch effort of bass increased at Bobwhite Lake where density of young bass was normally low. Stocking at Red Haw, where natural reproduction and survival was higher, had no measurable effect on 0-age bass populations.*

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

JOB 3 OBJECTIVE

Determine the contribution of fingerling largemouth bass stocked at a rate of 250 per ha to the fishery at two man-made lakes with different physical, chemical and biological characteristics.

INTRODUCTION

Poor fisheries are often the result of poor survival of predator species and particularly their progeny. If reproduction and survival of the terminal consumer group is consistantly low the whole fishery will ultimately deminish in importance. Largemouth bass populations with low reproductive success are prime examples of how problem fisheries develop. Supplemental stocking of fingerling bass in the fall is one method to attempt increasing the 0-age stock and ultimately the adult population. Experimental stocking and evaluation of 0-age bass abundance commenced at three lakes in 1971 to evaluate the effect of the supplemental stocking method in Iowa.

Year class abundance of age 0 bass were monitored at Red Haw, Bobwhite and Green Valley Lakes in 1971-1973 followed by experimental stocking at Red Haw and Bobwhite Lakes in 1973. Seine sampling and experimental stocking continued in this segment as before except at Green Valley Lake where the fish population was killed with Fintrol.

STUDY BACKGROUND

Apparent abundance of young largemouth bass ranged from 0 bass per seine haul (F/H) at Green Valley in 1971 to 5.4 F/H at Red Haw in 1972. Abundance indices at Bobwhite Lake ranged from .8 F/H in 1973 to 1.4 F/H in 1971. Mean catch of young bass at Red Haw Lake was significantly greater ($P < .05$) in 1972, while yearly indices at the other lakes were not different ($P < .05$). Sampling in 1973 showed catches were significantly greater at Bobwhite after fingerling bass were stocked, but abundance at Red Haw Lake remained about the same after stocking.

METHODS AND PROCEDURES

The sampling regime and gear used in 1974 were identical as other years. Seining commenced in early July and continued monthly through September at four sites for each study lake. On 6 August, 5,270 largemouth bass fingerlings were stocked at Bobwhite Lake after excising the left pectoral fin so they could be identified in seine samples at later dates. Mean length and weight was 103 mm (4.1 in) at 15 g (30 per lbs).

FINDINGS

Apparent abundance of 0-age largemouth bass was systematically measured at Red Haw and Bobwhite Lakes by seining monthly at four sites for each lake in July-September. Catch statistics were transformed to $\log_{10}X + 1$ and evaluated by analysis of variance in catch means.

Seine haul catches at Red Haw ranged from one bass at site 1 in August to 16 at the same site in September; overall mean was 4.7 bass per haul (F/H). Greatest catch was in September with a mean of 5.8 F/H, while the sample in August was lowest with 3.5 F/H (Table 7). Mean catch in July was 4.8 F/H. Catch analysis showed no significant differences ($P > .05$) in mean catch between stations or periods.

Seine haul indices at Bobwhite Lake in 1974 had an overall mean of 2 F/H, but ranged from 0 at all sites in July to 12 F/H at site 1 in August. Bass per haul was far greater in August with a mean of 5.8 F/H (Table 7). All bass in the seine hauls in August were identified as stocked fish. Catches in July and September were 0 and 1, respectively. Analysis of variance showed the difference in mean F/H in seine hauls between months was significant ($P < .01$) and the high value in August was due entirely to stocked fingerling bass.

Table 7. Apparent abundance of 0-age largemouth bass in numer per seine haul at two man-made impoundments.

	Red Haw			Bobwhite		
	July	August	September	July	August	September
1971	.3	.3	.3	2.5	1.3	.5
1972	8.5	2.3	5.0	2.3	1.0	.3
1973	0	.3	1.5	0	.5	1.8
1974	4.8	3.5	5.8	0	5.8	.3

Electrofishing gear was used to capture yearling bass stocked in 1973 by examination for right pectoral fin excision. At Red Haw Lake 90 bass were sampled, of which 19 were yearling bass, and none were fin clipped. At Bobwhite Lake 92 bass were captured and none were age 1.

DISCUSSION OF FINDINGS

Catch effort of young largemouth bass by shore seining was used to determine relative year class abundance at the two study lakes in 1971-1974. The findings showed abundance varied considerably between lakes, but year class strength also ranged widely at each lake.

The greatest difference in apparent abundance of young bass was between lakes. Comparison of age 0 bass populations for the past four years showed catch effort at Red Haw Lake was generally greater than at Bobwhite Lake. Abundance at Red Haw was greater in 1972 and 1974. In 1973 catch values were nearly identical, and only in 1971 was catch effort of 0-age bass at Bobwhite greater. Mean seine haul index at Red Haw from 1971-1974 was 2.7 F/H, while catch effort at Bobwhite Lake was 1.4 F/H.

Year class abundance during the four year period was most variable at Red Haw Lake where weak year classes were systematically followed by stronger year classes. Sample years 1971 and 1973 were represented by low catch indices while 1972 and 1974 catches were much greater. At Bobwhite Lake catch of young bass declined steadily since 1971 when the mean index was 1.4 F/H. In 1972 the value was 1.2 F/H, while in 1973 and 1974 catch effort declined to 1.1 F/H and .1 F/H.

Influence of stocking fingerling bass on the 0-age population was greatest at Bobwhite Lake in 1974 when 5,270 bass were stocked. Catch effort increased significantly ($P < .05$) after stocking and all but one bass in seine catches was a stocked bass. The stocking in 1973 of 10,000 young bass also increased the catch of bass significantly ($P < .05$), but the magnitude of increase was not as great as in 1974. Fingerling stocking at Red Haw Lake showed no significant difference in abundance of young bass. Results of three experimental stockings showed catch effort of bass was increased at Bobwhite Lake where density of young bass was normally low. Stocking at Red Haw, where natural reproduction and survival was higher, had no measurable affect on the 0-age bass populations.

RECOMMENDATIONS

Sampling of 0-age largemouth bass should continue and hatchery reared fingerling bass stocked in October at both lakes. Red Haw Lake will be stocked with 7,200 bass and Bobwhite Lake with 10,000 bass with mean length of 127 mm (5 in) and weight of 15 g (30 per lbs).

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa NAME: Evaluation of Biological Control of Nuisance Aquatic Vegetation by White Amur

PROJECT NO.: F-88-R-2

STUDY NO.: 504-1 TITLE: Standing crop of vascular plants, primary productivity and water quality at Red Haw Lake

JOB NO.: 1

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: *Maximum biomass of aquatic vegetation in 1974 was 1,687 g/m² on 4 June, while the lowest estimate was 556 g/m² on 7 May. Vegetation biomass declined gradually from June to September when it was 930 g/m². Species structure was dominated by Potamogeton in May and June and Elodea during July-September. Maximum biomass declined significantly from 2,438 g/m² in 1973 to 1,687 g/m² in 1974. Water quality was monitored by measuring concentration of phosphorus, nitrogen, alkalinity, pH, dissolved oxyen and biochemical oxygen demand. Water temperature and turbidity were also recorded. Analysis of variance showed mean nitrate nitrogen concentration of 1.0 mg/ℓ in 1974 was significantly higher than .18 mg/ℓ in 1968, but the mean in 1970 was not significantly greater than for 1974. Mean dissolved oxygen at the surface in 1974 was 9.9 mg/ℓ which differed significantly from the mean in 1970 of 6.6 mg/ℓ. All other water quality parameters were unchanged after grass carp were stocked. Primary production in 1974 ranged from .41 gC/m²/day in June to 3.03 gC/m²/day in December with an overall mean of 1.87 gC/m²/day. Overall primary production values were significantly lower than those before grass carp were introduced, but production in 1974 remained high into winter. Production before grass carp were introduced declined abruptly in October. The relationships between vegetation control, water quality, and primary production were discussed.*

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

STUDY OBJECTIVE

To evaluate the effectiveness of white amur to biologically control dense beds of nuisance aquatic vegetation in a 29 ha recreational lake in order to improve angler success along the shorelines, to describe the vital statistics of white amur with emphasis on food consumption, growth, condition, mortality and behavioral activity, and measure the indirect impact of biological vegetation control on (a) primary productivity of phytoplankton, (b) water quality of the lake, and (c) sport fish harvest.

JOB 1 OBJECTIVE

To measure standing crop of common semi-rooted aquatic plants, primary production, and water quality in Red Haw Lake following introduction of white amur.

INTRODUCTION

The primary objective of this investigation is to evaluate the effectiveness of aquatic vegetation control by white amur in a man-made lake. In 1974, determination of macrophyte abundance continued as before, but was expanded to measure the indirect effect of egested plant material on water quality and primary production of algae populations. Water quality parameters were measured to describe the nutrient budget and algae populations were monitored by determining primary production. Presently, most studies of grass carp are confined to small ponds or aquaria and the results are remotely applicable to the real problem of massive weed beds in Iowa man-made lakes. This is particularly true of water quality and primary production estimates in experimental tanks and aquaria where thermal stratification and soil substrate are lacking.

STUDY BACKGROUND

Estimated aquatic vegetation biomass declined following introduction of 530 white amur from 2,438 g/m^2 in July to 668 g/m^2 in August, 1973. Based on growth rate of white amur at Red Haw and the expected food conversion ratio 37 metric tons (41 tons) or 49% of the biomass was consumed.

An additional 255 white amur were released on 26 June, 1974. Mean length of this group was 351 mm and ranged from 245 to 511 mm. Mean weight was 526 g with a range from 150 to 1,480 g. Forty-one dead fish were found in shoreline searches up to 15 days after stocking. All fish were heavily infected with *Gyrodactylus* and to a lesser degree with *Lernaea*. Divers found several fish on the bottom indicating mortality was higher.

METHODS AND PROCEDURES

Standing stock and species composition of the macrophytes was estimated by the identical quantitative procedures as in the first segment. Plant growth was checked by divers equipped with SCUBA starting 18 April. Initial samples were taken 7 May and continued at monthly intervals.

Primary productivity was measured by the light and dark bottle method (Strickland, 1968). Replicate light and dark bottles were suspended at 1 m (3 ft) intervals to a depth of 5 m (16 ft) at a single permanent location near the dam. A two liter water sample was collected from each depth. The bottles were filled, returned to the same depth and incubated for 6 hrs commencing at 9 AM. Sampling was conducted biweekly commencing on 22 March, 1974.

Difference in dissolved oxygen concentration between light and dark bottles was determined by a YSI Model 51 oxygen meter. The sample was placed on a magnetic stirrer and the sensing probe immersed in the sample for 2 minutes before the values were recorded.

