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AN ECOLOGICAL STUDY OF THE FISH FAUNA OF THE DOUGLAS LAKE REGION (MICHIGAN) WITH SPECIAL REFERENCE TO THE MORTALITY OF THE SPECIES.

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In this study of the fish fauna of the Douglas Lake (Michigan) region special attention was given to the mortality of the various species found and it is thought that the data collected in this connection have a direct bearing on the general ecology of the species involved. In order that the data on the mortality might be more easily understood, records of species frequency were taken for several typical habitats and a general survey of the intra-lake distribution of the species made. The collection of fishes from which the data were gathered includes several hundred specimens taken during the summer sessions of 1913 and 1914 at the University of Michigan Biological Station at Douglas Lake.

Opportunities for procuring data on these particular problems were especially favorable. Douglas Lake affords an ample variety of aquatic habitats which are easily accessible for study. The shores of the lake are covered with their natural growth of vegetation and timber, and as yet neither the inlets nor the outlet, Maple River, have been dredged or changed to any large extent. The lake and its adjacent waters may be divided into the following units for the purpose of this study: North Lake, that part of Douglas Lake west of Fairy Island and Robert's Point; North Fishtail Bay; Bessey Creek region together with the other small inlets of the lake; and Maple River (See map, Fig. 2). Each of these regions has a condition or set of conditions distinguishing it from the others and encouraging the predominance of certain species of fish.

The prevailing winds of the region blow from the west and northwest, hence North Lake, the part of Douglas Lake west of Fairy Island and Robert's Point, is seldom disturbed by heavy winds and waves, and the aquatic vegetation, especially *Myriophyllum* and *Potomogeton*, has a better chance to grow. This is particularly true immediately west of Fairy Island. In this region the pike-pickerel, *Esox lucius*, and the rock bass, *Ambloplites rupestris*, are very common, and along the marshy shallows of the west shore the cat fish, *Amieurus melas*, nest and are found in great abundance.

North Fishtail Bay affords two somewhat different habitats. The north portion is a quiet bay surrounded by a thick pine and cedar

forest. The water increases in depth very gradually from the shoals along the shore. The bottom here is covered with a thin layer of decayed vegetation and the yellow water lilies, *Nymphaea americana*, *Potomogeton*, and *Myriophyllum* are very abundant. This particular habitat was studied from two standpoints: (1) to ascertain the relative frequency of the various species belonging in this habitat, breeding and feeding there, and (2) to learn what fishes come into the habitat to feed. Several nests of the catfish, *Amieurus melas*, and the pumpkin seed, *Eupomotis gibbosus*, were found both summers early in July with the adults still guarding them. Several schools of small catfish were seen all through the summer in the very shallow water near the bank.

The frequency study of this habitat was made by placing a fyke net in the bay, about 100 feet from the shore, with the wings extending almost to the shore on either side and with the open mouth of the trap toward the shore. The trap in this position collected the fishes belonging to the habitat, and breeding and feeding there. The following table gives the results of six days typical collecting.

TABLE NO. 1.

Species.	Number.	Average size.	Frequency.
1. Pumpkin seed, *Eupomotis gibbosus*	63	100 m.m.	.583
2. Blue gill, *Lepomis pallidus*	24	108 m.m.	.223
3. Sucker, *Catostomus commersonii*	14	276 m.m.	.130
4. Cat fish, *Amieurus melas*	7	177 m.m.	.064

During the two summer's work, in addition to the species listed in the table, two specimens of the yellow perch, *Perca flavescens*, and one trout perch, *Percopsis guttatus*, were taken in the net. Both of these species are from deeper water and were in this habitat presumably by accident.

To determine what species enter the habitat to feed, a gill net was set across the bay just outside the fyke net. Particular care was taken to note in what direction each fish entered the net, i. e., whether it was coming in from the lake or going out into deep water. The following table gives the results of six days collecting with the gill net:

TABLE NO. 2.

Species.	Number of individuals.	Direction.		Average size.
		In.	Out.	
1. Sun fish, *Eupomotis gibbosus*	18	0	18	121 m.m.
2. Sucker, *Catostomus commersonii*	14	4	9	294 m.m.
3. Pickerel pike, *Esox lucius*	6	6	0	360 m.m.
4. Blue gill, *Lepomis pallidus*	3	0	3	126 m.m.

It will be seen from Table No. 2 that all *Eupomotis gibbosus* and *Lepomis pallidus* were inside the enclosed area and were caught going out. *Catostomus commersonii*, however, were taken on both sides of the net and near the bottom where they feed. The frequency of this particular species all over the lake, except in very deep water, is practically the same, and as expected it occurs in both shallow and deep water. *Esox lucius*, however, belongs in a different habitat in deeper water. Since none were taken in either the fyke net or on the inside of the gill net, it is quite evident they visit the habitat for feeding. The nets were emptied every morning and evening, and about as many of the various species were taken at one time as another, except *Esox lucius*, which in every instance was gilled at night during the usual time of feeding.

The combined frequency of all species collected in this habitat, including visitors, as shown by the combined collections, is as follows:

TABLE NO. 3.

Species.	Average size.	Frequency.
1. Pumpkin seed, *Eupomotis gibbosus*	111 m.m.	.534
2. Blue gill, *Lepomis pallidus*	117 m.m.	.180
3. Sucker, *Catostomus commersonii*	285 m.m.	.180
4. Catfish, *Amieurus melas*	177 m.m.	.047
5. Trout perch, *Percopsis guttatus*	110 m.m.	.008
6. Yellow perch, *Perca flavescens*	120 m.m.	.007
7. Pickerel-pike, *Esox lucius*	360 m.m.	.030
8. Bowfin, *Amia calva*	700 m.m.	.007

The south bay of North Fishtail Bay presents a situation more nearly like that of the lake proper. It gets about the same amount of wind and wave action; its bottom is sandy and drops abruptly from a narrow, shallow shoal to a depth of 40 feet. It has, however, along the edge of the step-off and in the shallows of the south side, where the wind and waves have less sweep, a considerable patch of yellow water lilies, *Nymphaea americana* and *Potomogeton*. The fyke net was placed in this situation for a period of ten days with the open mouth of the trap toward the shore. The catch, therefore, while it represents the relative frequency of the species in the habitat, was not large. The result of the collections is as follows:

TABLE NO. 4.

