A BIOLOGICAL STUDY OF FISH PARASITES FROM THE CENTRAL STATES.*

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INTRODUCTION.

During the last thirty years only a few papers have appeared which deal with the general occurrence of the parasites of fresh-water fish in North America. Ward (1894) reported on an investigation of the extent of infection with parasitic worms among 20 different species of fish inhabiting the water of Lake Saint Clair. Marshall and Gilbert (1905) published notes on the food and parasites of 13 species of fish found in the lakes near Madison, Wisconsin. In 1912 a more extensive paper by Ward appeared which dealt with the data accumulated from examinations of 991 fish among which were representatives of 62 species. This material was collected over a period of years and included such migratory fish as the salmon, (besides the strictly fresh-water fish).

Studies concerning the distribution of certain families of parasites have been made by various workers. LaRue (1914) published a comprehensive monograph on the Proteocephalidae. Cooper's monograph of 1918 on the Pseudophyllidea describes over 50 genera of parasites which occur in freshwater fish. Little has been done in the study of the seasonal distribution of fish parasites from fresh-water hosts. The report of Van Cleave (1916) on the seasonal distribution of Acanthocephala represents the only work that has been done in this field. Studies have also been made of the parasitic fauna of certain species of fish. An intensive investigation of the parasites of the Sebago salmon was reported by Ward (1910). Pearse (1924) gives an account of the parasites of the yellow perch. Taken as a whole, however, the literature is lacking in extensive surveys of the parasitic infection of fish inhabiting the fresh-water lakes and streams of North America. More work along these lines would prove of great value to those investi-

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gating the life cycles, seasonal distribution and other similar questions of parasitology. The purpose of the investigation which we are reporting was to collect data looking to the solution of some of these problems.

The major portion of the data with which this account deals was gathered during the past summer (1925) when the writers, at the suggestion of Dr. Henry B. Ward and under his direction, made a preliminary survey of the parasites of fish inhabiting some of the inland lakes and rivers in the upper Mississippi and Missouri basin. The investigation was chiefly concerned with internal parasites. That is, with the flukes, tapeworms, roundworms and spiny-headed worms which infect most fish in varying degrees of intensity. To carry on this work successfully it was necessary to travel by auto. A touring car was fitted out with the necessary camping equipment and scientific apparatus requisite for field work such as dissecting instruments, microscopes, vials and preservatives. Accessories in the form of fishing tackle, nets etc. were included.

We wish here to express our gratitude to Dr. Henry B. Ward for his part in making possible the survey and for much helpful criticism and advice during the preparation of the report. We also acknowledge indebtedness to Dr. G. W. Hunter for his interest and aid in the undertaking, and to the Natural History Survey for the loan of camping equipment. Dr. David H. Thompson of the Illinois Natural History Survey merits especial thanks for his invaluable assistance in furnishing us with material for examination, especially during our stay on the Rock River. We are also grateful to F. Clippinger and P. A. Netland for material sent from Beaver Dam Lake and Lakes Miltona and Irene.

GENERAL ACCOUNT.

The expedition set out from the University of Illinois early in June and returned early in September having covered a distance of about 8,000 miles. During that time collections were made from the following rivers and lakes: rivers, 1. Rock River (northern Illinois); 2. upper Mississippi; 3. Cannon River (east-central Minne-

sota); 4. Cannon Ball River (southern N. Dakota); lakes, 1. Lake Mendota (Wisconsin); 2. Lake Mazaska (southeastern Minnesota); 3. Lakes Miltona and Irene (west-central Minnesota); 4. Mystic Lake (Bear Tooth Mts. southern Montana) (see map). All of the rivers named are tributary to the Mississippi with the exception of the Cannon Ball which is a part of the Missouri system. With the aid of fishermen along these streams we were able to secure an abundance of material for examination. The commercial fishermen along the Mississippi gave us every possible assistance in our work. It might be pointed out here that efforts were made to secure fish for examination from the Little Missouri in North Dakota, near Medora, and from the Yellowstone River in eastern Montana (Glendive and Intake) but both streams were too turbid for successful hook and line fishing and the rapid current, sandy banks and bottom in each instance made seining dangerous if not impossible. The lakes are found in Wisconsin and Minnesota and are typical of the lakes of those regions. Lakes Miltona and Irene in Minnesota are connected by a stream and may be regarded as one lake. Mystic Lake which lies in the Bear Tooth Mountains 7,600 ft. above sea level, is of interest from the scenic viewpoint and also in a biological way as will be indicated later. The records from the lakes are less extensive than those from the rivers since we had to depend on hook and line fishing for material, because commercial fishing is not allowed in those lakes.

In addition to the records made from the above rivers and lakes the data considered here include material collected individually by the writers from the Illinois, Sangamon, and Spoon (Fulton Co.) rivers, and Salt Fork, branch of the Vermilion river, Champaign Co. including the Urbana Drainage Ditch. The records from Lake Winnebago, Beaver Dam Lake, Wisconsin and a portion of those from Lake Miltona were made from examinations of fish sent to the zoological laboratory at Urbana, Illinois. The data from Rock River were augmented from notes made by Justus F. Mueller in October 1924 for the department of zoology of the University of Illinois. Taken as a whole the data represent collec-

tions made from eight streams and 7 lakes at various seasons of the year from August 1923 to March 1926. The most complete records, however, were made during the summer months. Representatives of fourteen families and forty different species of fresh-water fish came under observation during that time. In all 652 individuals were examined and the internal parasites recorded. The majority of the fish belong to four families, namely, 145 to Catostomidae, 139 to Centrarchidae, 107 to Dorosomidae and 127 to Siluridae (Table 7).