Method of computing gross photosynthesis was identical to Corkum (1971). The equation

$$p = \frac{2(LB - DB)F}{PQ}$$

was used where

p = gross photosynthesis (mg carbon assimilated per liter per day)

LB = net oxygen increase due to the photosynthesis in the light bottle

DB = oxygen decrease in the dark bottle

PQ = photosynthetic quotient (molecules of oxygen produced/molecules of carbon assimilated or 1.2)

F = ratio of molecular weights of carbon and oxygen (.375).

Photosyntehsis was estimated for a water column five m deep by one m^2 by summing all values for each meter in the column. Units of production at each meter was gC/m^3/day, while production in the water column was gC/m^2/day. The methods used were identical to Corkum (1971) so results could be statistically compared.

Temperature, turbidity, total phosphates, organic phosphates, meta and ortho phosphates, nitrate N, nitrite N, alkalinity, pH, dissolved oxygen and biochemical oxygen demand were recorded monthly from March, 1974. Samples were collected at the surface, 4 m (13 ft) and 8 m (26 ft) depths at a single, sampling location. Chemical analysis were determined by standard water analysis methods.

Water quality statistics were previously recorded in 1968 (unpublished data) and 1970 by Corkum (1971) which allowed statistical comparison of mean values before and after introduction of white amur.

FINDINGS

DISTRIBUTION AND BIOMASS OF MACROPHYTES

Growth of vegetation during April was extremely slow. The first qualitative samples collected on 7 May had a mean weight of 556 g/m^2. Mean surface water temperature was 15°C (59°F). During May vegetation grew rapidly and on 4 June achieved a maximum biomass of 1,687 g/m^2 (Table 1). Vegetation biomass declined to a mean sample weight of 1,322 g/m^2 on 2 July. The decline gradually continued throughout July and August and by 1 September the standing stock of vegetation was 930 g/m^2.

Table 1. Sample weights of aquatic macrophytes at Red Haw Lake in g/m^2.

	Sample period						
	1973		1974				
Station	July	August	May	June	July	August	September
1	816	24	400	508	180	124	240
2	4,408	688	944	1,852	400	280	480
3	2,340	888	924	1,560	2,956	4,168	2,000
4	2,440	508	328	1,688	416	116	720
5	2,784	288	836	4,244	4,008	1,064	1,240
6	1,688	444	636	1,740	616	1,688	1,280
7	2,648	944	164	980	472	820	460
8	2,568	1,380	600	1,180	2,376	1,064	720
9	2,032	996	328	2,704	1,072	2,404	1,120
10	2,660	552	400	416	724	400	1,040
Mean	2,438	668	556	1,687	1,322	1,213	930

Sample weights ranged from 116 g/m^2 at Station 4 in August to 4,244 g/m^2 at Station 5 in June. Station 3 produced the greatest mass of plant material with a mean of 2,322 g/m^2, but Station 5 was also high with a mean of 2,278 g/m^2. Mean weights at other sites were 1,526 g/m^2 at Station 9, 1,301 g/m^2 at Station 8, 1,192 g/m^2 at Station 6, 791 g/m^2 at Station 2, 654 g/m^2 at Station 4, 596 g/m^2 at Station 10, 579 g/m^2 at Station 7 and 290 g/m^2 at Station 1. Stations 1 and 10 were located near the dam where the gradient was steep and vegetation less abundant. All other stations were located in dense stands of vegetation.

The premise of this investigation was that white amur would reduce aquatic vegetation biomass from pre-introduction levels. Standing stock of macrophytes at Red Haw in July, 1973, was 2,438 g/m^2. The mean sample weight in July 1974, was 1,322 g/m^2, a decline of 44%. Analysis of variance showed the difference in July samples between years was significant ($P < .05$).

The August sample mean in 1973 was 668 g/m^2, while the 1974 late August sample was 930 g/m^2. Although the 1974 value was larger the difference between the means was not significant ($P > .05$).

Species composition of plants in 1974 was dominated by *Potamogeton* in May and June, but *Elodea* became dominant by July and continued as the most abundant group in 1974 (Table 2). *Ceratophyllum* was second in importance and became most prevalent during August. *Najas* was least abundant, but increased slightly by late August when other plant groups decreased.

Table 2. Composition of the plant community at Red Haw Lake in g/m^2.

	Sample period						
	1973		1974				
	July	August	May	June	July	August	September
Potamogeton	1,400	244	370	926	433	277	94
Elodea	85	42	163	703	871	785	671
Ceratophyllum	175	6	22	53	15	144	144
Najas	778	376	1	5	3	7	21
Total	2,438	668	556	1,687	1,322	1,213	930

May samples were comprised of 67% *Potamogeton* by weight compared to 29% for *Elodea*, 4% for *Ceratophyllum* and < 1% for *Najas*. By June, the mean sample weight of *Potamogeton* increased to a maximum of 926 g/m^2, but *Elodea* increased more rapidly to 703 g/m^2. Species composition during June was *Potamogeton*, 55%; *Elodea*, 42%; *Ceratophyllum*, 3%; and *Najas*, < 1%. In July, *Elodea* reached maximum standing stock of 871 g/m^2, while *Potamogeton* declined to 433 g/m^2. *Ceratophyllum* and *Najas* remained unimportant in July. By August, *Elodea* started to decline, but remained the most abundant group comprising 65% of the sample. The importance of *Potamogeton* continued to decline contributing 23% to the biomass, while *Ceratophyllum* increased to 12% compared to 1% in the previous sample. By late August, *Potamogeton* and *Elodea* biomass decreased to 94 g/m^2 and 671 g/m^2, respectively. Even though *Elodea* decreased it still comprised 73% of the sample weight. *Ceratophyllum* biomass remained at 144 g/m^2 and made up 16% of the sample, while *Najas* increased to 21 g/m^2, comprising 2% of the biomass.

Comparisons of sample plant group means showed significant differences in species structure between 1973 and 1974. The greatest change was *Najas* which declined from 778 g/m^2 to 3 g/m^2 from July, 1973 to July, 1974, and was never greater than 21 g/m^2 in 1974. Analysis of variance showed the difference in mean sample weights between 1973 and 1974 was significant at the 95% level.

Elodea biomass increased in abundance from 1973 to 1974. In July, 1973, mean biomass was 85 g/m^2 compared to 871 g/m^2 in July, 1974. The increase was also apparent in the August samples when mean weight was 42 g/m^2 in 1973 compared to 785 g/m^2 the next year. Analysis of variance showed differences in mean weight for *Elodea* between 1973 and 1974 for both July and August were significant ($P < .05$).

Mean biomass for *Potamogeton* in July, 1973, was 1,400 g/m^2 compared to 433 g/m^2 in July, 1974. In the following sample period biomass was nearly the same. Mean weight was 42 g/m^2 in August, 1973 compared to 94 g/m^2 the next year. The difference in mean weight for the July samples was significant ($P < .05$), but August samples were not significantly different ($P > .05$). Maximum biomass of *Ceratophyllum* was recorded in July, 1973 with 175 g/m^2. In 1974, the mean sample weight for July was 15 g/m^2. Mean biomass for the August samples in the two years were 6 g/m^2 and 144 g/m^2, respectively. Values in either month were not significantly different ($P > .05$) between 1973 and 1974.

WATER QUALITY

Organic phosphates ranged from < .01 mg/ℓ in October at 8 m to .7 mg/ℓ during September at 8 m. Mean organic phosphates at the surface and 4 m was .25 mg/ℓ, while at 8 m the concentration was .32 mg/ℓ for an overall mean of .27 mg/ℓ (Table 3).

Inorganic phosphates had an overall mean of .52 mg/ℓ and ranged from .10 mg/ℓ at the surface in September to 3.90 mg/ℓ at 8 m in August (Table 3). Inorganic phosphate concentration increased with depth. Mean values at the surface and 4 m were .26 mg/ℓ and .29 mg/ℓ, while at 8 m, well below the thermocline, the concentration was 1.04 mg/ℓ. Greatest concentration was in August with 1.42 mg/ℓ and smallest concentration in March with .16 mg/ℓ in March. During summer stratification inorganic phosphates increased greatly in the hypolimnion. For example, in August mean inorganic phosphates at 8 m were 3.9 mg/ℓ compared to .20 mg/ℓ and .14 mg/ℓ at the surface and 4 m.

Mean nitrate nitrogen concentration was .7 mg/ℓ, but ranged from < .1 mg/ℓ at the surface in July to 2.0 mg/ℓ at 4 m in March. There was little difference in concentration between depths. At the surface and 4 m the mean was .8 mg/ℓ, while at 8 m the concentration was .5 mg/ℓ. Monthly samples showed nitrates were highest in March with a mean of 1.8 mg/ℓ and lowest in July with < .1 mg/ℓ.

Lowest nitrite values were measured in September and October with < .01 mg/ℓ, while highest concentrations occurred in November and December with .03 mg/ℓ. Depth was not important in nitrite concentration.

Mean total alkalinity from March-December was 114 mg/ℓ. Values tended to be greater below the thermocline. At the surface and 4 m overall mean alkalinity was 108 and 107 mg/ℓ, while at 8 m the concentration was 128 mg/ℓ. During thermal

Table 3. Water quality at Red Haw Lake from March-December, 1974.

Parameter	Mean	Overall range	Depth range	Period range
Organic P	.27	< .01- .70	.25- .32	.07- .50
Inorganic P	.52	.12- 3.90	.26- 1.04	.16- 1.42
Nitrate N	.7	< .1- 2.0	.5 - .8	.1 - 1.8
Nitrite N	.02	< .01- .03	.02	< .01- .03
Alkalinity	114	103 -137	107 -128	103 -128
pH	7.6	7.1 - 8.5	7.5 - 7.8	7.2 - 8.2
Turbidity (FTU)	8	4 - 23	6 - 11	4 - 15
Dissolved oxygen	7.4	0 - 12.6	5.2 - 9.9	3.0 - 12.6
BOD	6	1 ->30	4 - 8	1 - 12
Temperature (°C)	14	3 - 28	11 - 16	3 - 21

stratification the difference was more pronounced. In July-September mean alkalinity at 8 m was 157 mg/ℓ, while at the surface it was 103 mg/ℓ. Values were lowest in March and April with a mean of 103 mg/ℓ. Alkalinity concentration recorded in August was greatest with 128 mg/ℓ.

Hydrogen ion concentration generally decreased with depth, particularly in the summer. Overall mean at the surface was 7.8, while pH at 4 m and 8 m was 7.6 and 7.5. In August and September surface pH was 7.7, but 7.2 at 8 m. Lowest monthly pH was 7.2 in September, while December was greatest with a pH of 8.2.

