Proceedings of the Iowa Academy of Science

Volume 60 | Annual Issue Article 91

1953

Food Habits of the Carp in Northwest Iowa Lakes

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Introduction

In the comparatively short time since carp (*Cyprinus carpio*) were brought to the United States, they have dominated an amazingly large percentage of the fishery resources of this country and an equally large percent of the efforts of fishery management. Carp have been credited at one time or another, by sportsmen and biologists alike, with being the root of all fishery problems and in many cases game problems as well. The food and feeding habits of the carp usually receive the lion's share of this blame.

Any food habits study is necessarily time consuming and often fraught with many difficulties. The value of the facts revealed is not always apparent, or seemingly commensurate with the time, energy and money expended. Bailey and Harrison (1948) state that the food and feeding relationships of fishes commonly dominate their ecological association and that an understanding of the food-habits relationships is necessary for the proper handling of our fishery resources.

Although a number of carp food habit references appear in literature, most of these are general statements and have resulted in considerable misunderstanding about the food of carp. Cole (1904) states that, ". . . , the evidence seems to be pretty strong that in general they are very destructive, and are probably in part, at least, responsible for the great reduction of wild celery and wild rice that has been noted in many of our inland marshes in the last few years." Forbes and Richardson (1920) report that carp are omniverous feeders, taking principally vegetable matter.

American literature contains relatively few references to definite food analyses. Gerking (1950) in a review of the literature found only five references, involving four authors, who had examined a total of 399 carp. An additional 176 adults and 41 young, overlooked by Gerking, were reported by Struthers (1932), and Gerking do not include 24 young carp examined by Sibley (1920) or the 39 young fish reported by Struthers (1930), bringing the total to 679 fish. (Table 1).

The data presented in this study form a portion of a general study of rough fish, their relation to game fish and to acquatic environments. The results reported here concern a comparison of

Table 1

Food of carp as reported by various authors, expressed in percent of total volume.*

Reference	No. of carp examined	Size	Percent Animal	Percent Plant
Pearse, 1918	42		90	6
Pearse, 1922	1		87	3
Sibley, 1929	24	.75-2.2"	62	14
Sibley, 1929	4	5-8"	50	14
Struthers, 1929	42	adult	69	31
Struthers, 1930	39	young	84	9
Struthers, 1930	300	adult		**
Struthers, 1932	41	young	93.99	1.7
Struthers, 1932	176	adult	26.92	4-64
Ewers and Boesel, 1935	10	23-57mm	88	
Total carp examined	679			

*One hundred percent is not achieved in each case because silt, and miscellaneous material are not included.

**The author states that considerably more than half of the diet of adult carp was plant material but that the tabulation of the results did not indicate this because so much of the "unidentified" material was plant.

food habits of 687 carp from several Northwest Iowa lakes during the period of 1946-49.

Description of Lakes From Which Carp Were Taken

An attempt was made to sample carp living under a variety of conditions. Fish used in this study were collected from fourteen lakes and one small pond: Spirit, East Okoboji, West Okoboji, Marble, Hottes, Little Spirit, Prairie and Diamond Lakes in Dickinson County; Lost Island, Rush and Silver Lakes in Palo Alto County; Trumbull Lake, Clay County; High Lake in Emmet County; Storm Lake in Buena Vista County; and the Spirit Lake Hatchery pond known as the "L" pond. They are all shallow, glacial, eutophic lakes except West Okoboji which exceed 100 feet in depth. Spirit and Storm Lakes have been described by Sigler (1949) and (1949) respectively; West Okoboji by Birge and Juday (1920) and Stromsten (1927). The Clay and Palo Alto County Lakes have been described by Hayden (1943). Marble, Hottes and Little Spirit are small, shallow lakes lying adjacent to and draining into Spirit Lake. The "L" pond is a one-half acre pond located on the grounds of the State Fish Hatchery at Spirit Lake, (Appendix Table 9).

Methods and Procedure

Collections were made with a wide variety of gear including gill nets, various lengths of large and small mesh drag seines and traps. Drag seines were used for the majority of collections and consequently took most of the fish, with gill nets and traps catching about ten and twenty percent respectively. In order to reduce the number of empty stomachs to a minimum, no stomachs were examined from fish held for more than 12 hours in summer collections or 24 hours in winter collections.

Fish from all collections were returned to the laboratory where routine data were recorded which included collection and serial numbers, standard and total lengths, weight, sex, maturity and any pertinent remarks. The entire intestinal tract was removed and either examined immediately or preserved in formalin.

The relatively few accounts of food habits of carp appearing in the literature have failed to present an adequate discussion of methods used in handling and analyzing the stomach or intestinal contents. Struthers (1930) used samples from the stomach, upper, middle, and lower intestine; these samples were then studied as to type and percent of food present.

There are two important anatomical features of carp that influence the condition of the intestinal contents. Probably most important is the excellent masticating features of the pharyngeal teeth. These teeth tend to reduce insect larvae, snails, seeds and acquatic vegetation to small bits. Even in the anterior portions of the intestine the chitinous parts of insect larvae often provided the only means of identification, however, crustaceans, and the skin of some larvae, such as those of dipters, proved surprisingly resistant to mastication and digestion. Trichoptera cases usually remained intact but relatively little besides chitinous parts of the larvae remained. Vegetation, although ground to small pieces, showed little evidence of digestion.

The second anatomical feature concerns the fact that there is relatively little separation between what can be called a stomach and the intestine. The walls of the anterior portion of the digestive tract are considerably thicker than the posterior, but there is no pocketing or holding area comparable to that of piscivorous fish. For practical purposes, the ease of identification of the food items varied but little from the anterior to posterior regions of the intestinal tract. In addition to this the anterior portion was often empty. Therefore, it was felt that a better picture of the feeding habits, volume of food taken, and occurrence could be gained by

examination of the entire contents of the digestive tract. For the remainder of this paper any reference to stomach will indicate the total digestive tract.