Thirty-nine per cent of all the individuals studied were found to harbor one or more kinds of parasitic worms. This rather low figure for the percentage of infection must not be interpreted to mean that fish are usually free from parasites, as quite the contrary is true. It is not uncommon to find in the intestinal tract of the same specimen a large number of trematodes and cestodes as well as nematodes or Acanthocephala. Such forms as the large and small-mouthed bass, the bowfin, black bullhead and the yellow perch are almost invariably parasitized. On the other hand certain species of fresh-water fish are rarely infected. For example, our records show over a hundred gizzard shad (*Dorosoma cepedianum*) examined and no parasites found. The only parasites recorded for this fish are Acanthocephala. The feeding habits of the gizzard shad seem to be such as to preclude the acquiring of an extensive parasitic fauna. Since it feeds largely on vegetable debris at the bottom of streams and lakes, very seldom ingesting animal food, there is little opportunity for parasites which have an extremely complex life cycle, to find in it a suitable host. The European Carp (*Cyprinus carpio*) is another form which shows only occasional infection with helminths. Of the 26 examined only 5 were parasitized; one with nematodes and four with Acanthocephala. These fish are not native to American waters but were introduced from Europe. According to Forbes and Richardson adult carp were brought to Washington, D. C. in 1877 and the young produced by them were distributed to 25 states. The first shipment to Illinois arrived in 1880. In Europe von Linstow and Lühe list sixteen helminths

parasitic in this fish: one nematode (larval stage), two Acanthocephala, eleven trematodes, and two Cestodaria.

Any of these parasites that might have been imported with the adult fish were doubtless held in check because of the absence of the intermediate hosts necessary for their life cycles. In order that a parasite may establish itself in a new environment it must find the proper animal for each of its stages between the egg and the adult. In the case of the trematodes a part of the life cycle is passed in molluscs usually of a definite species. Should a parasite which uses a specific mollusc in Europe be brought to America, its chance of continuing its kind would depend upon the presence here of that mollusc or at least one closely related to it. The hazards to which a helminth is subjected under such circumstances are greater than commonly recognized. Since the adult carp were placed in the fish ponds in Washington, D. C., where conditions were very restricted, there is little likelihood that the necessary intermediate hosts for its parasites were present. In the case of the trematode the lack of snails of the proper species would mean the interruption of the life cycle of the trematode and its early destruction. In the event that any of the parasites found conditions suitable for continued existence their spread was checked by the distribution only of young fish which under natural conditions are seldom heavily parasitized. The nematodes and Acanthocephala found in the carp are evidently forms which have been able to adapt themselves to it as a host. They may be also only occasional parasites since the percentage of individuals which harbor them is very low. Many helminths are able to live in animals which are not their normal hosts but it is questionable whether they can reach sexual maturity and continue the cycle necessary for their perpetuation as a species. Consequently the occasional presence of a parasite in a certain host should not be taken as indicative that it is usually present. The acquisition of a parasite by a host is a very complex process since the anatomical and physiological make-up of both organisms must be such that neither will be destroyed by the relationship. Further, the habits of

the two must be such as to insure the continuity of the association in more than a single generation. Thus should a fish only rarely ingest the crustacean which is the larval host of a certain helminth, the infrequency with which the larva of the parasite was ingested would preclude the possibility of such a fish becoming the final host of the helminth in question.

Another factor which determines to some extent the presence or absence of parasites is the age of the fish. Usually adults are found to be more heavily infected than immature forms. In the case of the 100 channel cat (*Ictalurus punctatus*) listed in the tables, 32 young individuals were examined at one time and none of them contained parasites while in the adult specimens about 50 per cent were found to be infected.*

Where a sufficient number of individuals was available an effort was made during the survey to select adults. We likewise tried to examine equal numbers of the forms available. It is hardly necessary to state that such a procedure was not always possible. Therefore our records of most species contain a small percentage of young individuals. It is quite evident that when a large number of fish which are known to harbor but few parasites, or young individuals of any species, are included in the data, a low percentage of infection will result and consequently false inferences may be drawn as to the prevalence of parasites.

A more representative idea of the extent of infection among the majority of the native adult lake and river fish is gained when the 107 shad, 26 carp and 32 young channel catfish are excluded from the computation of the percentage of infection. When this is done nearly 50 per cent of the other individuals examined show some infection. As has already been stated the external parasites do not form a part of the data with which we are dealing. Parasitic copepods, which are frequently found on the gills of fish, and leeches which often attack catfish in large numbers would, if considered, greatly increase the percentage of individuals parasitized.

* Twelve adult individuals of this species from the Rock River were examined April 14, 1926, and 11 were parasitized. This record is not a part of the tabulated data.

A study of the comparative occurrence of infection among the different classes of helminths should prove of interest. Considering only the adults of the native fish and excluding the gizzard shad which is seldom parasitized, the remainder show infection as follows: 7.5 per cent with trematodes; 10 per cent with Cestodaria; 14 per cent with cestodes;* 12.6 per cent with nematodes and 20 per cent with Acanthocephala. This evidence shows that the Acanthocephala are most frequently found as internal parasites of fresh-water fish and Cestodes follow with nematodes third. Although it appears that nematodes occur more frequently, they never occur in as great abundance as do the trematodes which often may be counted by hundreds. This is especially true of the smaller species of flukes. The Cestodaria are limited to the Catostomidae and the fact that they show a higher percentage of occurrence than the trematodes which have a much wider range of fish hosts can be explained on the basis of the examination of a larger number of species belonging to the Catostomidae. Among ten species of that family, trematodes were found in only the small-mouthed buffalo and the red-mouthed buffalo. Among these same ten species no tapeworms were found, but six harbored Cestodaria.

In connection with our work in Montana some interesting observations were made on conditions at Mystic Lake. This lake which is about two miles long is fed by the waters from Grasshopper Glacier, near Yellowstone National Park. Hundreds of fishermen visit this beautiful region every month during the fishing season to angle for rainbow trout which are found there in unusual abundance. Many of the fish at the lower end of the lake have been rendered less desirable for food because of their thin, "snaky" appearance. The sportsmen of that region have applied to them the very descriptive term of "horseshoe nails" because of their large heads and slender bodies. We were able to secure 9 fish from the lower part of the lake and 6 from near the head waters. Those taken near the source were plump and normal in

* This term as used in this paper includes only the polyzootic cestodes.

appearance and showed a great deal of activity while being landed but the ones caught near the outlet were in very poor flesh and were less resistant to capture. An examination of the thin individuals showed extremely heavy infection with cestode larvae which were about 18 mm. in length. In every instance the liver, intestinal wall, and in fact all the viscera, were permeated with this parasite. The normal fish, however, revealed the entire absence of this helminth or only moderate infection. This is a striking instance of the localization of a parasite and would seem to indicate the presence of the intermediate host in greater numbers at the lower end of the lake. The local fishermen attribute the snaky appearance of the fish to lack of food but such a large number (some specimens contained a hundred or more) of parasites drawing nutriment from the vital organs of the host would very materially affect the health of the fish. Even a greater number of mature tapeworms or trematodes when contained in the lumen of the intestine seem to exert little influence on the well-being of their host but when parasites bore into the wall of the intestine and the tissues of the pancreas, liver and spleen the effect is much more destructive. Thus fish so afflicted could hardly be expected to look well fed.