Turbidity had an overall value of 8 FTU and ranged from 4 FTU to 23 FTU at 8 m in August. Turbidity increased with depth in all months except June when it was 22 FTU at the surface and 7 FTU at 4 m. Overall mean was 8 FTU at the surface and 11 FTU at 8 m. Greatest turbidity was 15 FTU in October, with lowest turbidity of 4 FTU in March.

Dissolved oxygen concentration varied widely between strata and was closely associated with thermal stratification from May-September. Surface values were always > 8.2 mg/ℓ, while at 4 m oxygen was always < 2 mg/ℓ in June, July and August. During the same months, oxygen at the 8 m strata was $\leq$ .1 mg/ℓ. Overall mean at the surface was 9.9 mg/ℓ. At 4 m the concentration was 7.1 mg/ℓ and at 8 m it was 5.2 mg/ℓ. Greatest concentration occurred on 5 December with 12.6 mg/ℓ at all depths.

Biochemical oxygen demand (BOD) varied from 1 mg/ℓ during many sample periods to > 30 mg/ℓ at 8 m in August. BOD was uniform at each depth varying no more than 3 mg/ℓ except in August and September when BOD at the surface was 4 mg/ℓ, but at 8 m mean BOD was 26 mg/ℓ.

Temperature ranged from 28°C at the surface for the July sample to 3°C at the surface in December. Thermal stratification occurred during June-August with a maximum gradient in July when temperature differed 14°C from the surface to 8 m. Mean water temperature in March-December was 14°C.

PRIMARY PRODUCTION

Gross primary production ranged from .41 gC/m^2/day in early June to 3.03 gC/m^2/day in early December with an overall mean of 1.87 gC/m^2/day (Table 4). Production ranged widely between sample periods. Maximum production occurred in March, August and December with lowest values in April, May and June (Figure 1).

Most production occurred near the surface with an overall mean of .74 gC/m^3/day and a range of -.09 to 2.53 gC/m^3/day. Within the second meter production declined and the annual mean was .31 gC/m^3/day ranging from -.47 to .78 gC/m^3/day. Production increased slightly at the fourth and fifth meter strata to .26 and .33 gC/m^3/day. Analysis of variance showed significant differences in mean production between strata at the 95% level. Further analysis by t-test of paired variates showed the mean at 1 m was significantly greater than the 3 m and 4 m strata.

Primary production in 1974 was compared to those values recorded by Corkum (1971). Greatest productivity in 1970 occurred in late June with 6.25 gC/m^2/day, while the minimum was 3.06 gC/m^2/day in late August (Table 5). At 1 m production

Table 4. Gross primary production at Red Haw Lake in 1974 measured as g carbon/m^3/day.

	Depth					
Date	1 m	2 m	3 m	4 m	5 m	Total
March 22	1.09	.19	.06	.53	.88	2.75
April 17	0	.06	.19	.16	.25	.66
May 17	.22	.22	.03	.13	.41	1.00
May 31	.50	.09	.28	.06	.03	.97
June 14	.22	-.47	.41	-.13	.38	.41
June 28	.50	.41	.84	0	-.03	1.72
July 12	1.00	.40	-.68	-.03	.03	.72
July 26	1.00	.63	.38	0	.25	2.25
August 9	.88	.13	.09	1.03	.53	2.66
August 22	.63	.22	-.16	.72	1.16	2.56
September 6	.84	.22	-.09	.44	.41	1.81
September 18	1.09	.69	-.25	.16	.50	2.19
October 4	2.53	.28	.22	-.03	-.50	2.50
October 18	1.03	.25	.13	.13	-.22	1.31
November 7	.31	.75	.72	.09	.62	2.50
November 22	.25	.78	.47	.44	.09	2.03
December 5	1.28	.16	.72	.09	.78	3.03
December 20	-.09	.59	.78	.87	.34	2.49
Mean	.74	.31	.23	.26	.33	1.87

Table 5. Gross primary production at Red Haw Lake in 1970 measured as gC/m^3/day (Corkum, 1971).

	Depth					
Date	1 m	2 m	3 m	4 m	5 m	Total
May 28	2.25	.38	.62	.75	.62	4.62
June 27	1.88	1.75	1.00	1.62	0	6.25
July 25	2.20	1.80	.20	.20	0	4.40
August 22	1.69	1.12	.25	0	0	3.06
September 19	1.31	1.88	1.12	.38	.31	5.00
October 17	.88	.62	.38	.75	.50	3.13
Mean	1.70	1.26	.60	.62	.24	4.41

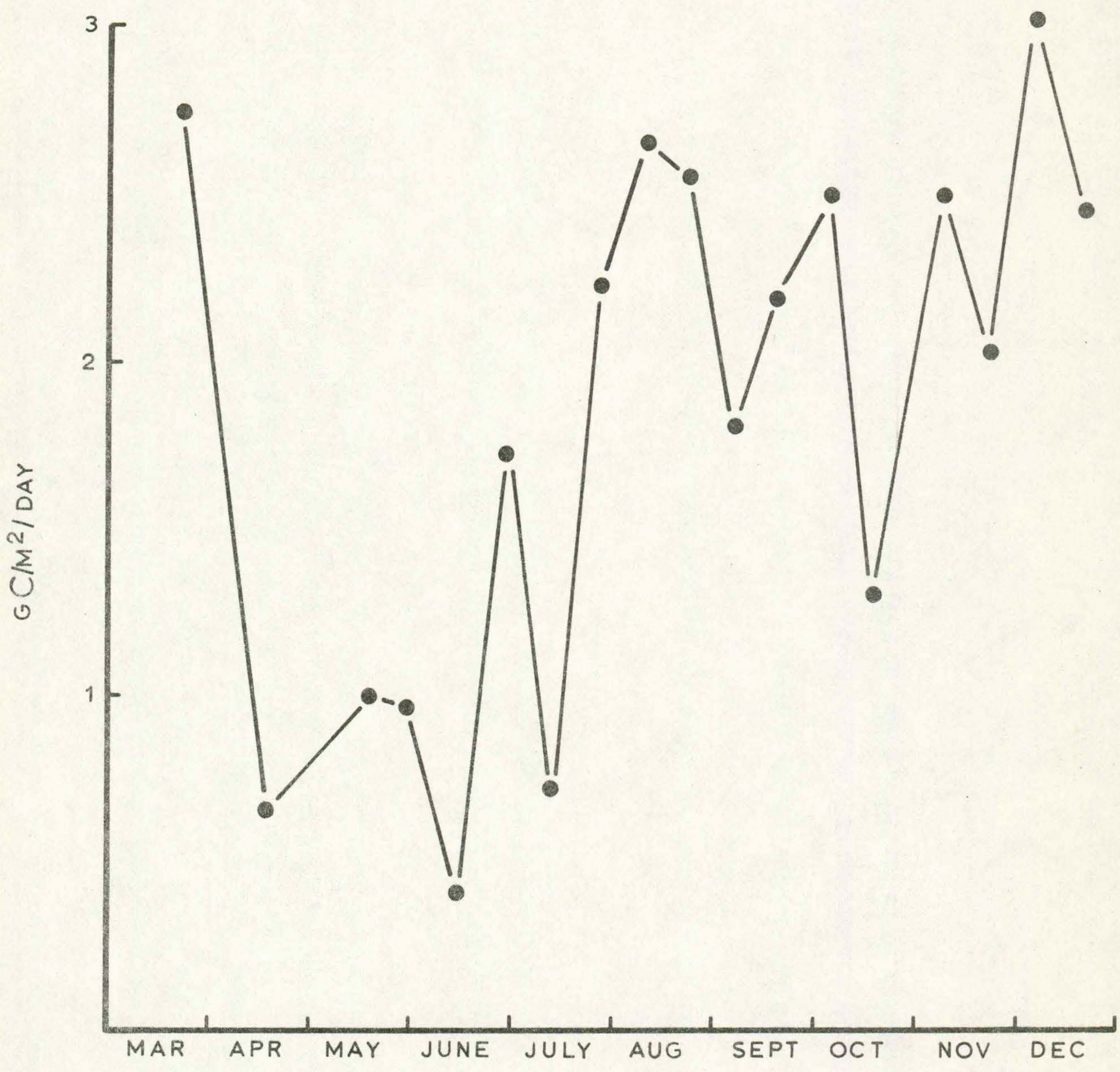

Figure 1. Gross primary production at Red Haw Lake in 1974.

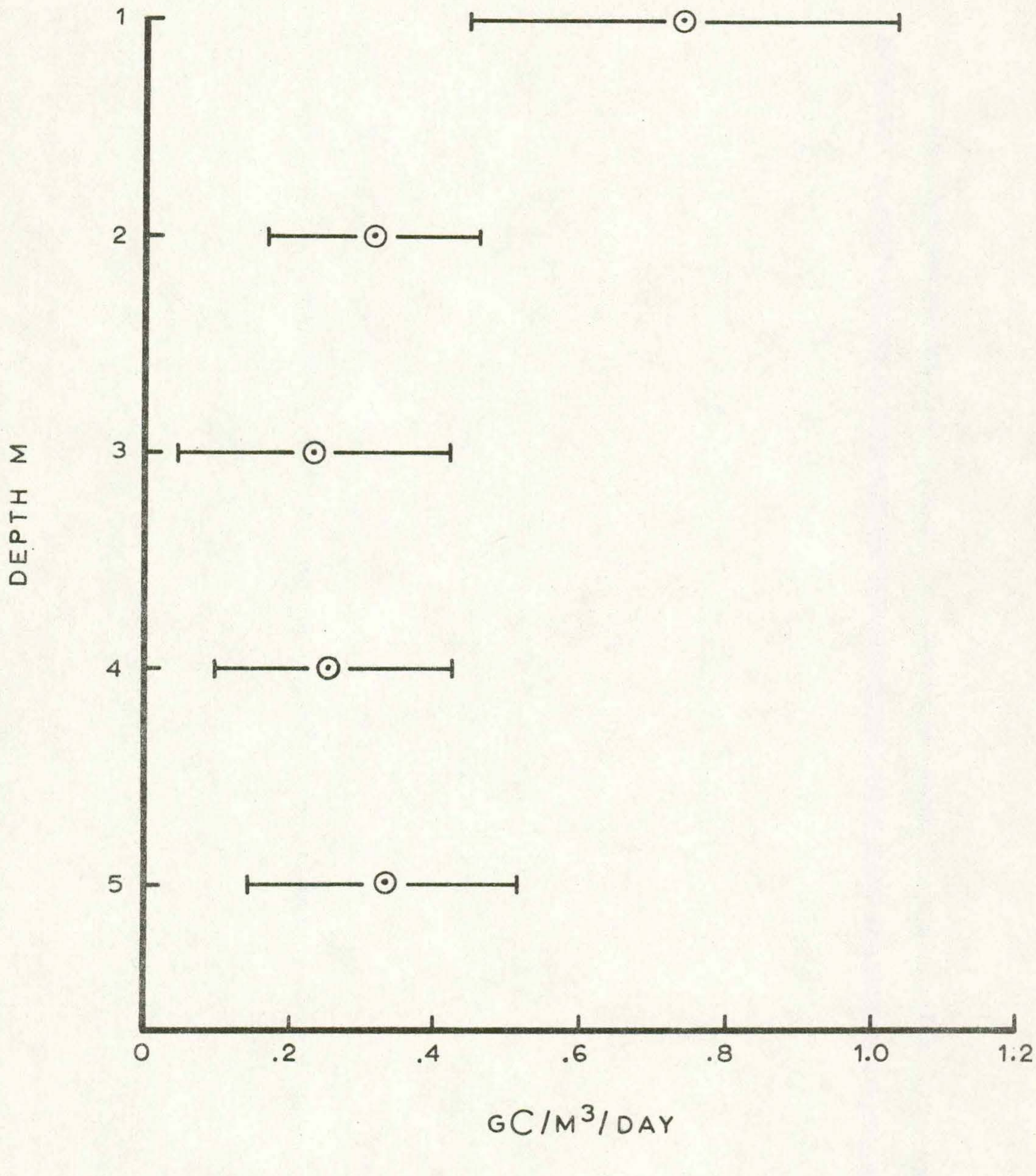

Figure 2. Mean annual primary production at Red Haw Lake in 1974. Horizontal lines are 95% confidence limits.