The method of handling each stomach consisted of placing the contents of the digestive tract in a graduated cylinder and recording the volume to the nearest tenth of a cubic centimeter. No volumes were recorded for young fish. All volumes were measured while the material was moist or slightly wet. A water displacement method was not satisfactory in most cases. There appeared to be no appreciable difference in volumes or in handling between fresh material or those preserved in formalin.

After volumeteric measurement was completed the contents were put into a beaker and thoroughly mixed. If the total volume was greater than ten cubic centimeters (which was often the case) a ten percent sample was removed for detailed study, the remaining portion was examined less critically. Water was then added to obtain a good separation of the food items. This mixture was placed in several petri dishes and examined under a binocular microscope.

After the items identified were recorded, another examination was made to estimate the percentage of total volume represented by each item. These percentages were then converted to volumes. Anthing less than one-tenth of a cubic centimeter was recorded as a trace. No effort was made to convert any demains to original volumes. The number of organisms per stomach were counted for a number of the fish; this will be discussed in another section.

The data from the analyses of the 687 stomachs, (407 containing food), are separated by season and expressed as percentages of total volume and as percentages of frequencies of occurrence for each lake (Appendix tables 1 to 6). The fish were also divided into three size groups as follows; 127 young, 83 small (0.3 to 1.7 lbs.) and 477 adults ranging up to 25 pounds. Other than young, no effort was made to separate the food habits by age groups. For the sake of simplification and brevity, and inasmuch as no special effort was made to secure specific identification on all food items, the material has been lumped by orders and larger groups in the tables and in much of the following discussion. However, during the routine analyses, identifications were carried as far as could be readily accomplished. A list of the identifications appear in appendix table 7. Although determinations of available bottom fauna through bottom sampling was not a routine part of this study,

some data is available on several lakes from which carp were collected (Appendix table 8).

Discussion of Food Consumed

Although carp have long been accused of feeding on aquatic vegetation, the data from this study indicate that under normal lake conditions the diet of carp of all sizes is predominately animal material of three principal groups, insect larvae, crustaceans and molluscs.

Of these three groups, insect larvae were consistently the most important with diptera larvae, principally chironomids, ranking number one in the group. Pupae of diptera occurred frequently but were never important in volume. Diptera larvae constituted an important part in the diet of all sizes of carp under various environmental conditions, including young carp with an average weight of only 3.5 grams. Midge larvae were also important as food of carp from lakes where bottom fauna was considered poor. Trichoptera larvae (caddice-fly larvae) were next in importance from the standpoint of insects, but their occurrence was confined to carp which had been taken from larger lakes during open water periods. Apparently the larger lakes offered a more suitable habitat for caddice than small lakes. Caddice larvae were seldom taken by carp inhabiting lakes having a low volume of bottom organisms and/or a scarcity of acquatic vegetation. Caddice are somewhat less important than shown in the tables due to the fact that no allowance was made for volume of caddice cases. Caddice larvae in the stomach were usually associated with varying amounts of green vegetation in the form of parts of leaves of pondweeds (*Potamogeton spp.*) Although each caddice case was not examined, there were few times that the author found an empty case or evidence of the case having been taken without its larval inhabitant.

Larval and immature forms of the orders Hemiptera, Odonata, Ephemerida, and Neuroptera were taken by carp in varying amounts, but contributed heavily only in a few individual fish.

In the overall picture, crustaceans, primarily the small crustaceans (Entomostraca) were second in importance from the standpoint of volume and ranked just below insects in occurrence. Crustaceans ranked high as food of young and small carp all year and in the food of adults during the winter. Among the larger crustaceans (Malacostraca) only the scud, *Hyalella knickerbockeri,* was of importance and then only in the larger lakes. The scud was usually associated with excellent environmental conditions in the lake, as regard to bottom fauna, vegetation, turbidity, and a desirable balance be-

tween game fish and carp. Bailey and Harrison (1945) in the analyses of eight October carp from Clear Lake found scuds in large numbers when vegetation was abundant in the lake.

The third group, in the order of importance, was the molluscs. Small gastropods such as *Valvata tricarinata* and *Amnicola spp.* made up the bulk of the molluscs taken.

Pelecypods in the form of small fingernail clams occurred frequently but they seldom made up more than two percent of the total diet. Molluscs were taken primarily during the summer months. Stomach contents involving gastropods usually contained green vegetation. Carp seemed to vary in their individual ability to separate snails from vegetation but, in general, large volumes of snails in an individual stomach were associated with relatively small volumes of vegetation. It is likely that the relative abundance of snails accounted for most of the variations. Molluscs were also organisms that occurred only in the diet of carp from lakes having better than average environmental conditions.

In addition to the three major groups of food discussed above, a variety of miscellaneous animal material occurred, usually infrequently and apparently incidental to regular feeding. Among the annelids, the oligochaete worms occurred frequently but due to their delicate bodies and small size they were of little importance. This was also true of the free-living flatworms (*Turbellaria*). Leeches occurred only occasionally. Although water mites (*Hydrachnidae*) were fairly abundant and thir bodies durable, they were seldom taken by carp.

Egg predation has been cited, usually by non-biologists, as one of the objections to carp. The literature covering food studies to date has failed to show that carp take fish eggs. The present data indicates that carp will take walleye (*Stizostedion vitreum vitreum*) eggs during the spawning period, but the predation is not extensive. One stomach from an April collection of 37 Spirit Lake carp contained three walleye eggs. Moen (1950) in a study of walleye egg predation by various species of fish reported no walleye eggs in the stomachs of 51 Spirit Lake carp, and nine eggs in one stomach from a collection of two East Okoboji Lake carp (these 53 fish are not included in this study). Nest building fish were common in East Okoboji, West Okoboji, and Spirit Lakes during the period of study reported here, but no eggs or fry of these fish were found in the stomachs examined. In the analyses of 87 carp from the Des Moines River, Harrison (1950) found no evidence of egg predation

but did find that one percent of the diet, by occurrence, was fish. The fry of spotfin shiner and bullhead minnow were identified.