GEOGRAPHICAL DISTRIBUTION.

In making an attempt to analyze the data the first step would logically include a consideration of the material from the standpoint of geographical distribution. The writers have therefore attempted to make several comparisons first, to determine whether or not there is any difference in the fauna of various regions, and second, if there is any evidence of seasonal distribution of the parasites, and finally, to study the relation of the parasitic fauna of fish, as recorded by Ward (1912), to our data.

The analysis of the data from the geographical standpoint is based, of course, solely upon forms that were taken from both regions under examination. Thus, in a consideration of the data on the river fauna as compared with that of the lakes the same species found in

the rivers must also have been taken from the lakes. The numbers of individual specimens taken may vary considerably with the station, but where a number of different forms are examined, the percentages of infection, as well as the data upon the percentage infected with the various groups of heminths, should be significant. The percentage of infection is based upon the number of fish examined, while the percentage parasitized with trematodes, etc., is based upon the number infected, rather than the total number examined at that station. The data for these comparisons are presented in Table 7.

First of all let us examine the data available upon the rivers visited as compared with those from the lakes. Eight species of fish were taken both from rivers and lakes, and five of these forms were members of the Centrarchidae. The remaining three species were in three separate families. Table 1 shows a total of fifty specimens collected from the six rivers, while material from five lakes furnished data for comparison. Of the fifty individuals taken from the rivers nineteen, or 38 per cent, were infected as compared with sixty-seven taken from the lakes of which forty-two, or 62.9 per cent, were parasitized. This obviously shows that these eight species of fish were more heavily infected if they were taken from a lake, and opens the question as to whether or not this situation is typical.

An analysis of the percentages of infection of the various groups of parasites shows some interesting facts. Trematode infection in the fish from the rivers is nearly 12 times as heavy as in the specimens from the lakes. Tapeworms appeared nearly one half again as often in the river fish as in the lake fish, while the infection with nematodes was only some 7 per cent higher in the fish taken from the rivers. Upon the other hand, Acanthocephala show a higher infection in the specimens taken from the lakes.

The significance of these figures is clear, for in the case of the eight species under consideration it is evident that the general infection in the river forms is lower than in the same species taken from the lakes. It is apparent that even though there is a lower percentage of

TABLE 1.

A comparison of Infection from 6 Rivers and 5 Lakes.

Source	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.		Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.
Cannon (1)* ...	8	8	8	.....	6	.....	7	Beaver Dam (3).	14	10	.....	.....	6	3	7
Ill. (1)	4	4	1	.....	.....	1	4	Mazaska (3) ...	14	4	.....	.....	2	1	2
Miss.[1] (2)	2	1	.....	.....	.....	1	.....	Mendota (1)	1	1	1	.....	.....	1	.....
Rock (8)	32	3	1	.....	2	.....	1	Miltona (6)	35	24	1	.....	3	3	20
Sangamon (1) ..	2	1	.....	.....	.....	1	.....	Winnebago (2) .	3	3	.....	.....	3	.....	.....
Spoon (1)	2	2	.....	.....	.....	2	.....								

Percentage of infection.

	Rivers 38%	Lakes 62.9%
Trematoda	52.6%	4.7%
Cestodaria	00	00
Cestoda	50	33.3
Nematoda	26.3	19
Acanthocephala	63.1	69

* Indicates the number of different species taken at that station.

general infection in the case of the fish from the rivers there is a greater variety of parasites found in an infected river specimen. That is, that while only 38 per cent of the river fish were infected, over one half were the hosts for trematodes, while in the case of the 62.6 per cent of infected lake fish less than 5 per cent possessed trematode parasites. Furthermore, one half of the parasitized river fish were infected with cestodes, while only one third of those from the lakes were parasitized with tape worms. This shows then that a greater number of river fish is parasitized with both trematodes and cestodes than lake fish. Some idea of the multiple infection of these forms can be secured by the totaling of the infection percentages of the groups. In this case the infection percentages of the trematodes, cestodes, etc., for the parasitized river specimens totals 192 per cent compared with 136 per cent for the material from the lakes, clearly indicating a greater diversification of parasitic fauna of the river fish as compared with the infected individuals secured from the lakes.

The next analysis involves a study of the Rock River, which is a typical muddy-bottomed Illinois River, as contrasted with the same species of fish taken from the clear, cold lakes of northern Minnesota and Wisconsin which are represented by Lakes Miltona, Irene and Beaver Dam. The fish examined fell into six species and three families, Centrarchidae, Esocidae, and Percidae. Twenty-six specimens of fish were secured from the Rock River, only three of which, or 11.5 per cent, were infected with helminths as contrasted with the forty taken from Lakes Miltona, Irene and Beaver Dam which showed 72.5 per cent infection. No reliance can be placed farther than this particular upon the data from the Rock River, for the number of infected fish secured was insufficient to give accurate infection percentages for the various groups of parasites.

The tables giving the percentages of parasitization show that no specimens were secured from the three lakes under consideration infected with trematodes, while the cestode infection was over twice as great in the specimens taken from the river as those from the

TABLE 2.

A Comparison of Infection of the Rock River and Lakes Miltona, Irene and Beaver Dam.

Species.	Rock River.							Lakes Miltona, Irene and Beaver Dam.						
	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.
Lepomis pallidus	7	1	1	.....	.....	.....	.....	3	2	.....	.....	.....	.....	2
Micropterus dolomieu	2	2	.....	.....	2	.....	1	6	6	.....	.....	5	1	4
Micropterus salmoides	2	0	.....	.....	.....	.....	.....	15	15	.....	.....	.....	.....	15
Pomoxis sparoides	10	0	.....	.....	.....	.....	.....	12	2	.....	.....	.....	2	.....
Esox lucius	2	0	.....	.....	.....	.....	.....	3	3	.....	.....	3	3	2
Stizostedion vitreum	3	0	.....	.....	.....	.....	.....	1	1	.....	.....	1	.....	.....

Percentages of Infection.