ranged from .88 gC/m^3/day in October to 2.25 gC/m^2/day with an overall mean of 1.7 gC/m^3/day. Primary production decreased steadily with depth and at 2 m it was 1.26 gC/m^3/day followed in succession by .60, .62 and .24 gC/m^3/day. Overall mean in 1970 was 4.41 gC/m^2/day compared to 1.84 gC/m^2/day for the same period in 1974.

Analysis of variance showed mean gross primary production was significantly less in 1974 compared to 1970 ($P < .01$). Evaluation at each level showed values at 1 m and 2 m were greater in 1970 than in 1974 ($P < .05$); difference in mean productivity at 2 m was highly significant ($P < .01$). At 3 m, 4 m and 5 m mean production was not significantly different between 1970 and 1974 ($P > .05$).

DISCUSSION OF FINDINGS

The impact of stocking grass carp in a man-made impoundment can be viewed in terms of several simplistic hypotheses. First, they will control aquatic vegetation. Second, in consuming vegetation they alter water quality of the lake. Third, as nutrient concentrations increase in the water column algae populations increase. Grass carp consume approximately 40 units of vegetation to gain 1 unit of body weight. The unused fraction of vegetation is returned to the lake as egesta which is decomposed by bacteria and chemically altered by oxydation-reduction and the outcome is similar to a prescribed fertilization program using organic fertilizer. Higher algae populations can either be beneficial to the lake by providing a larger food supply to primary consumers, or detrimental by causing nuisance algae blooms. The findings of this study segment support the hypotheses in some instances, but in other instances they do not.

The most important fact in the study was maximum plant biomass was reduced from a mean of 2,438 g/m^2 in 1973 to 1,322 g/m^2 in 1974, or a decline of 44%. During that interval 780 grass carp were stocked and they consumed an estimated 37 MT (41 ton) of vegetation in 1973 and 63 MT (69 ton) in 1974. Other parameters affecting plant production such as water temperature, nutrients and turbidity were unchanged. Grass carp were the most important, if not the single factor in reducing vegetation.

An important aspect of vegetation control is uniformity, or control where it is most needed. Vegetation biomass was reduced 44% overall, but at some sampling stations there was no change or even a slight increase in density. At Stations 3 and 5 there was an increase, while Stations 6 and 8 were approximately the same as before and after grass carp introduction. Station 3 was in the southeast embayment, while 5 and 6 were in the southwest embayment. Station 8 was adjacent to the causway in the west bay. Other stations, particularly 2, 7 and 10 showed a large decline in vegetation biomass. Station 10 was near the spillway, while 2 was on the east part of the lake near a point and 7 was near the campground at the west part of the lake. Nonuniform distribution and behavioral activity of grass carp were probably responsible for the irregular control.

With reduced plant biomass there was a succession of plant groups. The most important change was for *Najas* which was almost completely eliminated from the plant community. In 1973 *Najas* was second in importance with maximum biomass of 778 g/m^2, but in 1974 greatest biomass was 2 g/m^2. As *Najas* decreased *Elodea* became more important. *Elodea* contributed 6% to the plant composition in 1973, but in 1974 *Elodea* contributed as much as 72% by weight to the plant community. White amur had a large impact on the plant community by consuming 100 MT (110 ton) in two years, particularly when certain plant groups were consumed in greater abundance than others. In 1973, *Elodea* was important in the grass carp ration with a mean electivity index of +.52. Many plants attain greater production and become more dominant when they are moderately cropped. *Elodea* was probably better adapted to compete with other plant groups, while *Najas* was less adapted to withstand cropping by grass carp. Regardless of the change in species structure, total vegetation biomass was reduced by 44%.

Findings did not support the hypothesis that egesta from grass carp would change the water quality at Red Haw Lake. In 1973, 37 MT (41 ton) of vegetation were consumed and in 1974 an additional 63 MT (69 ton) were consumed, most of which became available as egesta for bacterial decomposition and chemical oxydation-reduction.

Water quality in 1974 was compared with values in 1968 and 1970. Inorganic phosphate, alkalinity, pH, temperature, dissolved oxygen and Secchi disc turbidity were similar before grass carp were introduced (Table 6). Analysis of variance procedure showed there was no significant difference ($P > .05$) in the means of these parameters between 1968, 1970 and 1974.

Table 6. Water quality at Red Haw Lake from May-October in 1970 and January-December in 1968.

	1968		1970	
Parameter	Mean	Range	Mean	Range
Inorganic P	-----	-----	.35	.01- 1.59
Alkalinity	107	84 -152	112	74 -192
pH	7.6	7.1 8.4	7.4	7.1 - 8.3
Temperature	12	3 - 27	19	12 - 27
Dissolved oxygen	7.5	0 - 13.4	3.6	0 - 8.6
Secchi disc (m)	-----	-----	1.54	.70- 3.30

Results of water quality investigations indicated primary production should remain approximately the same, but in fact primary production decreased 57%. The relationship between primary production and limiting factors of light, temperature and nutrients is complex. At certain periods temperature will limit plankton production, while at other times light intensity or nutrient concentrations are critically low. Obviously, primary production was not associated with a single factor during the investigation, but reduced production in 1974 was apparently influenced by at least two other factors.

RECOMMENDATIONS

Sampling should continue in 1975 using identical methods as before.

LITERATURE CITED

Corkum, L. 1971. A comparison of productivity in three Iowa lakes. Masters Degree Thesis. Drake Univ., Des Moines, Iowa. 49 pp.

________. 1972. Primary productivity in Lake Red Haw, Lucas County, Iowa. Proc. Ia. Acad. Sci., 78(3,4):48-49.

Fassett, N. 1966. A manual of aquatic plants. Univ. Wisc. Press, Madison, Wisc. 405 pp.

Krause, D. 1971. Winter and spring primary productivity using C-14 and light and dark bottle methods in Red Haw Lake, Lucas County, Iowa. Masters Degree Thesis. Drake Univ., Des Moines, Iowa. 39 pp.

Strickland, J. and T. Parsons. 1968. A practical handbook of seawater analysis. Bull. Fish. Res. Bd. Can. No. 167. 311 pp.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE:	Iowa	NAME:	Evaluation of Biological Control of Nuisance Aquatic Vegetation by White Amur
PROJECT NO.:	F-88-R-2		
STUDY NO.:	504-1	TITLE:	Vital statistics of white amur in Red Haw Lake
JOB NO.:	2		

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: Mean length and weight of age 2 white amur on 15 October was 702 mm (27.6 in) and 4,263 g (9.416). Mean daily growth was 16.2 g (.6 oz). Condition factors ranged from 1.16 for age 2 fish in winter to 1.37 for age 1 fish at stocking. Length-weight relationships of white amur were described. Sources of known mortality accounted for a loss of 55 fish. The main source of mortality was disease and parasitism of age 1 fish, but 16 were lost by electrofishing, netting and holding. Food habit studies showed white amur consumed vegetation almost entirely. Insects were found in the alimentary tract, but contributed only .1% to the diet by volume. Potamogeton was the major plant group consumed in April and June, while Ceratophyllum, Elodea and Najas were most often consumed in July-September. Najas and Ceratophyllum had electivity indices of +.93 and +.24, while Elodea and Potamogeton indices were always near zero or negative. Standing stock of both age groups in June was 1,023 kg (2,260 lbs), but by December it increased to 2,346 kg (5,180 lbs). During the growing season they consumed 63 metric ton (69 ton) of vascular plants and the ratio of maximum fish biomass to maximum plant biomass was 1:24.

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

JOB 2 OBJECTIVE

To determine the vital statistics of white amur with emphasis on growth, condition, food consumption, and mortality.

INTRODUCTION

Estimates of growth, body condition, length-weight relationship, food habits and mortality for white amur were continued at Red Haw Lake in 1974.

STUDY BACKGROUND

Growth of white amur in 1973 was rapid with mean rate of growth in weight of 19 g per day. Body weight increased nearly fivefold in 78 days. Condition factor increased from 1.15 at release to 1.45 at the end of the growing season. Vascular plants were the main ration of white amur and *Potamogeton* was the most frequently consumed taxa, occurring in 66% of the samples. *Elodea* was second in importance and comprised 24% of the food items. *Najas* and *Ceratophyllum* were also consumed, but were much less important. Frequency of *Elodea* and *Ceratophyllum* in the plant community was low and the food preference of these plants was greater than *Potamogeton* or *Najas*. Estimated consumption of aquatic plants by white amur in 1973 was 37 MT (41 ton), consuming approximately 50% of the estimated July vegetation biomass.

METHODS AND PROCEDURES

Methods used in this segment were identical as in 1973.

FINDINGS

GROWTH AND CONDITION

During the study segment 57 age 2 and one age 1 white amur were captured to compute growth. Mean weight of age 2 white amur in May, 1974, was 1,817 g (4 lbs) and ranged from 1,202 g (2.7 lbs) to 2,105 g (4.6 lbs). Growth was rapid during the summer and by October mean weight was 4,263 g (9.4 lbs) with a range of 3,100 g (6.8 lbs) to 5,460 g (12 lbs). Mean daily growth was 16.2 g (.6 oz) per day with one standard deviation of ± 2.6 g per day.