Plant Food

Although the bulk of the diet of carp is animal, plants have their place as food and should be discussed in order to clarify the role of plant material in the food of carp. The plant material taken by carp can be conveniently divided into three categories; debris or dead plant material, green fragments of living plants, and seeds of aquatic plants, both the size of the fish and the quality of its habitat influenced the type, volume and frequency of plant material.

Any sample of an average lake bottom includes various amounts of dead and decaying plant material readily classified as debris. Debris was the most consistent form of plant material found in carp stomachs, both from the standpoint of volume and occurrence. The value of debris in the diet of carp is questionable but its removal and later return to the lake bottom surely could not be classed as harmful. In general, the quantity of debris taken by carp increased as the quantity of bottom fauna decreased. Lakes supporting a small quantity of bottom organisms (0.1 cubic centimeter or less per square foot) usually had little or no green vegetation. Debris and diptera larvae usually occurred together in the stomachs of carp but individual carp differed in their ability to separate the larvae from the debris.

The majority of the green fragments consisted of leaf parts of pondweeds with smaller amounts of filamentous algae, stonewort (*Chara vulgaris*) and coontail (*Ceratophyllum demersum*). The ingestion of green plant material was apparently both deliberate and incidental. Where green material was taken by choice the bulk of the volume was taken by relatively few individuals of any one collection. For example, one fish contributed two-thirds of the total volume of green material found in 14 carp collected in September from East Okoboji Lake. This particular individual had taken 5.5 cubic centimeters of pure scuds followed by 27 cubic centimeters of green fragments of pondweeds. Green material was considered incidental when liberal numbers of animal organisms such as midge larvae, caddice larvae and snails were found mixed with the plant material. Green material was taken primarily by adults weighing two or more pounds, with a maximum of one percent of the total volume in the diet of carp less than two pounds in weight. In large fish the maximum was 28 percent, and the average about 10 percent.

Seeds of aquatic plants appeared in the diet of carp the year around, but the volume and occurrence increased during late sum-

mer months. Seeds were taken in numbers by certain individuals but the volume did not exceed two percent of the total volume in any period for any lake except one collection of two fish from Spirit Lake in September.

Blue-green algae, diatoms and desmids were not considered because they could be found in the diet of midge larvae and were therefore considered incidental to the regular diet of animal organisms. A single carp from East Okoboji had taken diatoms to the extent that the ingestion appeared deliberate.

Winter Food

Although thousands of pounds of carp are removed from ice covered water each winter, nothing has appeared in the literature in regard to food and feeding habits during this winter period. The analyses of the intestinal contents of 167 adult carp from four Iowa lakes reveal that there is considerable feeding during winter months but both the volume of food and the percent of stomachs containing food was considerably less than during summer or open water periods. During winter months animal organisms made up 100 percent of the diet with only traces of plant material taken. The bulk of these animal organisms were crustaceans with dipterous larvae a close second in importance.

Plankton studies were not conducted, but personal observation and the high volume of crustaceans taken during certain winter periods indicate that feeding takes place primarily at the time of plankton pulses. There was some indication that feeding may be at its lowest ebb during early winter months. All stomachs examined during December were either empty or nearly so. At the same time only one stomach from a February collection of 27 carp from Spirit Lake contained food, but food was found in 17 of 32 stomachs taken in January.

Low oxygen during winter months apparently reduces feeding to the zero point. Eighty adults from Hottes Lake and 45 from Little Spirit Lake taken during low oxygen conditions (less than 1.0 ppm) were all empty. (These do not appear in the tables).

The importance of winter food may be questioned but it is evident that a high carp population could exert considerable pressure on the available midge larvae.

Number of Items per Stomach

Anyone working with the food of carp cannot help but be impressed with the number of organisms taken per individual. Bailey and Harrison (1945) mentioned that large numbers of scuds were

often taken. Nelson (1940) found a maximum of 550 midge larvae per gut in Utah carp. During the course of the analyses reported here no less than eighteen intestinal tracts were examined with the intent of determining how many animal organisms, particularly midge larvae, were taken by an individual carp. These 18 fish did not necessarily represent a random selection. One of three counting techniques was employed; a total count, a count of ten percent sample, or a grid count based on several samples. In counting midge larvae only the heads were counted.

The results varied considerably. The number of diptera larvae found in eight winter stomachs varied from one to 5,000 with an average of 1,099 per stomach. The volume occupied by diptera in the stomachs of these eight fish ran from a trace (less than 0.1 c.c.) to 15.0 c.c. per stomach. A count of the midge larvae in seven stomachs taken during open water periods ranged from 904 to 18,800 for an average of 5,969 per stomach. The volume occupied by midge larvae in this series ran from 7 to 30 c.c. per stomach. The number of midge per cubic centimeter of volume depends on the amount of digestion and the original size of the larvae. This figure had a low of 74 midge per c.c. in winter stomachs and a high of 990 in summer stomachs.

In the series of eight winter stomachs mentioned above, entomostracans ran from 7,000 to 24,000 individuals per stomach. One summer stomach contained 369 caddice larvae and cases (*Hesperophylax sp.*) having a volume of 15 cubic centimeters; another contained 500 caddice larvae and cases. One stomach from Lost Island Lake, where debris of vegetation ranked fairly high in the stomachs of carp, contained 3,050 midge larvae and 6,000 pieces of plant debris.