Rock River	11.5%	Lakes	72.5%
Trematoda	33.3%		00%
Cestoda	66.6		31
Nematoda	00		20.6
Acanthocephala	33.3		79.3

lakes. Furthermore, the six species examined showed no infection by nematodes in the individuals obtained from the Rock River, as compared with a significant percentage of infection among the lake fish. The Acanthocephala infection was nearly three times as heavy in the fish taken from the lakes as in those examined from the Rock River.

One outstanding feature of the Acanthocephala infection from the lake region was the fact that of the 15 specimens of *Micropterus salmoides* (large mouth black bass) examined all were parasitized with Acanthocephala in great numbers. The three *Micropterus dolomieu* (small mouth black bass) examined also showed parasitization with Acanthocephala, although here the infection also included cestodes and nematodes. This condition is closely correlated with the feeding habits of the fish, and indicates that great numbers of infected intermediate hosts had doubtless been ingested.

Having considered the situation as found in the lakes and rivers, followed by a study of the Rock River and several typical lakes of northern Minnesota and Wisconsin, attention may be directed to that body of water which in places is a lake and in other regions a river, the Mississippi. Here at Camanche and Bellevue, Iowa, spoken of as Mississippi 1, it was found that ten of the sixteen individuals from three families were parasitized to the extent of 62.5 per cent as compared with Lake Pepin where fifteen of the nineteen specimens, or 78.9 per cent were infected.

It must be borne in mind that the conditions found in Lake Pepin are not the same as those of the typical lake, for obviously it is not subjected to all of the conditions characteristic of lakes. An example of this is the extreme variation of water level which is known to occur in Lake Pepin, due to the rise of the river level during the spring months, or when flood conditions are present on the Mississippi River. Normally this vast body of water would be expected to furnish conditions nearer those of the typical lake than of the river. The forms used as the basis for a comparison here are limited to the species of fish generally found in greater numbers

TABLE 3.

Comparison of Infection of Mississippi 1 and Mississippi 2.

Species.	Mississippi No. 1.							Mississippi No. 2.						
	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.
Amiatus calvus	3	3	3	.....	3	3	.....	1	1	.....	.....	1	1	1
Carpiodes carpio	1	1	.....	.....	.....	1	.....	2	1	.....	1	.....	1	1
Ictiobus bubalus	3	0	.....	.....	.....	.....	.....	1	0	.....	.....	.....	.....	.....
Ictiobus cyprinella	4	3	2	2	.....	.....	.....	8	7	.....	7	.....	2	2
Cyprinus carpio	1	0	.....	.....	.....	.....	.....	2	2	.....	.....	.....	.....	2
Ictulurus punctatus	4	3	.....	.....	.....	3	1	5	4	.....	.....	4	.....	.....

Percentages of Infection.

Mississippi 1	62.5%	Mississippi 2	78.9%
Trematoda	50%		00%
Cestodaria	20		53.3
Cestoda	30		33.3
Nematoda	70		26.6
Acanthocephala	10		40

in the rivers, and hence the comparison may not be entirely representative.

Trematode infection averaged 50 per cent in the material secured from Mississippi 1, as compared with the situation at Lake Pepin where no specimens infected with trematodes were found. This is significant when it is realized that the four specimens of *Amiatus calvus,* for example, which were taken from both the Rock and Mississippi 1 stations showed 100 per cent infection with trematodes, whereas the one specimen secured from Lake Pepin did not have any trematode parasites, although it did harbor cestodes, nematodes, and Acanthocephala. Here for the first time in these tables, Cestodarian infection appeared, being present over twice as often in the material examined at Mississippi 2. The infection with cestodes was approximately the same at both stations, whereas the nematode infection was exceedingly high in the material examined from Mississippi 1. Parasitizaton by Acanthocephala was four times as great in the individuals examined from Mississippi 2 as in those from Mississippi 1.

Having completed a comparison of the data from two different regions of the Mississippi River, attention can now be directed to a study of the Rock and Mississippi 1 stations in an attempt to see whether or not the fauna of these two regions is alike, since both rivers are fundamentally similar. Here eight species of fish included in five different families were examined and the Rock River material showed twenty-five of the thirty-nine individuals, or 64.1 per cent infection, while fourteen of the twenty-one, or 66.6 per cent, from Mississippi 1 were parasitized. This shows a remarkably close identity in general infection, and this corresponds to the expectation based upon the fact that both of the streams are connected, and both are typical mid-west rivers. The higher percentage of general infection in the data for six of the rivers found in Table 1 is due primarily to the fact that in this comparson specimens examined from these two stations were typically river forms and included such genera as Carpiodes, Ictiobus, Cyprinus, Ictalurus, and Leptops.

TABLE 4.

A Comparison of Infection of Rock and Mississippi No. 1.

Species.	Rock.							Mississippi No. 1.						
	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.
Amiatus calvus	1	1	1	.....	1	.....	.....	3	3	3	.....	3	3	.....
Carpiodes carpio	4	3	.....	2	.....	.....	2	1	1	.....	.....	.....	1	.....
Ictiobus bubalus	6	2	.....	2	.....	.....	.....	3	0	.....	.....	.....	.....	.....
Ictiobus cyprinella	2	1	.....	.....	.....	.....	1	4	3	2	2	.....	.....	.....
Pomoxis annularis	2	0	.....	.....	.....	.....	.....	1	0	.....	.....	.....	.....	.....
Cyprinus carpio	4	0	.....	.....	.....	.....	.....	1	0	.....	.....	.....	.....	.....
Ictalurus punctatus	19	17	2	.....	15	.....	.....	4	3	.....	.....	3	1	.....
Leptops olivaris	1	1	.....	.....	1	1	.....	4	4	.....	.....	3	1	.....

Percentages of Infection.

Rock	64.1%	Mississippi No. 1	66.6%
Trematoda	12		35.7
Cestodaria	16		14.2
Cestoda	68		64.2
Nematoda	4		42.8
Acanthocephala	12		00

A detailed study of the parasitic fauna of these two groups shows a much higher trematode infection in the material secured from the Camanche and Bellevue station. The infection with Cestodaria and cestodes was about the same in the specimens taken from the Rock and Mississippi 1, while the nematode infection of the Rock River fish was much lower than in those from Camanche and Bellevue. An interesting situation occurred in the analysis of the infection data of Acanthocephala. This parasite showed the highest percentage of general infection, being present more frequently (though not in greater numbers) than any other helminth which came under observation, and yet none of the eight species of fish in this table from Mississippi 1 were parasitized by Acanthocephala.