Mean total length of age 2 white amur in May was 472 mm (18.5 in) increasing to 702 mm (27.6 in) by October. Range in size in May was 348-532 mm (13.7-20.9 in), while in October it was 602-750 mm (23.7-29.4 in). Mean daily growth from May-October was 1.5 mm with one standard deviation of ± .2 mm.

Condition factor (K) of age 2 fish in January and February was 1.16 compared to 1.22 in July, August and September. Length-weight relationship during January and February was best described by the function

$$\log_{10}W = -3.484 + 2.477 \log_{10}TL$$

where W was weight in grams and TL was total length in mm.

Growth of age 1 white amur stocked in 1974 was based on only one fish. Mean weight of all fish at stocking was 526 g (.95 lbs) with mean length of 351 mm (13.8 in). Mean condition factor at stocking was 1.10. In February, 1975, one individual of the 1974 introduction was captured, but it had lost the tag. Mean length and weight was 423 mm (16.6 in) and 1,040 g (2.3 lbs) with condition factor of 1.37.

MORTALITY

Three known sources of mortality were accounted for during the 1974 season. Most prevalent was parasitism origniating from a hatchery pond infestation. On 28 June, 255 white amur were stocked and within the following 15 days, 38 dead fish were found. Three white amur were also found by divers on the lake bottom. Several white amur from the transport truck which were held in an aquaria became heavily infected with *Gyrodactylus* and *Lernaea*. Dead fish were partially decayed, but also showed skin lesions from parasitism. None of the 1973 stocked fish were found dead during this period.

The second most numerous cause of mortality was from netting and holding. From January through May white amur were captured to develop surgical techniques for implantation of sonic tags. This activity accounted for the loss of eight fish. Another source of known mortality was sampling by electrofishing. In early June electrofishing gear was used to capture white amur for sonic tagging. Two were captured and held in a live box. They never recovered equillibrium and died within a week. Later in June six dead white amur were found in the area where electrofishing gear was used.

Fishing mortality and natural attrition were immeasurable. Two fish were known to be caught by anglers in May, but both were released. During 1974, 55 fish died from known causes. The *Gyrodactylus* and *Lernaea* infection undoubtedly caused greater mortality than observed, because some of the dead fish did not surface.

FOOD HABITS

Eight alimentary tracts were examined for food items. The first was collected in mid-April with two each in June and August and three in July. Mean length and weight of the fish was 594 mm at 3,540 g. Weight ranged from 2,410 g to 5,230 g.

Alimentary tract length and volume were measured. Six tracts contained food, while two were empty. The tracts containing food had a mean volume of 534 ml and varied from 354 ml to 543 ml. Mean length of the gut was 1,240 mm and ranged from 900-1,420 mm. Gut length was 2.1 times longer than the body length and gut volume, with food, comprised about 15% of the body weight.

The first step was a cursory examination of the gut contents for large invertebrates. Ten percent of the stomach content was scanned under low magnification. The most numerous insect was *Chironomidae* with 24 found in five alimentary tracts. Eight were present in one tract with fewer in others. Other groups present were one damsel fly nymph, one water mite, one roundworm and two *Cladocera*. Expansion of aliquot fractions showed the density of insects in the alimentary tract was < 1 insect per ml of ingested vegetation, varying from .2-2 insects per ml. Insects accounted for approximately .001 of the volumetric food intake.

The major food item was aquatic vascular plants. Plant groups consumed were *Potamogeton*, *Elodea*, *Najas* and *Ceratophyllum*. Most numerous groups in the alimentary tract was influenced by the time of year. During April, 57% of the contents were *Potamogeton*. By mid-June, *Potamogeton* contributed 72% of the diet. *Potamogeton* was an unimportant item by August and contributed < 1% to the sample. *Najas* was not found in the April sample, but increased to 29% occurrence by mid-June. *Najas* accounted for 23% of the food in late July and 39% in late August. *Ceratophyllum* was the major food item in July comprising 51% of the stomach contents. During other sample periods *Ceratophyllum* contributed < 4% to the diet. *Elodea* was never of primary importance, but in April it was second in occurrence contributing 34% to the ration.

Electivity indices showed *Najas* was by far the most selected plant group with a mean value of +.93, followed by *Ceratophyllum* with +.27. *Elodea* and *Potamogeton* had electivity indices of -.51 and were always zero or negative regardless of the sample period.

STANDING STOCK AND FOOD CONSUMPTION OF WHITE AMUR

Fish biomass resulting from the 1973 introduction on 15 May was the product of mean weight and number of white amur in the population. Mean weight of the fish in May was 1,817 g (4 lbs), yielding a maximum biomass of 911 kg (2,010 lbs). From May to December, 1974, five more fish died from known sources leaving a population of 497 fish. Mean weight in December was 4,263 g (94 lbs) with standing stock of 2,123 kg (4,650 lbs).

Fish stocked on June 28 added to the population. Initially, 255 fish were stocked, but at least 41 died leaving a population of 214 fish. Mean weight was 526 g (1.1 lbs) and yielded a biomass of 112 kg (248 lbs). By December mean weight increased to 1,040 g (2.3 lbs) and maximum standing stock was 223 kg (506 lbs). Total standing stock attributed to both year classes in June was 1,023 kg (2,260 lbs), but by December stock was 2,346 (5,180 lbs). The increase in biomass was 1,323 kg (2,920 lbs) for both year classes.

Macrophyte consumption by white amur was computed from growth increment and food conversion rate. Hickling (1966) showed white amur consumed 48 units of food and gained 1 unit of body weight. This value was used to compute consumption of aquatic vegetation at Red Haw.

The 1972 year class gained 1,212 kg (2,480 lbs) during the growing season by consuming 58 metric ton (63 ton) of aquatic plants. The 1973 year class increased in biomass from 112 kg (247 lbs) to 223 kg (493 lbs) for a net gain of 111 kg (245 lbs). This gain required consumption of approximately 5 MT (6 ton). During 1974 both groups of white amur consumed an estimated 63 MT (69 ton) of vascular aquatic plants.

DISCUSSION OF FINDINGS

Growth of the two white amur introductions were vastly different. White amur stocked this year grew slower than the original stock during their first year in Red Haw. Increment of growth for the 1973 year class was 72 mm and 514 g compared to 162 mm and 1,437 g for growth of the 1972 year class in 1973. The reduction in growth of 55% by length and 64% by weight may be partly explained by small sample size, but even when minimum growth in 1973 was compared there was a 30% reduction in weight increment.

Growth in length and weight of the 1972 year class of white amur was most rapid in 1974. Increment of growth in 1973 was 1,437 g and 162 mm compared to mean increment in 1974 of 2,446 g and 230 mm. Growth of age 1 white amur stocked this year was much less than age 1 fish stocked the previous year.

Condition factor of white amur stocked in 1973 declined during the winter from 1.45 in October to 1.16 in January, 1974, but my mid-summer condition increased slightly to 1.22. Condition factors of age 1 fish released this year were similar to the age 1 fish released in 1973. Mean condition in 1973 and 1974 was 1.15 and 1.10, respectively.

Parasitism originating from pond rearing was a major source of mortality and numerical abundance of fish stocked in 1974 was probably reduced more than observed from dead fish. Fish were in rather poor physical condition when they were stocked and the mucous coating was absent from most of the fish. Netting and electrofishing were other sources of mortality, but were controlled with a maximum loss of 14 white amur from the population.

Food habit studies showed white amur consumed invertebrates, but were a minor part of the diet. A large portion of the insects consumed originated on the macrophytes and were probably consumed incidental to grazing vegetation. Approximately 22 kg/ha (19 lbs/ac) of insects were consumed, but this was a small portion of invertebrate production. In a nearby man-made impoundment benthic production was 1,000-1,800 kg/ha/year (Mitzner, 1974).

White amur consumed 63 MT (69 ton) of vascular plants, nearly double the 37 MT (40 ton) of vegetation consumed in 1973. The increase was due to the introduction of 255 age 1 fish and the biomass increase of both year classes. Composition of the diet changed since 1973 as did composition in the plant community. In 1973, *Potamogeton* was the major food item and most abundant in the plant community, but became increasingly less important. In 1974, *Potamogeton* declined even more in abundance and was replaced to some extent by *Elodea*. The steady decline in *Potamogeton* was associated with the large quantities of *Potamogeton* consumed and an electivity index of +.27 in 1973. By September, 1974, *Potamogeton* was least important in the diet and contributed only 10% to the biomass of the plant community.

Biological vegetation control would be most effectively attained with the proper density of grass carp. The relationship of white amur stock, vegetation biomass and consumption of vegetation can be expressed in several ways. Standing stock of both year classes of white amur increased from 1,023 kg in June to 2,346 kg by December with a growth increment of 1,323 kg. As grass carp were increasing in weight, vegetation biomass was reduced. Maximum vegetation biomass in 1973 was 76 MT (84 ton), but in 1974 it was 56 MT (62 ton). White amur consumed 63 MT (69 ton) of vegetation, while maximum biomass estimate was reduced 20 MT (22 ton). The ratio was 3 units consumed to 1 unit decline in plant biomass. Another expression of vegetation control was the ratio of maximum fish biomass to maximum plant biomass. In 1973, the ratio was 1:79, while in 1974 it was 1:24. These ratios showed a 79% decline in unit plant biomass per unit fish biomass.

RECOMMENDATIONS

Life history statistics of white amur should continue to relate growth, mortality and food consumption with vegetation control, water quality and primary production.

LITERATURE CITED

Hickling, C. 1966. On the feeding process of white amur, *Ctenopharyngodon idella*. Proc. Zool. Soc. Lond., 148:408-419.

Mitzner, L. 1974. The effects of cage reared and released channel catfish on established fish and benthic fish food populations. D-J Project No. F-88-R-1, Study No. 501-2, 29 pp.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa   NAME: Evaluation of Biological Control of Nuisance Aquatic Vegetation by White Amur

PROJECT NO.: F-88-R-2

STUDY NO.: 504-1   TITLE: Behavioral activity patterns of white amur

JOB NO.: 3

Period Covered: 1 July, 1974 through 30 June, 1975

ABSTRACT: Ultrasonic tags were surgically implanted in nine white amur to determine their distribution, movement and behavioral activity by radio telemetry. In June, fish were contacted 51% of the time within 10 m of shore while in July and August they were contacted 62% and 65% of the time near shore. All contacts were near shore in September, but by October white amur were located 51% of the time in the littoral zone. The decline continued and in November 20% of the contacts were in shore habitat. Grass carp were rarely found near the dam or boat ramps, but a greater proportion of contacts were made near the upper ends of larger embayments. Tagged white amur were disturbed by sudden boat movement and noise, particularly rowing. Electric trolling motors had little affect on the activity of white amur. Tagged fish readily evaded gill nets during daylight, but during darkness gill nets were more effective. Behavioral activity, distribution and the effectiveness of vegetation control were discussed. First, control was not equal along the shoreline. Second, white amur were unevenly distributed in the lake and third, behavior showed some white amur established activity centers and normal activity was altered by noise and sudden movement.