Rate of Digestion

In order to have a better understanding of how often these tremendous numbers of organisms were consumed it seemed desirable to know the rate of digestion. Two general methods were used to determine this. One consisted of holding carp for a week or more without food, then feeding them midge larvae. The second method involved the examination of a series of carp to record the time of passage rate of digestion of natural food already in the stomach.

After having been starved for a period of two weeks three carp were fed 300 midge larvae. The first carp was examined 2½ hours later; 75 midge larvae were recovered. The total length of the gut was 28 inches. The first larvae were found four and one-half inches from the anterior end (examination was made from front to rear)

and the last was found 12 inches from the anterior end; the main concentration was between 6 and 12 inches. A copious supply of bile was noted in the area of the bloodworms. (Examination of these larvae after partial digestion confirmed observations made during routine analyses.) The second carp was examined five hours after feeding. Thirty-five larvae were recovered; the first larvae was located 8½ inches from the anterior end and the last at 6 inches from the posterior end. The third carp was examined after an elapsed time of 50 hours. The stomach of this fish was empty. In a similar feeding experiment three carp consumed and passed 600 large midge larvae during a period of 14 hours. Both experiments were conducted with water temperatures at 73°F. A third feeding experiment involved 360 midge fed to two carp with the water temperature at 68°F. These two carp had ingested the midge within 5 hours; they were examined 23 hours following the addition of the food. Both fish were empty except for two dozen midge larvae in the posterior three inches of the intestine of one fish.

In order to determine whether or not this method was biased by withholding food for a long period of time prior to feeding, a series of carp were taken from seine hauls, placed in tanks and a few individuals examined at various intervals of time. In the first check of this method twenty-eight carp were placed in a tank at noon. Six of these fish were examined at 3 P.M. and no empty stomachs were found. The amount of material in each stomach was estimated as representing one-third to two-thirds of the total capacity in each case with four of the six fish noted as one-half full. Seining had started at 9 A.M. that morning, thus about 6 hours had elapsed since interruption of normal feeding. Thirty hours after interruption of feeding, five fish were examined and all were empty. The remaining seventeen fish were examined after 48 hours of elapsed time and all were empty. Water temperature remained at 64°F. for the duration of the experiment. Another group of 17 fish were given the same treatment. Eight fish were examined about four hours after interruption of feeding and all stomachs were noted as being more than three-fourths full. The remaining nine fish were examined approximately twenty-nine hours after capture and all stomachs were empty. The water temperature had dropped from 64°F. to 62°F. during the experiment. The final experiment in this series was conducted with 25 carp and a water temperature of 49°F. Five fish were examined seven hours after collection; one was empty, four stomachs were estimated as one-fourth to one-half

full. Twenty-four hours after collection the remaining 20 fish were examined; 15 stomachs were empty, five contained only traces of food in the extreme posterior portion of the intestine.

The above data seems to indicate that with water temperatures at 49°F. or higher, adult carp will digest all the material in the stomach in about 24 hours. The lowest water temperature recorded for collections made during open water periods was 48°F.

Then to carry this thought one step further, the volume of animal food per pound of carp (including empty stomachs) was computed for each of six lakes for open water periods. These figures ran from 0.5 c.c. for Rush Lake carp to 9.2 c.c. for West Okoboji Lake carp, averaging 3.7 c.c. Among the six lakes, Rush Lake was considered the poorest in aquatic environment while West Okoboji Lake represented near optimum conditions. Using the average figure of 3.7 c.c., the consumption of animal food by a carp population of 100 pounds per acre amounts to 370 c.c. per day, or slightly more than 0.1 cubic centimeter per square foot every two weeks. Converted to pounds this amounts to about 5 pounds of animal food per acre per week.

Although the above statements may be considered controversial, it is quite apparent that carp offer considerable competition for the available food. This competition would be intensified in lakes having a poor supply of bottom organisms and a high population of carp.

Summary

Although carp have been accussed of feeding on vegetation, the data from the analyses of 687 carp stomachs from 14 Northwest Iowa lakes indicate that their food is predominately animal material. Aquatic insect larvae, small crustaceans and snails made up the bulk of the animal foods during summer periods.

Plant material found in carp stomachs consisted of debris, green fragments of living plants, and seeds of aquatic plants, in that order of importance. Debris was usually associated with midge larvae with higher amounts of debris occurring in stomachs of carp from lakes having a poor bottom fauna. Green fragments seldom made up more than 10 percent of the food of carp and seed of aquatic plants less than 2 per cent.

The winter food of carp was 100 per cent animal material with small crustaceans and midge larvae of about equal importance.

Counts of animal organisms in the stomachs of carp indicated that large numbers of midge larvae and other animal organisms were taken.

Rate of digestion experiments pointed out that carp could digest the stomach contents within 24 hours with water temperature of 49°F. or warmer.

ACKNOWLEDGEMENT

The author wishes to thank Dr. William F. Sigler, Utah State College, for his suggestions in the preparations of the manuscript. The writer appreciates the help and encouragement given by Mr. E. B. Speaker, Superintendent of Biology Section, Iowa State Conservation Commission; and he is indebted to Dr. Kenneth Carlander, Iowa State College, and the writer's associates in the biology section for their cooperation and assistance.

Food of adult carp from Spirit Lake, in 1946, 1947, and 1948 (open water), expressed as percentages of total volume of food organisms and as percentages of frequencies of occurrence.