A comparison of the Rock and Mississippi 1 during the summer of 1925 is logically followed by one of the Rock River and Lake Pepin, or Mississippi 2. The data are based upon practically the same number of species as used in the comparison with Mississippi 1, although several have been added and a few subtracted. The Rock shows that twenty-seven of the forty specimens examined, or 65.8 per cent, were parasitized as compared with eighteen of the twenty-two, or 81.8 per cent, infection of the Lake Pepin specimens.

The fish from Lake Pepin were uninfected with trematodes, and here again, as in the case of the comparison of the Mississippi 1 and 2 stations, the infection of fish with Cestodaria was over twice as heavy in the specimens taken from Lake Pepin. On the other hand, cestode infection was nearly three times greater in the fish secured from the Rock River, while the infection with both nematodes and Acanthocephala was higher in the specimens examined from Lake Pepin.

DISCUSSION.

It must be borne in mind that the relation shown in the preceding paragraphs are at the best only approximate, and are based upon percentages which are modified several percent by the mere addition or subtraction of a single individual to the columns. The most

TABLE 5.

A Comparison of Infection of Rock and Mississippi No. 2.

Species.	Rock.							Mississippi No. 2.						
	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.	Number examined.	Number Para.	Trematoda.	Cestodaria.	Cestoda.	Nematoda.	Acantho-cephala.
Amiatus calvus	1	1	1	.....	1	.....	.....	1	1	.....	.....	1	1	1
Carpiodes carpio	4	3	.....	2	.....	.....	2	2	1	.....	1	.....	1	1
Carpiodes velifer	6	2	.....	1	.....	.....	1	1	1	.....	1	.....	.....	.....
Ictiobus bubalus	6	2	.....	2	.....	.....	.....	1	0	.....	.....	.....	.....	.....
Ictiobus cyprinella	2	1	.....	.....	.....	.....	1	8	7	.....	7	.....	2	2
Moxostoma breviceps	1	0	.....	.....	.....	.....	.....	1	1	.....	.....	.....	.....	1
Cyprinus carpio	4	0	.....	.....	.....	.....	.....	2	2	.....	.....	.....	.....	2
Lepisosteus platostomus	2	1	.....	.....	1	.....	.....	1	1	.....	.....	1	.....	.....
Ictalurus punctatus	19	17	2	.....	15	.....	.....	5	4	.....	.....	4	.....	.....

Percentages of Infection.

Rock	65.8%	Mississippi No. 2	81.8%
Trematoda	11.1%		00%
Cestodaria	18.5		50
Cestoda	62.9		33.3
Nematoda	00		22.2
Acanthocephala	14.8		38.8

accurate index is given by the general infection data which present a fair picture of the conditions of the forms under consideration for that particular season of the year. Nevertheless, an analysis of the data for the five regions shows several significant facts.

From our material, it appears that the river systems have a lower percentage of parasitization than do the lakes. The infection data derived from eight species of fish from six rivers as compared with those from five lakes, show there is a difference of 24 per cent between the two. This is the most significant figure as it includes data on over 50 specimens in each case, and these data are derived from eight species of fish from three families. All other data, tend to support this conclusion though the percentages vary, due to the different species of fish considered in the diffeernt tables. Thus the Rock River and the three lakes from Minnesota and Wisconsin show 11.5 per cent and 72.5 per cent infection. Even the two stations on the Mississippi River: Camanche and Bellevue, and Lake Pepin, show marked differences. Even though Lake Pepin departs in a measure from lake conditions, the fish show more parasitization from Mississippi 2 than from Mississippi 1. A comparison of the Rock River and Lake Pepin shows an equally great difference, for Mississippi 2 has 16 per cent higher infection among the fish than the Rock River. Our data show, therefore, that the fish examined from the lakes have a higher percentage of infection than do the same species taken from the rivers.

The trematode infection data also indicate several facts of interest. All records from the rivers and lakes clearly show a very low percentage of infection with trematodes among fish from the lakes. Infection ranges from 4.7 per cent in the data based upon the fish examined from five lakes to no infection in the material from Lakes Miltona, Irene, Beaver Dam and Lake Pepin. The statement concerning Lake Pepin should be qualified since collections were made only from the vicinity of Lake City, Minnesota, and did not include data for the upper end of the lake. However, as far as our data are

concerned, trematode infection is very low in the fish taken from lakes.

Little can be said concerning the infection by Cestodaria except that in this region it is limited exclusively to members of the Catastomidae, although in Europe *Cyprinus carpio* is frequently found to serve as the host for two species of Cestodaria. The individuals showing the highest degree of infection were members of the genus Ictiobus, although *Carpiodes* sp. also carried infection. Cestodarian infection occurs in rather significant percentages, and varies from 14.2 per cent to as high as 53.3 per cent, although the latter condition was found only in the material from Lake Pepin. The more usual condition seems to be that of the Rock and Mississippi 1 stations where the infection percentages range between 15 and 20 per cent.

Several interesting facts concerning the data furnished by the cestodes should be pointed out. The summary of these data show that of the forty-two infected specimens taken from five of the lakes examined, fourteen or 33.3 per cent of them, contained tapeworms. This figure remained remarkably constant throughout the other tables, the entire range was from 31 to 33.3 per cent, the former in the lakes of northern Minnesota (Lakes Miltona and Irene) and Wisconsin (Beaver Dam), as compared with the 33.3 per cent found not only in the five lakes but also in Lake Pepin upon two occasions and in two different sets of data. It appears, therefore, that this figure is significant and that the cestode infection of lake fish, even including those from Lake Pepin, is uniform during the summer months.

Infection with cestodes in the river fauna is variable as is shown by the data on six rivers which indicate 50 per cent tapeworm infection as compared with the minimum of 30 per cent at Mississippi 1 (Table 3). The maximum infection is shown in Table 4 where the Rock River fish carried an infection of 68 per cent. It is evident from the foregoing discussion that the percentage of river fish infected with cestodes is variable, whereas the percentages of infection found in the specimens examined from the lakes was nearly constant.