Author: Larry Mitzner
Fisheries Research Biologist

Date Prepared: 1 June, 1975

Approved by: James Mayhew
Fisheries Research Supervisor

JOB 3 OBJECTIVE

To measure the daily and seasonal activity of white amur at Red Haw Lake by radiosonic telemetry.

INTRODUCTION

The primary purpose of this job segment was to describe the behavioral activity and distribution of white amur at Red Haw Lake by ultrasonic telemetry. Behavior of white amur, particularly daily activity, seasonal activity and distribution is closely allied with their ability to effectively control aquatic vegetation. Maximum control can only be attained if distribution is uniform, and behavioral activity is associated with vegetated habitat.

METHODS AND PROCEDURES

Ultrasonic transmitters encased in a polypropylene tubes were surgically implanted in the body cavity. Dimensions of the sonic device were 16 mm x 60 mm (.6 x 2.4 in). Weight was 20 g with 8 g negative bouyancy in water. Nine transmitters were used, each with different signal frequency (kHz) and impulse rate. Frequency ranged from 74.00 kHz to 76.56 kHz and impulse rate ranged from 46-120 signals per minute (Table 7). The battery operated multi-frequency receiver was capable of tuning 65-84 kHz with direct imput from the hydrophone. Standard headsets were used to monitor output.

Table 7. Characteristics of sonic devices implanted in white amur at Red Haw Lake.

Tag number	Date implanted	Name	kHz	Impulse/second
1	4 June	Alice	75.50	98
2	15 June	Bertha	74.00	80
3	22 June	Carla	75.75	46
4	30 July	Debra	75.66	120
5	1 August	Ethel	75.25	56
6	7 August	Fay	74.44	68
7	29 August	Gertrude	76.56	86
8	4 September	Helen	76.45	76
9	4 September	Ida	76.27	60

Wild grass carp were captured by electrofishing and gill nets and held for eight hours in a live crib. The fish were anesthetized with 50-60 mg/l of MS-222 for 5-8 min. The fish were placed with ventral side up in a V-shaped holding table and wet cloth placed over the entire body. An incision approximately 20-25 mm was made 10 mm left of the midventral line and the sonic device inserted posteriorly. The incision was closed with 3-4 sutures using No. 000 braided surgical silk. Fresh water was occasionally sprayed on the gills during the procedure. Time from anesthetization to fresh water was 5-7 minutes with recovery time $<$ 12 minutes.

Tagged fish were designated by names in alphabetical order as shown in Table 7. Alice was held in the live crib 24 hours before release, but the remainder were released immediately after recovery from the anesthetic. Fish were tagged in groups of three. Alice, Bertha and Carla were released from 4-22 June; Debra, Ethel and Fay were tagged from 30 July-1 August; and Gertrude, Helen and Ida were tagged from 29 August-4 September.

Alice and Bertha were monitored for 24 continuous hours after release. Daily search and monitoring was conducted on Alice, Bertha and Carla through 3 July. From 5 July to 4 November a minimum of 12 hours per week were spent locating and monitoring all tagged white amur in the lake. Fish were located by following the lake perimeter approximately 50 m from shore with a small boat. The hydrophone was mounted on the gunnell with an adjustable bracket and aimed at the shore, but occasionally rotated 360° so fish could be located in midwater.

When a signal was received the observer moved close enough to count the impulse rate. The direction of signal was marked on a field map and the observer moved to a different location to obtain a more precise position by triangulation. If the fish was moving the observer followed, but if the fish was stationary a note was recorded of the position and the search continued for other tagged fish. The observer returned later to affirm the position of the stationary fish. All positions were marked on a map with corresponding time of day, signal strength, slight erratic movements, direction of movement and other notes relative to behavior.

A coordinate overlay was used to algebraically describe the position of tagged fish on the field map. Coordinates 1-11 were abscissa units, while A-L were ordinate units. Each unit was 100 m in length and each cell of the grid was 1 ha (2.5 a). The coordinate system was used to identify locations on the lake and facilitate analysis and evaluation of field observations.

FINDINGS

Signals were monitored from all fish with numerical contacts ranging from 201 for Alice to one for Helen. Helen's transmitter was operational 12 hours after release on 4 September, but was monitored only once after that date. Carla was monitored from 22 June to 29 August when the device was recovered in 3 m of water. Ethel was captured with gill net on 19 August and the sonic tag recovered after 19 days of transmission. Debra's transmitter was operational, but found immobile 39 days after release; the cause was either mortality or tag rejection. Bertha was monitored from 15 June to 3 July with no further response until 12 July. By November, four transmitters were being monitored and two were unaccounted for.

Monitoring time from June-November, was 190 hours with 85 hours of actual contact time. In June, more time was devoted to searching because fewer fish were tagged and the observer was less experienced in finding fish. The observer spent 105 hours monitoring in June, of which 29% was successful. In October, contact increased to 53% of total monitoring time.

Field observations were evaluated by arbitrarily classifying the information, first by overall distribution, second by movement and last by behavior. Distribution was determined without regard to time and described where white amur were most frequently found or where they were absent. Movement was time specific and described diel and seasonal activity. Behavior included observations of swimming speed, surfacing activity, schooling and reaction to boating, fishing and gill nets.

Ultrasonic tagged fish had one important trait in common, they spent varying amounts of time in midwater. Conversely, all fish were located in or near vegetation at some time, but none spent all their time near shore. All of the fish, except Carla, were found within 10 m of shore most of the time. Alice was contacted more in the littoral zone than any fish. In all 201 contacts were made, of which 139 (69%) were near shore (Figure 3).

Carla was located most of the time in midwater (Figure 4). Her signal was logged 82 separate times, of which 63 (77%) were midwater positions. Bertha, Debra, Ethel, Fay, Gertrude, Helen and Ida spent less time in midwater than Carla, but more than Alice.

Distribution of fish between midwater and shore was combined by weighed means so the number of observations on any particular fish was unity and based on 1,000 contacts (C/T). Combined data showed shallow water contacts were 683 C/T and the compliment, 317 C/T in midwater.

Fish associated with shore habitat changed during the season. In June, 510 C/T were littoral (Figure 5). Locations at shore increased in July and August, and by September all contacts were at shore positions. In October, 510 C/T were shoreline and by November 200 C/T were in the littoral zone.

General distribution of individual fish varied considerably. Alice and Bertha were most frequently located in the west embayment with few locations elsewhere. Carla was located most often at E-7 and 8 in the center of the lake with other contacts uniformly distributed. Debra had the widest distribution with the center of activity at H-8. Ethel was always found in either the west embayment or at the headwaters of the south bay (K and L-10) where she was recaptured. Gertrude was associated with the west arm of the lake. Helen and Ida had no particular distributional pattern.

Distribution of individual fish was unique, but provided no insight to the distribution of the whole population. When the distribution of all nine tagged fish was considered a trend was shown for use of some areas and avoidance of others. Overall distribution of white amur was described by superimposing the contact locations of all tagged fish on the grid map from June-November and adjusting to unity so all fish would be equally represented regardless of the number of contacts for each fish.

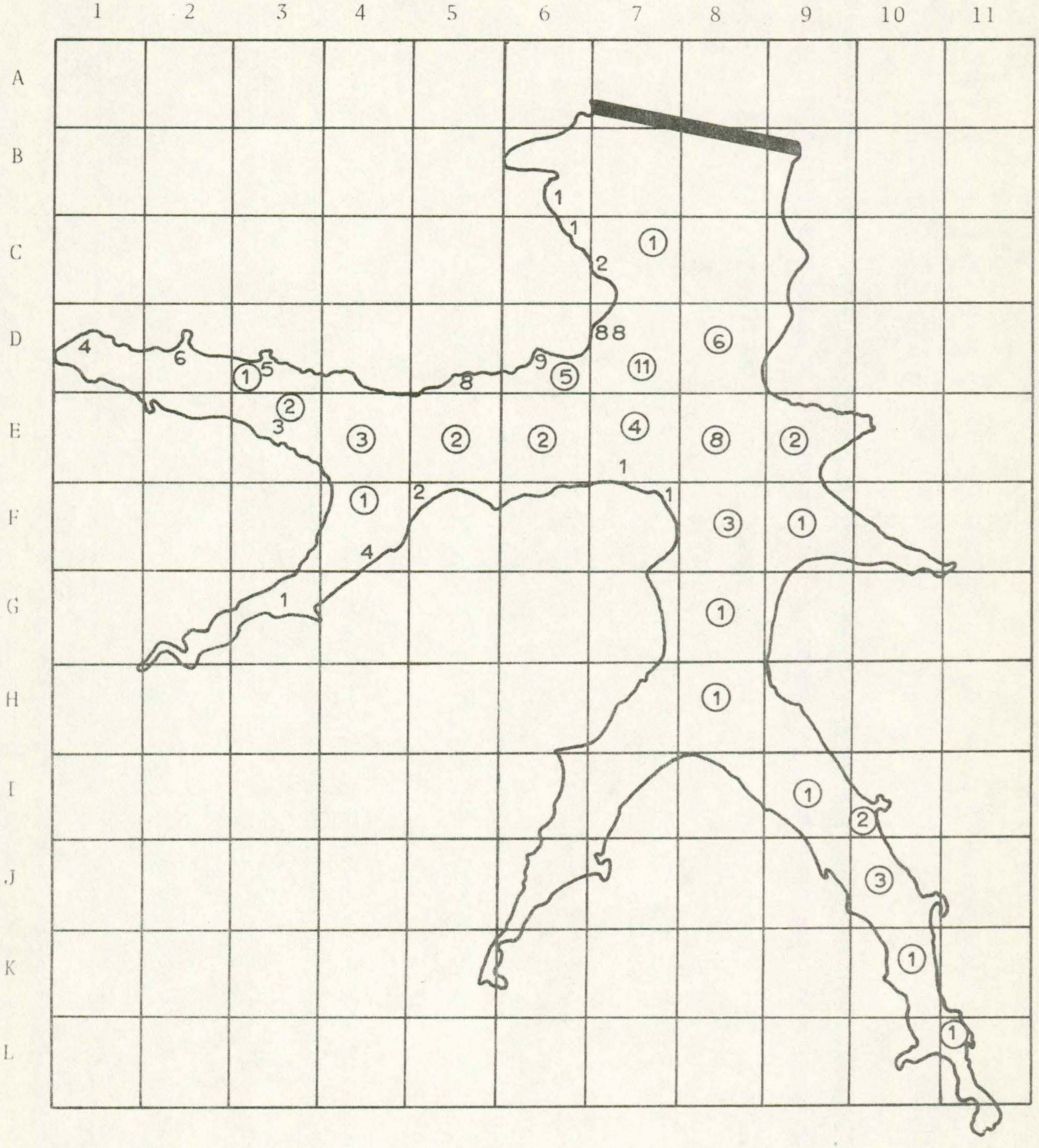

Figure 3. Frequency of contacts for Alice at Red Haw Lake with circled values open water positions.