Date of collection	April 1948		May 1946		June 1947		July 1946		July 1947		August 1947		Sept. 1947		Combined	
Number of stomachs taken	37		6		13		4		7		3		2		72	
Number of stomachs containing food	36		5		8		2		7		3		2		63	
Percent of stomachs containing food	97		83		61		50		100		100		100		88	
Total volume of food (c.c.)	384.0		87.0		109.1		11.8		302.0		125.0		73.0		1091.9	
Weight (pounds) mean	2.1		5.9		8.7		4.0		8.0		4.3		11.3		4.6	
Range	1.4-5.0		4.0-9.6		5.5-18.0		3.3-4.5		5.8-12.2		3.1-4.9		7.2-15.5		1.4-18.0	
	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Vol. Occ. Percent		Vol. Occ. Percent		Vol. Occ. Percent		Vol. Occ. Percent		Vol. Occ. Percent	
Animal	97	100	96	100	95	100	100	100	98	100	88	100	37	100	92	100
Insects	76	100	78	100	61	100	93	100	31	100	74	100	30	100	59	98
Neuroptera (Sialis)	T	50			4	13							T	50	1	32
Ephemeroptera	T	11			2	63			T	57					T	21
Hemiptera					1	38			T	14					T	6
Trichoptera	5	53	19	60	5	38	2	50	17	86	5	67	T	50	9	51
Diptera	70	100	59	80	49	87	91	100	13	100	69	100	30	100	49	97
Crustacea	19	92	7	60	34	100	3	50	46	100	2	100	T	100	23	86
Entomostraca	9	89			16	87	2	50	T	28	2	100	T	50	5	73
Cladocera	T	19			15	63	2	50	T	28	T	67	T	50	2	30
Copepoda	1	69			T	25					T	33	T	50	T	46
Ostracoda	8	83			1	38			T	14	2	100	T	50	3	60
Malacostraca	10	72	7	60	18	87	1	50	45	100	T	100	T	100	18	71
Hyalella	10	72	7	60	18	87	1	50	45	100	T	100	T	100	18	71
Mollusca	3	47	5	60	T	13	4	50	21	100	12	100	6	50	9	48
Gastropoda	2	44	5	60	T	13	4	50	21	100	8	67	6	50	9	44
Pelecypoda	1	19							T	28	3	67			1	17
Annelids	T	3													T	2
Turbellaria	T	3							T	28			T	50	T	6
Fish eggs	T	3													T	2
Unidentified	T	3	6	40					T	14	T	33			T	8
Plant	3	72	4	60	5	87	T	100	2	100	12	67	63	100	8	73
Debris	2	67	4	60	4	75	T	50	2	100	2	67	56	100	6	71
Green fragments	T	7			1	25			T	28	10	67	T	50	2	14
Seeds	T	22							T	57	T	33	7	100	T	24

Appendix Table 2

Food of adult carp from East Okoboji Lake, in 1946 and 1947 (open water), expressed as percentages of total volume of food organisms and as percentages of frequencies of occurrence.

Date of collection	June* 1946		June 1947		July 1946		July 1947		August 1947		Sept. 1947		October 1947		Combined	
Number of stomachs taken	8		9		6		4		9		14		13		63	
Number of stomachs containing food	6		6		6		4		9		14		12		57	
Percent of stomachs containing food	75		66		100		100		100		100		92		90	
Total volume of food (c.c.)	13.1		67.2		28.0		205.0		373.0		260.0		455.0		1,401.3	
Weight (lbs.) mean	4.2		10.5		5.4		8.8		6.1		5.5		6.8		6.6	
Range	2.8-7.5		6.1-25.5		2.7-12.4		4.8-10.8		2.3-12.6		2.1-12.3		2.0-11.5		2.0-25.5	
	Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent	
	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.
Animal	100	100	73	100	88	100	63	100	80	100	72	100	77	100	75	100
Insects	97	100	69	100	31	83	18	100	42	89	48	71	63	100	48	96
Neuroptera (Sialis)							T	50	T	11	T	43	T	50	T	23
Ephemeroptera			T	17	T	17					T	14	T	17	T	10
Odonata													T	8	T	8
Hemiptera	T	50													T	5
Trichoptera	66	50	25	83	15	83	T	50	25	78	26	71	2	92	14	76
Deptera	31	33	44	100	16	66	18	100	17	78	22	86	61	100	34	84
Crustacea	3	17	4	66	2	17	6	100	10	100	15	100	9	100	9	80
Entomostraca	3	17	T	33			T	50	T	67	4	93	6	100	3	63
Cladocera	3	17	T	33					T	67	2	57	6	100	2	49
Copepoda							T	50			T	36	T	92	T	30
Ostracoda			T	17					T	11	2	80	T	8	T	26
Malacostraca			4	50	2	17	6	100	10	67	11	71	3	58	6	56
Hyalella			4	50	2	17	6	100	10	67	11	71	3	58	6	56
Mollusca	T	17	T	33	55	100	38	100	27	89	8	71	5	67	17	68
Gastropoda	T	17	T	17	55	100	25	100	27	89	7	71	5	67	15	67
Pelecypoda			T	17			13	75			T	14	T	17	2	14
Annelida													T	25	T	5
Hydracarina											T	7			T	2
Turbellaria													T	25	T	5
Plant	T	17	27	83	12	100	37	100	20	100	28	100	23	100	25	89
Debris	T	17	26	83	6	100	3	75	2	100	12	93	5	58	6	77
Green fragments			T	33	6	33	27	100	18	89	14	71	16	83	18	67
Seeds									T	11	T	43	2	67	1	26

Comparison of the food of adult carp from several Iowa lakes collected in 1947 (open water), expressed as percentages of total volume of food organisms and as percentages of frequencies of occurrence.