Another indication of the more stable conditions in lakes is found in the infection data of nematodes. Here the percentages range from 19 per cent for the fish from the five lakes to the maximum of 26.6 per cent in the table showing the comparison of Lake Pepin with Mississippi 1. Here the difference is only 7.6 per cent whereas the river conditions show an infection range from 0 to 70 per cent. This clearly shows that nematode infection in lake fish is distinctly a stable factor, as compared with the infection of the fish from the rivers.

The infection data on the Acanthocephala disclose a rather unique condition, for the lakes, which are presumably more stable, show variations in the percentage of fish infected with Acanthocephala ranging from 38.8 per cent in fish from Lake Pepin to 79.3 per cent in the material from the lakes of Minnesota and Wisconsin. The higher percentage of infection of the game fish with Acanthocephala doubtless was responsible for the differences as noted. The individuals examined at Lake Pepin were primarily river fish as the carp, buffalo, etc., while those from the lakes of Minnesota and Wisconsin were almost exclusively bass, crappies, sunfish, etc. But even when the Lake Pepin data are included with those from the other lakes the maximum variation is 39.3 per cent in the lake fish, while the river fish show a range of infection from 0 to 63.1 per cent (Table 1). This condition shows, therefore, that infection of fish with Acanthocephala is highly variable, but there is less variability of infection in the fish examined from the lakes than in those taken from the rivers.

COMPARISONS BY REGIONS

Ambloplites rupestris

Several interesting comparisons may be made between the parasitic fauna from different localities. We have data concerning one host, *Ambloplites rupestris,* collected during the summers of 1924 and 1925 from two regions, Beaver Dam Lake, Wisconsin and Lakes Miltona and Irene, Minnesota. In both instances the collections ranged over the entire summer from the middle

of June to early September. The parasitic fauna consisted primarily of Acanthocephala but occasionally a few nematodes were present, although the degree of infection was not excessive. Twenty specimens were examined from Beaver Dam Lake, and 16, or 80 per cent, were infected. The 21 specimens from Lakes Miltona and Irene, (which are connected by a short stream of some depth, making migrations possible), showed infection in 19 individuals, or 95.3 per cent. This difference in the number of parasitized fish may be typical of the respective localities. It suggests an interesting study on the food and other conditions affecting the rock bass in the lakes of these two states.

SEASONABLE DISTRIBUTION

It has long been supposed that the number of parasites, as well as the types of parasites, found in a given host would be fewer during the winter months than at any other season of the year. An analysis of Table 6 shows this to be true in the case of *Amiatus calvus* (bowfin), for in November and December 1923 the fish were 100 per cent infected, but only with cestodes. The succeeding year a like situation prevailed, although there were only 60 per cent infected, but here again the infection was limited to the tapeworms. In the summer of 1925, however, this form was found to be more generally parasitized, for then trematodes, cestodes, nematodes and in one case Acanthocephala were all present and the infection was found to be 80 percent. The important fact, however, in the case of *Amiatus calvus* is not the percentage of infection, but rather the diversification of parasites which occurs during the summer months.

Carpiodes carpio (common river carp) like the first form shows a greater number of different parasites during the summer and early fall (October) than at any other season of the year at which we examined them. During the summer Cestodaria, nematodes and Acanthocephala were found as compared with the data for March (1926), and May (1925). In May no infection was found in the specimens examined, while in March

of the next year one out of eleven, or 9 per cent, were parasitized, but then only with Cestodaria. *Carpiodes velifer* (quillback) examined in the summer of 1923, fall of 1924, and summer of 1925 show parasitization consisting of Cestodaria, Acanthocephala and cysts, while in the spring of 1925 and 1926 no infected specimens were found. This is in close agreement with our data secured for *Carpiodes carpio*. The data indicate that there is a greater number of different parasites present in these species of fish during the summer months than in the winter.

An examination of fourteen specimens of *Ictiobus cyprinella* (red mouth buffalo) made in the summer of 1925, from three different stations, revealed the presence of trematodes, Cestodaria, nematodes, Acanthocephala and cysts to the extent of 85.7 per cent of the total number examined. In October (1924) five specimens were taken and were found to be 60 per cent infected; this infection consisted of trematodes, cestodaria and nematodes while ten fish examined in March (1926) and May (1925) indicate a still greater reduction in the types of parasites found, only Cestodaria and cysts being present, as well as in the percentage of parasitization which has now dropped to 50 per cent.

Both *Pomoxis annularis* and *Pomoxis sparoides* (white and black crappie) are unique forms in that they are remarkably free from helminths. Out of a total of fourteen specimens of *Pomoxis annularis,* examined at three different seasons, and from three different stations in as many states, from both rivers and lakes, only 28.5 per cent were infected; and then only the fish from one locality Beaver Dam Lake at Cumberland, Wisconsin. This infection occurred in 50 per cent of the eight fish examined during the summer of 1924, and was composed entirely of Acanthocephala. The six fish of this species which were secured in October (1924) and the summer of 1925 were entirely free from parasites.

Pomoxis sparoides (black crappie) affords a still more interesting case, for here with a total of 32 specimens examined from three distinctly different localities, which included both lakes and rivers, during the summers of

1924 and 1925 only 6.2 per cent were infected. As in the case of *Pomoxis annularis* the infection was limited solely to Acanthocephala. Seasonal data are confined to an examination of thirty-two specimens, six of which were collected during the summer of 1924 and seventeen during the summer of 1925. Of these fish which were studied two or 8.6 per cent of the twenty-three fish taken during the summers were infected with Acanthocephala, while of the nine forms examined in the latter part of October (1924), not one was found to be parasitized. Thus again it is evident that the percentage of infection becomes lower as the winter months approach.

It is apparent that we can do little more than point out the conditions as we found them and suggest one or two possible inferences. Our data show that in the six species analyzed there is a greater diversification of parasites during the summer than at any other season of the year. This is obviously correlated with the presence of those forms which serve as intermediate hosts for the parasites, and at the same time the frequency of infection will probably be greatest when these intermediate hosts are abundant enough to compose a high percentage of the food of the fish.

Furthermore the diversification of parasites in any season is apparently related to the time of infection, or the seasonal distribution of the intermediate hosts, and also to the length of life of the adult parasite. It seems to be the case that the adults of some fish cestodes at least occur only in an immature form in the final host during the winter season and in an active egg producing form during the summer.

FOOD AND PARASITES.