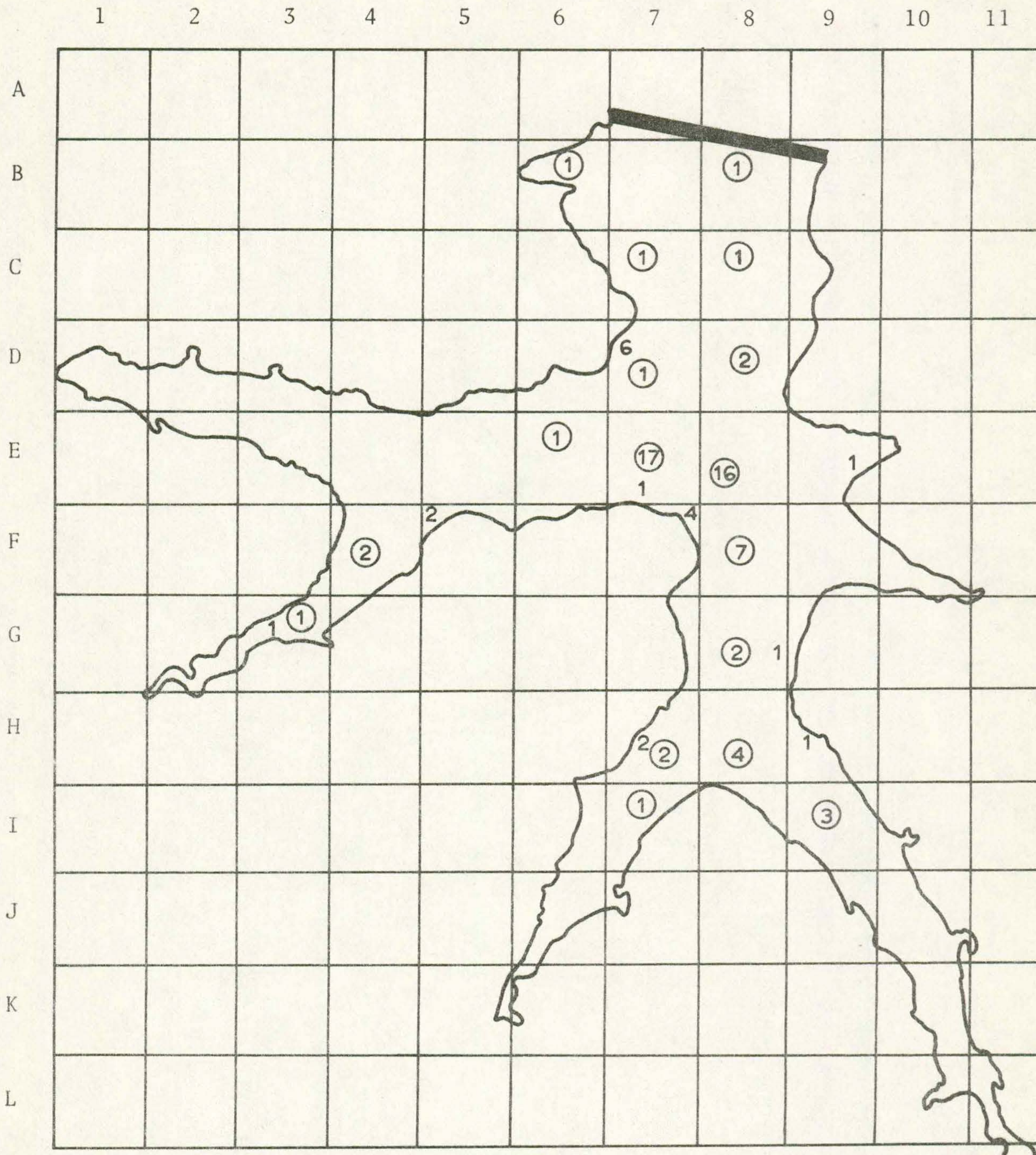

Figure 4. Frequency of contacts for Carla at Red Haw Lake with circled values open water positions.

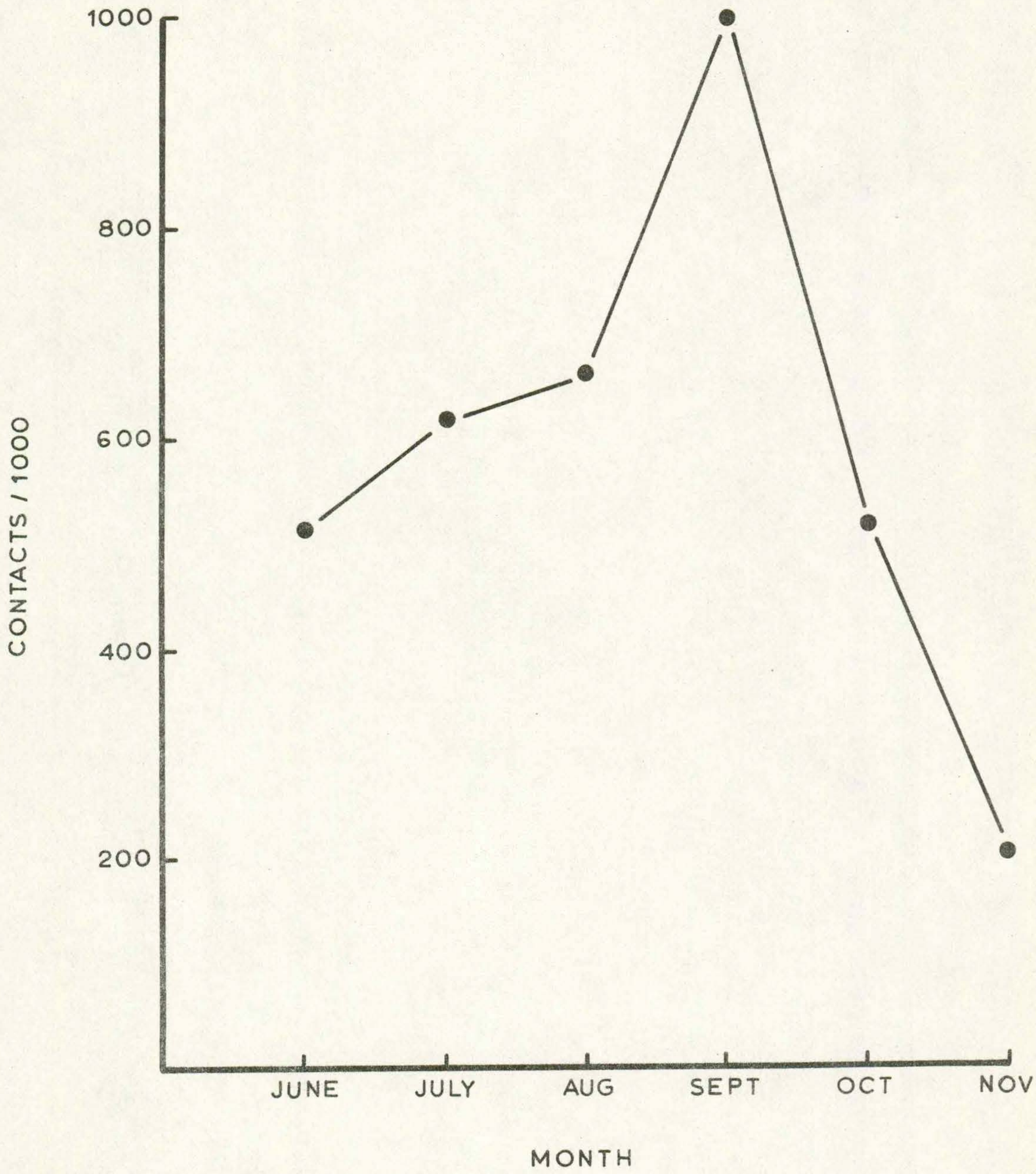

Figure 5. Frequency of contacts in the littoral zone for all fish combined by weighted means.

Fifty-five coordinates occurred in Red Haw Lake. Tagged white amur were located at all except A-7, G-7 and 9, I-6 and 8 and J-7 and 9 (Figure 6). One contact was made in three grids (C-6, E-4 and J-10), while at least 3 sonic contacts were recorded in each of the remaining 45 grid cells. Areas of low or missing coordinate contacts were in the embayments south of coordinate F. The area contained 33% of the coordinates, but only 180 C/T were recorded in the south embayment.

The coordinate with most contacts was D-7 with 92 C/T. Alice was most often located there; but Bertha, Carla and Debra were also monitored at D-7. The grid with second greatest contacts was nearby at D-5 with 89 C/T. Bertha was found most frequently there; but Alice, Gertrude and Ethel frequently inhabited D-5.

There was a greater concentration of contacts in the west embayments. The west arm contained 21 coordinates or 38% of available grids in the lake, but 580 C/T of the adjusted contacts were made in this area. Other areas of high contact frequency were near the headwaters of large bays. At Red Haw there are four major bays with inlets at D-1, G-2, J-6 and L-10 and 11. Contacts were made more frequently at these coordinates than adjacent areas closer to the lake axis. For instance, 42 C/T were logged in L-10 and 11, 27 C/T at J-6, 49 C/T at G-2 and 43 C/T at D-1. The five headwater grids contributed 9% to the total area, but accounted for 16% of the adjusted contacts.

The area near the dam (B-7, 8 and 9; C-6, 7, 8 and 9) was used less than other areas. Seven coordinates comprised 13% of the lake grid while 8% of the adjusted sonic contacts were logged there. The maximum number of contacts were 28 C/T at C-8 with a minimum at C-6 of 1 C/T.