Lake	Spirit		East Okoboji		West Okoboji		Rush*		Silver*		Lost Island	
Date of collection	June thru September		June thru October		July and August		August		July		July and October	
No. of stomachs taken	25		49		5		14		16		15	
No. of stomachs containing food	20		45		5		10		14		12	
% of stomachs containing food	80		92		100		71		87		80	
Total volume of food (c. c.)	609.1		1360.2		233.4		76.6		197.0		204.1	
Weight (lbs.) mean	8.2		7.1		5.0		3.7		3.4		2.3	
Range	3.1-18.0		2.0-25.5		3.3-6.5		2.7-4.7		2.0-5.2		1.9-3.0	
	Percent		Percent		Percent		Percent		Percent		Percent	
	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.
Animal	88	100	74	100	99	100	32	80	88	100	69	100
Insects	45	95	49	98	46	100	27	80	79	93	66	100
Neuroptera (Sialis)	1	10	T	33	T	20						
Ephemeroptera	1	45	T	9					T	14	1	58
Odonata			T	2								
Hemiptera	T	20					T	10			6	25
Coleoptera					T	20						
Trichoptera	10	60	14	78	6	20			6	29	8	67
Diptera	33	95	34	93	40	100	27	80	73	93	51	100
Crustacea	29	100	9	96	3	100	5	30	9	86	3	83
Entomostraca	4	65	2	78	T	20	5	30	9	86	3	83
Cladocera	3	50	2	60			2	20	7	86	3	75
Copepoda	T	20	T	38			3	20	2	64	T	33
Ostracoda	1	40	T	31	T	20						
Malacostraca (*Hyalella*)	25	95	7	69	3	100						
Mollusca	14	60	16	71	49	100						
Gastropoda	13	55	14	69	47	100						
Pelecypoda	1	20	2	16	2	20						
Annelida			T	7								
Hydracarina			T	2			T	10				
Turbellaria	T	15	T	7								
Unidentified	T	10										
Plant	12	90	26	98	1	60	68	100	12	86	31	92
Debris	9	85	6	82	1	60	41	100	11	86	31	92
Green fragments	2	35	19	82			27	50	1	7		
Seeds	1	35	1	33	T	20	T	60	T	21	T	42

*Palo Alto County.

Appendix Table 4

Food of small carp (.3 to 1.7 lbs.) from Trumbull, Rush*, West Okoboji, Spirit, Prairie and High Lakes, expressed as percentages of total volume of food organisms and as percentages of frequencies of occurrence.

Lake	Trumbull	Rush	West Okoboji	Spirit	Prairie	High	Combined
Date of Collection	August 1946	August 1947	July-Aug. 1947	August 1947	Sept. 1948	August 1948	
Number of stomachs taken	19	13	9	5	7	30	83
Number of stomachs containing food	19	13	8	5	7	29	81
Percent of stomachs containing food	100	100	89	100	100	97	98
Total volume of food (c.c.)	48.3	75.0	66.5	40.0	21.0	124.5	375.3
Weight (lbs.) mean	1.2	0.9	0.6	0.7	0.45	1.1	0.9
Range	.8-1.7	.4-1.2	.3-.9	.5-.9	.3-.8	.5-1.7	.3-1.7

	Trumbull		Rush		West Okoboji		Spirit		Prairie		High		Combined	
	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.
Animal	79	100	74	100	100	100	97	100	72	100	84	100	85	100
Insects	12	37	72	100	32	87	92	100	59	100	17	80	40	75
Neuroptera (Sialis)							T	20					T	1
Ephemeroptera	T	5											T	1
Odonata									18	86			1	7
Trichoptera					21	87	4	100					4	15
Diptera	11	32	72	100	11	75	88	100	41	100	17	80	35	73
Crustacea	67	100	2	100	31	100	5	80	13	100	67	100	38	99
Entomostraca	67	100	2	100	T	25	4	80	13	100	67	100	32	91
Cladocera	9	26	1	77			T	20	T	29	66	100	23	55
Copepoda	58	90	T	8			T	20	13	100	1	37	9	45
Ostracoda			T	46	T	25	4	80	T	29			T	17
Malacostraca					31	87	T	40					6	11
Hyalella					31	87	T	40					6	11
Mollusca					37	100	T	40					7	12
Gastropoda					37	100	T	40					7	12
Hydracarina	T	5					T	40					7	1
Plant	21	90	26	100	T	37	3	100	28	100	16	90	15	88
Debris	21	90	26	100	T	37	2	80	28	100	15	90	15	86
Green fragments							1	80					T	1
Seeds	T	5	T	39			T	80			T	28	T	22

Winter food of adult carp from Spirit, East Okoboji, Marble and Storm Lakes, expressed as percentages of total volume of food

Lake	Spirit Lake				East Okoboji						Marble		Storm	
Date of Collection	January* 1949		February 1948		February 1949		December 1947		March 1948		December 1948		February 1948	
Number of stomachs taken	32		10		27		13		21		27		37	
Number of stomachs containing food	17		7		1		3		20		4		33	
Percent of stomachs containing food	53		70		4		23		95		15		89	
Total volume of food (c.c.)	137		22.5		T		2.0		802.5		5.7		159.4	
Weight (lbs.) mean	7.2		7.7		1.6		9.0		9.0		2.4		2.1	
Range	0.9-18.1		6.8-9.5		1.0-3.0		3.0-17.1		3.2-15.1		0.9-4.5		0.3-5.8	
	Percent		Percent		Percent		Percent		Percent		Percent		Percent	
	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.
Animal	100	100	100	100	100	100	100	100	100	100	95	100	100	100
Insects	20	94	74	100	50	100	100	100	10	90	95	100	2	12
Neuroptera (Sialis)			T	14										
Odonata									T	10				
Diptera	20	94	73	100	50	100	100	100	10	90	95	100	2	12
Crustacea	80	94	23	71	50	100			90	100			98	100
Entomostraca	80	94	23	71	50	100			90	100			98	100
Cladocera	77	76	21	71					89	100			61	97
Copepoda	3	82	2	55	50	100			1	35			15	73
Ostracoda									T	20			22	64
Malacostraca			T	28					T	20				
Hyalella			T	28					T	15				
Gammerus									T	20				
Mollusca			1	55					T	10				
Gastropoda			T	55					T	10				
Pelecypoda			T	14										
Turbellaria			T	20										
Plant			T	28					T	25	5	25	T	3
Debris			T	14					T	20	5	25	T	3
Green fragments									T	5				
Seeds			T	14										

*Two stomachs from late December 1948.