A survey of the literature upon the food of the freshwater fish shows thorough work in a limited field. The chief contributor was Forbes who published an important series of articles (1878-1888). Following this Forbes and Richardson (1908) issued a monograph on the fish of Illinois which contained information on their food and habits. Pearse (1918) published on the food of fish, but unfortunately the data were confined to the

months of June to September. A report of the food and parasites of fresh-water fish from the lakes in the vicinity of Madison, Wisconsin, was made by Marshall and Gilbert (1908). Fish food manifests considerable seasonal as well as local variation as may be seen in the recorded data. A consideration of the food of five species of the fish mentioned above should be of value, since the presence of parasites is dependent upon the feeding habits of the fish.

The food of *Amiatus calvus* from the Illinois River was recorded by Forbes (1883). These data were gathered throughout the year, but were not listed by seasons. Forbes finds, however, that Mollusca constitute 25 per cent of the animal food while crayfish comprise 40 per cent. Pearse (1918) in studying the food of this species from lakes in the vicinity of Madison, Wisconsin, finds that it consists of 90.1 per cent fish remains and 9.4 per cent crayfish. A heavy infection with helminths would be expected in fish feeding upon Mollusca and Crustacea since both act as intermediate hosts for trematodes, and the latter have long been known to serve as hosts for many parasites. Crayfish were found by Ward (1894a) to be the intermediate host for the fluke *Distoma opacum*. Examinations of the intestinal tracts of *Amiatus calvus* made by the writers during the summer of 1925 also showed that crayfish and Mollusca had been eaten in large numbers. These examinations also revealed the fact that parasites from four different orders infected the bowfin to the extent of 77 per cent. It is clear that this type of food is responsible for the heavy parasitic infection of *Amiatus calvus*.

The food of the buffalo fish, *Ictiobus bubalus* and *Ictiobus cyprinella* is recorded in the work of Forbes (1888). Over a fourth of the *Ictiobus bubalus* examined were parasitized. Forbes lists 80 per cent animal food for this species and finds that it consists of 30 per cent Mollusca, 29 per cent insects and insect larvae, and 20 per cent Crustacea. In our examinations the parasites with one exception were exclusively Cestodaria. The absence of trematodes is striking considering the large percentage of Mollusca listed by Forbes as comprising the food

of this species. In the case of *Ictiobus cyprinella* (red mouth buffalo) the trematode infection ran much higher than in the case of *Ictiobus bubalus* and yet the amount of molluscan food recorded by Forbes was only 3 per cent, and the remainder of the animal food consisted of 33 per cent insects and 29 per cent Crustacea. More work upon the food of these forms is necessary in order to determine the relations of the parasites and the food.

In the case of the food of *Pomoxis annularis* Forbes and Richardson (1908) state that it consists of insects, Crustacea and fish. On the other hand, the food of *Pomoxis sparoides* according to these two workers is "substantially identical with that of *annularis*, except that 11 specimens examined had taken a larger percentage of both *Entomostraca* and fishes, and a smaller one of aquatic insects. These differences of ratio are, however, very likely local and seasonal." Our data show over 22 per cent higher infection with helminths in *Pomoxis annularis* than *Pomoxis sparoides*. Furthermore, these data cover collections from three localities made over two summers and one fall. These differences in the percentage of infection between the two species show that the variations as noted are probably due to the feeding habits of these forms rather than to local and seasonal causes as suggested by Forbes and Richardson.

COMPARISONS OF DATA WITH OTHER RECORDS.

In Table 6 a comparison is made of the parasites from all the species of fish common to our records and those of Ward (1912). His data were gathered over a period of 10 or 12 years and represent material from numerous sources. This, to a lesser degree, is true of our records. A study of this table reveals, with a few exceptions, close agreement between these two sets of data. This similarity is evident in the following species, when allowance is made for differences in the number of individuals examined: *Acipenser rubicundus, Amiatus calvus, Carpiodes carpio, Micropterus dolomieu, Micropterus salmoides, Esox lucius, Cyprinus carpio, Notropis blennius, Hiodon tergisus, Perca flavescens* and *Salmo irideus*.

Besides the inequality in the number of fish examined, the differences may, in many instances, be accounted for on the basis of variations in the presence of the intermediate hosts of certain parasites. The widest difference occurs in the records of trematode infection. This explanation has some evidence for its support since the Mollusca are not always present in lakes where fish abound and trematodes would be wanting in fish developed in a mollusc-free lake. These records taken together constitute a fair sample of the usual parasitic fauna of the fish listed in the table considering the wide distribution of the sources of the material and the probable differences in the seasons when the collections were made.

SUMMARY AND CONCLUSIONS.

1. Thirty-nine percent of the 652 fish examined harbor one or more kinds of intestinal worms.
2. The lowest percentage of infection was found in *Dorosoma cepedianum*, *Cyprinus carpio*, and *Pomoxis sparoides*.
3. The Cestodaria occur exclusively in members of the Catostomidae; no fish belonging to that family harbored polyzootic cestodes.
4. Acanthocephala are more frequently found in examinations of fresh-water fish than any other parasitic worms.
5. The percentage of infection is divided among the parasitic groups as follows: Acanthocephala 20.0 percent, Cestoda 14.0 percent, Nematoda 12.6 percent, Cestodaria 10.0 percent, Trematoda 7.5 percent.
6. The lakes show a higher percent of infection than the rivers. This is supported by a comparison of the fish from the lakes and rivers infected with Trematoda, Cestodaria, Cestoda, Nematoda and Acanthocephala.
7. According to data for the different groups of helminths on seasonal distribution in 6 species, greater numbers were present during the summer than during the fall, winter or spring.
8. In the family Centrarchidae both extremes of parasitization were present; the members of the genus Pomoxis possess but few helminths, while Micropterus showed nearly 100 percent infection.
9. *Amblopites rupestris* from Lakes Miltona and Irene showed over 95.3 percent infection with Nematoda and Acanthocephala, while those from Beaver Dam Lake showed 80.0 percent infection.
10. Our data on the parasites of 25 species of fish are in substantial agreement with those of Ward (1912).

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TABLE 6.

Comparison of Ward's Data of 1912 with those of Essex and Hunter, Table 7.