MOVEMENT AND BEHAVIOR

Most of the time where amur were stationary or moved very little as they were monitored. Movement associated with locations in and near vegetation was slow and erratic, but midwater movement was fast and extended over long distances. When directional movement occurred the observer recorded the direction and extent of activity. On 1 August, Debra was monitored for 125 minutes in midwater where she moved 930 m (1,021 yd) for a mean swimming speed of .12 m/sec (.41 ft/sec). Midwater movement of Alice was monitored on 10 July when she traveled 1,910 m (2,090 yd) in 90 min. Average swimming speed was .35 m/sec (1.16 ft/sec). Maximum speed was recorded over a distance of 175 m (192 yd) in 120 seconds or 1.46 m/sec (4.8 ft/sec).

Activity pattern in midwater was entirely dependent on individual fish. Alice generally moved from a shore location at D-7 to midwater locations at D-7 and 8, E-7, 8 and 9 and F-8 and 9 in a haphazard direction. For example, on 12 June, Alice moved in the following sequence: D-7, E-8, E-9, F-9, F-8, E-8, D-8, E-8, F-9, E-8, D-8, C-7 and back to D-7. Only one instance of extended, directional movement was observed. Debra moved from F-4 in one of the west embayments to I-9 in the southeast bay on 1 August.

Movement activity of Alice and Carla showed a definite homing tendency. Both fish were monitored leaving from, and returning to, their main activity center. Alice was monitored on 12 June, 10 July and 12 July leaving coordinate D-7 for midwater. In all cases the fish was monitored in midwater and within

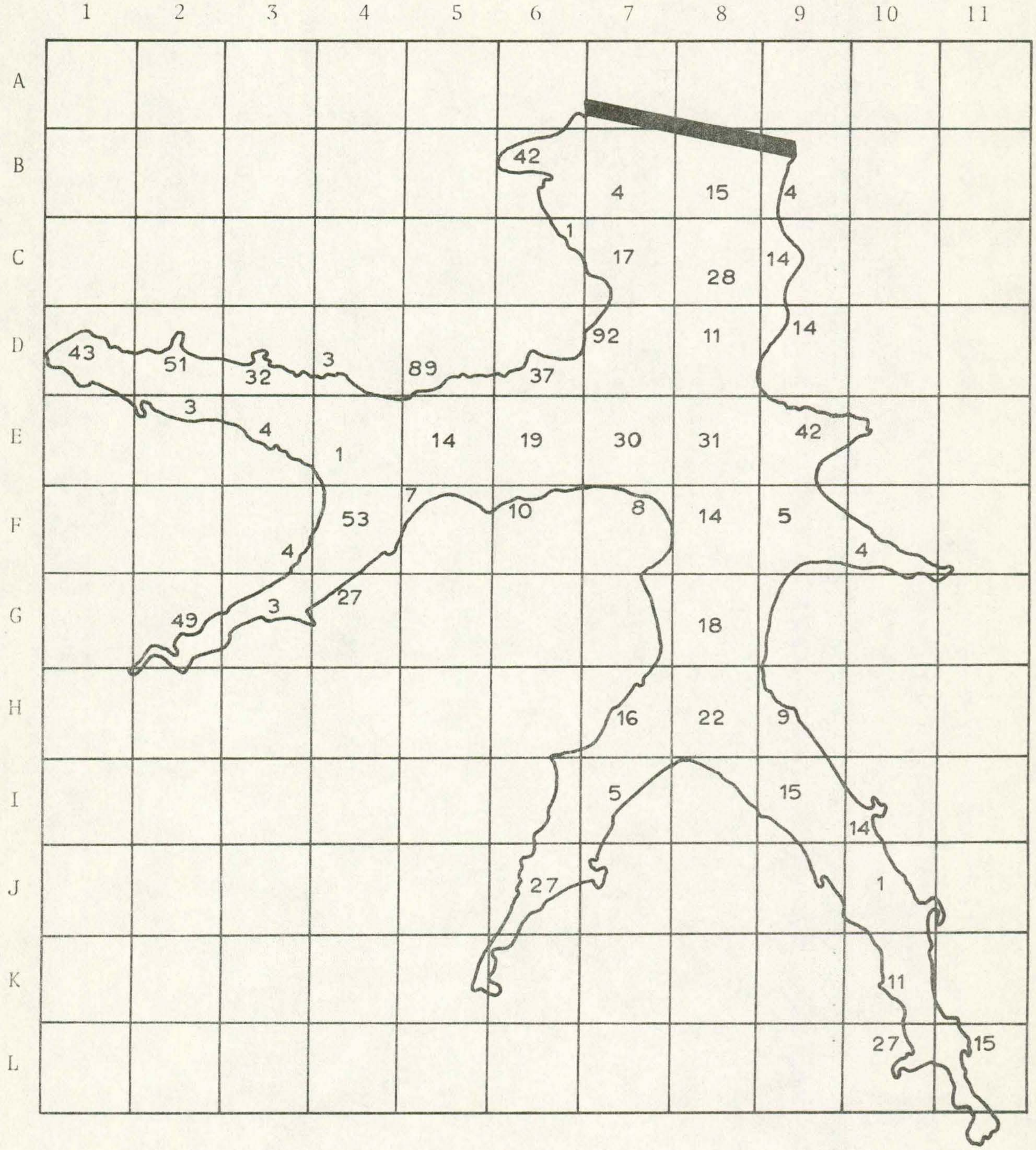

Figure 6. Frequency of contacts for all fish from June-November adjusted by weighted means.

5-147 minutes returned directly to coordinate D-7. On 10 July Alice returned to D-7 twice. On two other occasions Alice was contacted in open water where the observer continued to monitor her activity. Eventually she returned to coordinate D-7.

Carla was found travelling to her activity center E-7 and 8, four times. On 24 June she was contacted at C-8 and within 27 minutes she was at E-7. On 16 July, Carla was located at coordinate I-9. After moving toward the dam at C-8 she returned to E-8 within 20 minutes. Again on 13 August Carla was contacted at B-9 near the dam and followed directly to her activity center at E-8. She remained there for 5 minutes and moved to E-9, and from there to D-7 and back to E-8. On 12 August, Carla was located at E-9 where she moved in sequence to E-8, F-9, E-7, E-6 and back to E-7. Homing activity of other tagged white amur was not demonstrated because of a failure to establish an activity center.

Movement was not noticeably different between daylight and darkness. Between dusk and dawn nearly 20 hours of contact time were logged. Frequency and extent of movement was similar to daytime movement. One difference in behavior was noted from sunset to dusk. White amur would alternately surface and sound in the mid-water area. Carla was observed surfacing at dusk three times by two separate observers. The observation was confirmed by the change in pitch of the sonic input as she surfaced. On two occasions there was a group of four fish surfacing almost simultaneously with her. Surfacing activity during daylight was rare.

Behavior of white amur to boating and fishing activity was recorded when fishermen were close to the fishes location. Occasionally the observer drifted or rowed as close to the fish as possible to obtain a more precise location. The observer also recorded behavior as he approached the fish. Five times during the summer fishermen came within 20 m (45 ft) of tagged fish while they were being monitored. The observer approached tagged fish at close range on nine occasions.

Fishermen with electric trolling motors had little affect on the behavior of white amur. Trolling motors passed directly over tagged fish three times when they were located near vegetation. Each time the fish moved slightly but remained at the same location. On 1 July, a shore fisherman was casting directly over Bertha when she was near shore in a weed bed. She moved slowly and erratically in a small area, but did not leave the vicinity. On 28 June a boat drifted into a log near Alice at coordinate D-7. As the boat bumped the log she moved 7 m (20 ft) away from the boat and stopped.

White amur were not startled by boating but a sudden move or noise caused the fish to move rapidly away from the boat. Rowing near the fish always increased activity and finally when the boat was within 10 m (33 ft) the fish moved completely from the area.

There were three instances when tagged fish were monitored near gill nets. On 1 August, during daylight, Carla was located as she moved parallel to the shore directly toward a gill net which was set perpendicular to the shore. When she was close to the net she changed direction and swam to deeper water parallel to the gill net until she reached the outer edge. She then proceeded parallel along the shore as before. In July and August, turbidity was low and white amur were captured in gill nets only at night. On 24 June, gill nets were drifted near Carla's center of activity in midwater to recover her tag. At one time she came near the net, but turned and moved toward the dam where she remained for several hours.

Ethel was captured on 19 August after she was located in a small bay at L-10. The bay was blocked at the mouth by five nets. Then a boat was used to drive Ethel toward the nets. She was observed jumping over two nets. After an hour she remained between the third and fourth net moving rapidly back and forth between the nets. The following morning the nets were checked and she was captured in the fourth net.

DISCUSSION OF FINDINGS

White amur were found with increasing frequency in midwater as plant abundance deteriorated and water temperature declined. In September all contacts were near shore, but by November only 20% of the contacts were near shore. For example, Alice was contacted mostly at shore locations during the summer, but by September she was only found in midwater. There are two reasons for the change in distribution to midwater habitat.

First, vegetation biomass declined in September reducing the food source. Second, feeding activity was associated with water temperature and as temperature declined in the autumn feeding also subsided. Regardless of which factor was more important white amur became less dependent on the littoral zone in October and November.

Distribution and behavioral activity of white amur is closely related to their effectiveness in controlling aquatic vegetation, particularly where it is most needed. At Red Haw the total biomass of aquatic plants was reduced, but more importantly vegetation was reduced more in some areas than others.

Open shoreline at Red Haw is along the dam, at two picnic areas and near the campground. Vegetation was never a problem near the dam so control was unimportant. The areas needing vegetation control most are C-7, D-4, 5, 6 and 7; D-1, E-2, 3 and 4, F-4; and F-5, 6 and 7; G-7. Sonic tagged fish were located along the shore in all these coordinates, but low contact frequency of < 5 C/T were observed in D-4, E-2, 3 and 4, G-7. All these coordinates were located where there was greatest boating activity. Coordinate D-4 and E-2 contained boat ramps and the shoreline at E-2, 3 and 4 was a boat mooring area.

There was less vegetation control in the bay near the campground. Macrophyte sampling Stations 7, 8 and 9 were located by the campground. Mean biomass for these stations in July, 1973, was 2,416 g/m^2 compared to 2,020 g/m^2 in 1974. Reduction in vegetation biomass was 16%, while reduction for all sampling stations was 44%.

Probably more important to the homogeniety of vegetation control was the tendency for some white amur to remain in confined areas. Alice was contacted 49% of the time at D-7 and Carla was contacted at E-7 and 8, 66% of the time she was located. The probability of white amur being distributed homogeneously along the shoreline was remote as shown by the composite distribution of white amur with sonic tags. Plant consumption in confined areas was undoubtedly high, so homogeneous vegetation control seems dependent on the behavior of white amur and the tendency of white amur to confine most of their activity to small areas.

RECOMMENDATIONS

The information gained from this study segment has shown the basic activity, movement and distribution of white amur at Red Haw Lake. Results shall become part of the study completion document.