Appendix Table 6

Food of young of the year carp from various localities, expressed as percentages of frequencies of occurrence.

Lake	Spirit	Diamond			Little Spirit	Rush	"L" Pond	West Okoboji	Combined	Hottes
Date of Collection	July 1946	July 1946	July 1947	Aug. 1949	April 1947	August 1947	August 1948	Sept. 1949	(Open water)	Dec.-Jan.
Number of stomachs taken	18	5	20	10	16	2	11	3	85	42
Number of stomachs containing food	18	4	14	8	14	2	11	3	74	6
Percent of stomachs containing food	100	80	70	80	88	100	100	100	87	14
Weight (grs.) mean	3.5	0.8	7.7	105.0	107.0	48.0	14.1	78.0		283
Range	2.0-5.0	.5-1.0	2.0-15	73-155	25-184	40-50	8-22	73-86		43-482
	percent	percent	percent	percent	percent	percent	percent	percent	percent	percent
Animal	100	100	100	100	100	100	100	100	100	100
Insects	80		100	100	79	100	82	33	73	
Neuroptera (Sialis)	6								1	
Ephemeroptera			7						1	
Hemiptera				13					1	
Coleoptera					7			33	3	
Trichoptera			14		14				5	
Diptera	78		93	13	79	100	82		68	
Crustacea	78	100	50	100	100	100	100	67	84	100
Entomostraca	72		50	100	100	100	100	67	84	100
Cladocera	6			88	57	100	100		40	33
Copepoda	72	100	50	75	100		8		61	67
Ostracoda	22	75			14			67	11	67
Malacostraca (*Hyalella*)	6								1	
Mollusca								100	4	
Gastropoda								100	4	
Pelecypoda								67	3	
Oligochaets		25							1	
Turbellaria				50					5	
Hydracarina			7						1	
Plant	28		7		57	100	8	33	24	33
Debris	28				57	100		33	20	
Seeds						50		33	3	
Algae (blue green)			7		7		8		4	33

Appendix Table 7

A phylogenetic list of food items identified from carp stomachs. All determinations are those of the author, except for algae species which were identified by E. T. Rose.

Animal Material

PLATYHELMINTHES

Turbellaria

ANNELIDA

Oligochaeta
Tubificidae
Tubifex sp.
Limnodrilus sp.
Hirudinea
Hirudinidae

ARTHROPODA

Crustacea
Entomostraca
Cladocera (Brachiopoda)
Daphinidae
Daphnia longispina
Daphnia pulex
Ceriodaphnia sp.
Bosminidae
Bosmina sp.
Chydoridae
Chydorus sp.
Copepoda
Centropagidae
Diaptomus sp.
Cyclopidae
Cyclops sp.
Ostracoda
Malacostraca
Gammaridae
Gammarus sp.
Orchestiidae
Hyalella knickerbockeri

Insecta
Neuroptera
Sialidae
Sialis infumata
Ephemerida (Ephemeroptera)
Ephemeridae
Caenis sp.
Hexagenia sp.
Odonata
Anisoptera
Zygoptera
Hemiptera
Corixidae
Corixa sp.
Coleoptera
Dytiscidae
Haliplidae
Haliplus sp.
Trichoptera
Leptoceridae
Setodes sp.
Mystacides sp.
Limnephilidae sp.
Astenophylax sp.
Hesperophylax sp.
Molannidae
Molanna sp.
Helicopsychidae
Helicopsyche sp.
Diptera
Chironomidae (Tendipedidae)
Chironomus plumosus
Chironomus sp.
Tanypus sp.
Tanytarsus sp.
Ceratopogonidae
Ceratopogonid sp.

Arachnoidea
Hydrachinidae

MOLLUSCA

Gastropoda
Planorbidae
Planorbis antrosus
Heliocodiscus sp.
Heliosoma sp.
Gyraulus sp.
Physidae
Physa sp.
Amnicolidae
Amnicola sp.
Valvatidae
Valvata tricarinata
Viviparidae
Vivaparus sp. (*contectoides* ?)

Plecypoda
Sphaeriidae
Pisidium sp.
Sphaerium sp.
Musculium sp.

Plant Material

ALGAE

Ulothrichaceae
Ulothrix sp.
Chroococceae
Microcystis sp.
Nostocaceae
Aphanizomenon flos-aquae
Oscillatoriaceae
Oscillatoria sp.
Cladophoraceae
Cladophora sp.
Characeae
Chara vulgaris
Desmidiaceae
Bacillariaceae

VASCULAR, Parts of

Zosteraceae (Najadaceae)
Potamogeton pectinatus
Potamogeton foliosus
Potamogeton richardsonii
Potamogeton spp.
Najadaceae
Najas sp.
Hydrocharitaceae
Vallisnearia americana
Lemnaceae
Lemna minor
Ceratophyllaceae
Ceratophyllum demursum

SEEDS, of

Zosteraceae (Najadaceae)
Potamogeton spp.
Najadaceae
Najas quadalupensis
Najas sp.
Graminae
Spartina sp.
Cyperaceae
Scirpus sp.
Ulmaceae
Ulmus sp.
Polygonaceae
Rumex sp.

Appendix Table 8

Abundance of bottom fauna per square foot of bottom for several Iowa lakes, 1946-1949. The periods given here roughly correspond to periods in which carp were taken for stomach analysis.