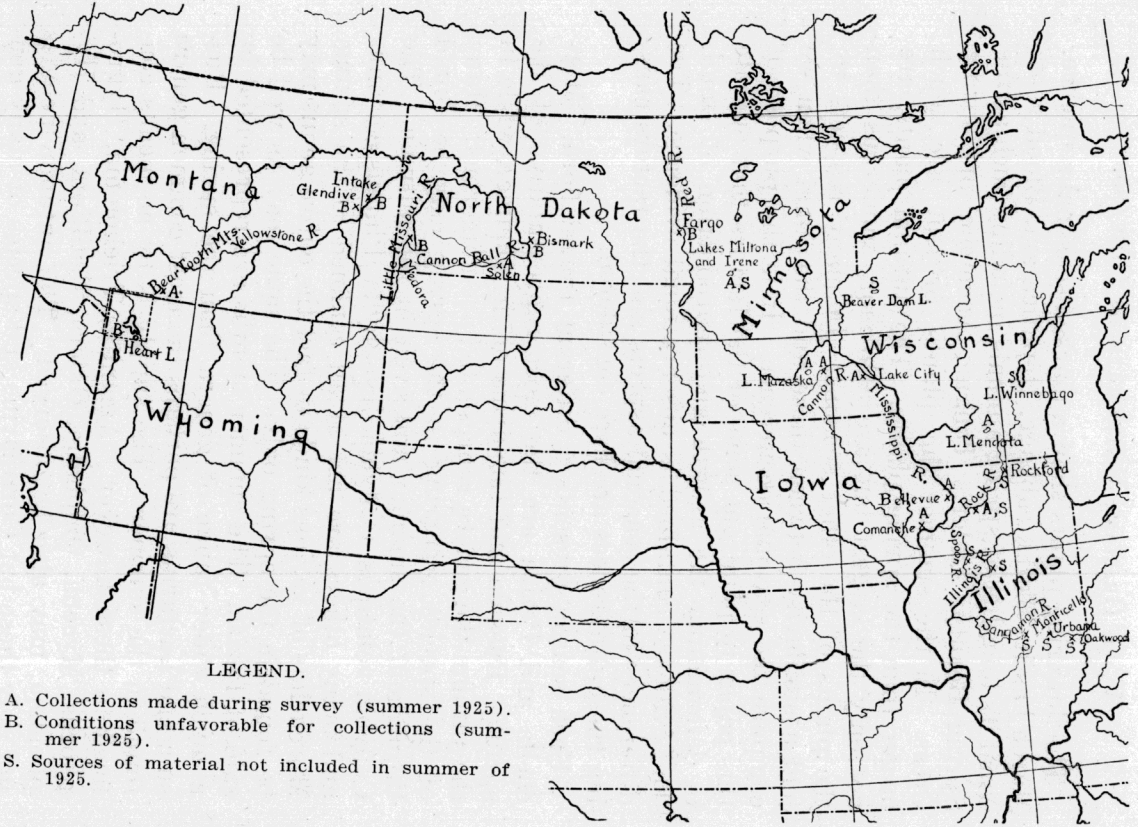
Hosts.	Total.						Number of Fish Infected With							
	No. examined.		No. Par.		No. Non-Par.		Trematodes.		Cestodes.		Nematodes.		Acanthocephala.	
	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.
Acipenseridae—														
Acipenser rubicundus	2	2	2	1	0	1	2	1	0	0	2	0	0	0
Amiatidae—														
Amiatus calvus	32	13	27	10	5	3	16	4	21	10	18	4	8	1
Catastomidae—														
Carpiodes carpio*	15	37	13	12	2	25	6	0	12	8	14	3	14	4
Carpiodes velifer*	1	22	1	7	0	15	0	0	1	5	0	0	0	1
Catostomus commersonii ...	6	3	6	1	0	2	1	0	4	0	0	1	4	0
Ictiobus bubalus*	17	15	17	4	0	11	5	1	16	3	1	0	5	0
Centrarchidae—														
Ambloplites rupestris	31	41	31	35	0	6	4	0	11	0	15	19	29	33
Eupomotis gibbosus	15	1	8	1	7	0	4	0	2	0	7	0	11	1
Micropterus dolomieu	45	8	44	8	1	0	21	0	18	7	7	1	31	5
Micropterus salomoides	2	28	2	25	0	3	1	1	2	0	0	6	2	20
Pomoxis sparoides	12	32	10	2	2	30	2	0	1	0	6	2	7	0
Cyprinidae—														
Cyprinus carpio	10	26	3	5	7	21	0	0	0	0	0	1	3	4
Notropis blennius	28	7	5	0	23	7	0	0	5	0	0	0	0	0
Dorosomidae—														
Dorosoma cepedianum	4	107	2	0	2	107	0	0	1	0	0	0	1	0
Esocidae—														
Esox lucius	3	8	3	6	0	2	1	0	2	5	0	3	3	3
Hiodontidae—														
Hiodon tergisus	13	2	7	2	6	0	6	1	3	2	6	0	1	0
Lepisosteidae—														
Lepisosteus osseus	4	8	3	1	1	7	1	0	2	1	0	0	0	0
Lepisosteusplatostomus.....	9	3	9	2	0	1	5	0	9	2	3	0	1	0

TABLE 6—Concluded.

Comparison of Ward's Data of 1912 with those of Essex and Hunter, Table 7.

Hosts.	Total.						Number of Fish Infected With							
	No. examined.		No. Par.		No. Non-Par.		Trematodes.		Cestodes.		Nematodes.		Acanthocephala.	
	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.	Ward's data.	Our data.
Percidae—														
Perca flavescens	40	8	39	8	1	0	5	0	31	8	19	2	6	0
Salmonidae														
Salmo irideus	2	15	2	10	0	5	2	10	0	10	1	1	0	0
Sciænidae—														
Aplodinotus grunniens	14	28	14	7	0	21	14	0	1	1	2	6	0	0
Serranidae														
Roccus chrysops	13	1	12	0	1	1	12	0	2	0	1	0	0	0
Siluridae														
Amieurus melas	1	9	1	9	0	0	1	9	0	6	0	0	0	7
Amieurus nebulosus	15	11	14	10	1	1	7	0	4	9	10	1	4	0
Ictalurus punctatus†	6	100	6	29	0	71	3	4	4	27	1	1	1	0

* Cestodaria are included under the heading cestodes.
† Includes 32 young non-parasitized specimens.



LEGEND.

A. Collections made during survey (summer 1925).

B. Conditions unfavorable for collections (summer 1925).

S. Sources of material not included in summer of 1925.