Lake	Year	Month	Number of Stations	Av. Volume in cubic centimeters	Av. Number of Organisms
Spirit Lake	1946	February	7	1.4	28.2
		March	13	1.8	51.0
		June	3	2.0	41.0
	1947	June	2	4.7	190.8
	1948	July	14	.1	35.6
		November	4	.3	56.9
	1949	February	11	.3	68.5
East Okoboji	1946	February	3	.4	15.3
	1947	May	6	1.5	111.2
	1948	September	10	1.8	132.7
Rush Lake	1947	July	4	T*	5.4
Lost Island	1947	June	10	0.1	19.4
		October	10	T	12.5
Trumbull Lake	1946	July	4	T	6.2
Prairie Lake	1949	March	3	1.2	149.0
High Lake	1949	February	5	T	8.5
Hottes Lake	1948	February	3	1.2	113.8
Marble Lake	1949	June	2	.3	118.7
Storm Lake	1948	February	9	.2	82.7

*less than 0.1

Appendix Table 9

Comparison of the physical features of 14 Iowa lakes and one pond from which carp were collected for food study.

Lake	Area (Acres)	Depth in Feet Maximum	Depth in Feet Average	Algae	Plants Submergent	Plants Emergent
Spirit Lake	5,684	27	15	Common	Abundant	Common
East Okoboji	1,875	26	10	Abundant	Abundant	Scarce
West Okoboji	3,939	132	60	Scarce to Common	Abundant	Scarce
Marble	175	6	4		Winter Sample	
Hottes	312	9	5		Winter Sample	
Little Spirit	214	10	6		Winter Sample	
Prairie	136	4	3	Common	Scarce	Scarce
Diamond	166	6	4	Common	Abundant	Absent
Lost Island	1,260	12	8	Common	Scarce to Absent	Absent
Rush	460	4	3	Scarce	Scarce	Common
Silver	638	7	5	Common	Scarce to Absent	Absent
Trumbull	1,190	5	4	Absent	Absent	Scarce
High	467	7	5	Common	Scarce to Absent	Absent
Storm	3,060	10	8		Winter Sample	
"L" Pond	½			Common	Abundant	None

Literature Cited

Bailey, Reeve M. and Harry M. Harrison, Jr. 1945. The Fishes of Clear Lake, Iowa, Iowa State College Journal of Science, Vol. 20, No. 1, Oct. 1945, pp. 57-77.

Bailey, Reeve M. and Harry M. Harrison, Jr. 1948. The Food Habits of Southern Channel Catfish (*Ictalurus punctatus*) in the Des Moines River, Iowa. Trans. Am. Fish Soc. 1945, Vol. 75, pp. 110-138.

Birge, E. A. and Chancey Juday. 1920. A Limnological Reconnaissance of West Okoboji University of Iowa Studies—Studies in Natural History. Vol. 9, No. 1, Sept. 1920.

Cole, L. J. 1905. The German Carp in the United States. Report of the U. S. Bureau of Fisheries, 1904 (1905), pp. 523-641.

Ewers, Lela A. and M. W. Boesel. 1935. The food of some Buckeye Lake fishes. Trans. Am. Fish. Soc., 65:57-69.

Forbes, S. A. and R. E. Richardson. 1920. The Fishes of Illinois (Second Edition) Nat. Hist. Surv., Ill.

Gerking, S. D. 1950. A Carp Removal Experiment at Oliver Lake, Indiana. Investigations of Indiana Lakes and Streams, Vol. 3, No. 10, pp. 373-388.

Harrison, Harry M. 1950. The Foods Used by Some Common Fish of the Des Moines River Drainage. Mimeographed Ms., Proc. Iowa Cons. Comm. Biol. Seminar, July 1950.

Hayden, Ada. 1943. A Botanical Survey in the Iowa Lake Region of Clay and Palo Alto Counties. Iowa State College Journal of Science, Vol. 17, No. 3, April 1943, pp. 277-416.

Moen, Tom. 1950. Notes and Summary of Hatchery Operations., Mimeo. Ms., Proc. Iowa Cons. Comm. Biology Seminar, July 1950.

Nelson, Noland F. 1940. A report on Carp in Relation to Duck Food Plants and Bass at the Clear Lake, Utah, Waterfowl Project. Unpublished Ms.

Pearse, A. S. 1918. The food of the shore fishes of certain Wisconsin lakes. Bull. U. S. Bur. Fish. 35 (1915-1916): 245-292.

Sibley, C. K. 1929. The food of certain fishes of the Lake Erie drainage basin. N. Y. Cons. Dept. Suppl. to 18th Ann. Rept. pp. 180-188.

Sigler, William F. 1949. Life History of the White Bass, *Lepibema chrysops* (Rafinesque), of Spirit Lake, Iowa. Iowa State Col. Agr. Ext. Serv. Research Bull. 366. 1949.

Sigler, William F. 1949. Life History of the White Bass in Storm Lake, Iowa. Iowa State Col. Journal of Science, Vol. 23, No. 4, July 1949, pp. 311-316.

Stromsten, Frank A. 1927. Lake Okoboji as a Type of Aquatic Environment. University of Iowa Studies—Studies in Natural History, Vol. 12, No. 5, November 1927.

Struthers, P. H. 1929. A biological survey of the Erie-Niagara system. X. Carp control studies in the Erie Canal. N. Y. Cons. Dept. Suppl. to 18th Ann. Rept., pp. 208-219.

Struthers, P. H. 1930. A Biological Survey of the Champlain Watershed. VIII. Continuous studies. 1. Carp control studies in the Cayuga and Owasco Lake basin. N. Y. Cons. Dept. Suppl. to 19th annual rpt. pp. 261-280.

Struthers, P. H. 1932. A Biological Survey of the Oswegatchie and Black River Systems. XI. A review of the carp control problem in New York waters. N. Y. Cons. Dept. Suppl. to 21st annual rpt. pp. 272. 289.

Biology Section

State Conservation Commission

Des Moines, Iowa