Species.	Number.	Average size.	Frequency.
1. Pumpkin seed, *Eupomotis gibbosus*	5	148 m.m.	.217
2. Large-mouthed black bass, *Micropterus salmoides*	3	173 m.m.	.131
3. Small-mouthed black bass, *Micropterus dolomieu*	1	210 m.m.	.043
4. Sucker, *Catostomus commersonii*	4	332 m.m.	.173
5. Catfish, *Amieurus melas*	2	200 m.m.	.087
6. Blue gill, *Lepomis pallidus*	3	116 m.m.	.131
7. Rock bass, *Ambloplites rupestris*	3	131 m.m.	.131
8. Yellow perch, *Perca flavescens*	2	145 m.m.	.087

The fish taken from this habitat were larger than those of the same species taken from the north bay. The presence of both the large-mouth black bass, *Micropterus salmoides*, and the small-mouth black bass, *Micropterus dolomieu*, in the ratio of three to one, is a characteristic feature of this habitat.

The lake proper has four types of habitats, each of which must be dealt with separately: (1) the shallows and shoals; (2) the deep water near the step-off; (3) the mid-lake portion not exceeding 20 feet in depth; and (4) the deep cold water below the 20 foot line which includes most of South Fishtail Bay. (See map, Fig. 2).

In the shoals and shallows of South Fishtail Bay schools of young perch, *Perca flavescens*, shiners, *Notropis hudsonius*, *N. cayuga*, and *N. cornutus*, young suckers, *Catostomus commersonii*, blunt-nosed minnows, *Pimephales notatus*, and an occasional individual of the Johnny darter, *Boleosoma nigrum*, are found. Each of these species, however, is very abundant on the more rocky shoals between Grapevine and Bogardus Points, on the east side of Fairy Island, and along the northeast side of the lake (See map, Fig. 2). The relative frequency of these various species is seen in the following table, the combined results of seven different long-shore seinings made at various times during the sessions of 1913 and 1914:

TABLE NO. 5.

Species.	Number.	Average size.	Frequency.
1. Yellow perch, *Perca flavescens*	642	40-60 m.m.	.351
2. Sucker, *Catostomus commersonii*	360	30 m.m.	.214
3. Hudson's shiner, *Notropis hudsonius*	344	20-50 m.m.	.204
4. Johnny darter, *Boleosoma nigrum*	285	20-40 m.m.	.169
5. Common shiner, *Notropis cornutus*	34	20-60 m.m.	.020
6. Blunt-nosed minnow, *Pimephales notatus*	11	30 m.m.	.008
7. Cayuga shiner, *Notropis cayuga*	5	30 m.m.	.003
8. Pumpkin seed, *Eupomotis gibbosus*	1	10 m.m.	.0006

Practically all of the records included in Table 5 were adults of the species, excepting the perch, suckers, and pumpkin seeds. The adults of these three species frequent the deeper water of the lake, but lay their eggs in the shallows where the young remain until they are large enough to avoid the enemies commonly found in the deeper waters. Since the young suckers and perch are so abundant they form a very important part of the life of this habitat.

Just over the step-off, in water ranging from 10 to 20 feet deep in situations where the aquatic vegetation is more or less abundant, the trout perch, *Percopsis guttatus*, and yellow perch, *Perca flavescens*, are very abundant. Here also the schools of the log perch, *Percina caprodes*, are found, but the last species is by no means as abundant as the other two. The largest schools of the log perch were found

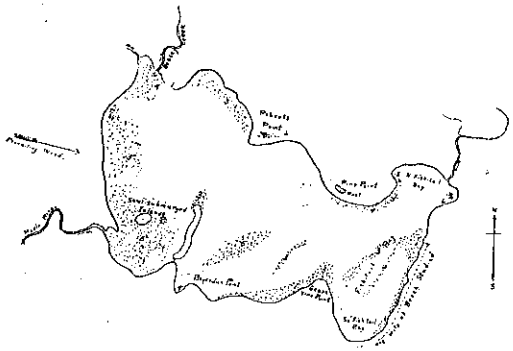


Figure 2.

near the east shore of South Fishtail Bay, where during the first two weeks of July they were seen spawning in the shallow water. Adult minnows are also fairly frequent in this habitat. As will be seen later, the great majority of adult yellow perch thrown upon the beach by the waves were stranded while feeding on the trout perch in this habitat, practically every individual having a half-swallowed trout perch in its mouth.

Over the submerged sand bar and on either side of it, where the reeds, *Scirpus* spp., grow, also between Grapevine Point and Fairy Island, where the various water plants grow to within four to six feet of the surface, the habitat is slightly different. Here the bass, both *M. dolomieu* and *M. salmoides*, the pickerel-pike, *Esox lucius*, and the rock bass, *Ambloplites rupestris*, are abundant. A trammel net placed with one end barely on the sand-bar, i. e. in about 10 feet of water, and the other end extending into water forty feet deep gave the following results during both sessions:

TABLE NO. 6.

Species.	Average size.	Depth of water	Number.	Frequency.
1. Rock bass, *Ambloplites rupestris*	135 m.m.	10-15 ft.	52	.305
2. Sucker, *Catostomus commersonii*	310 m.m.	At all depths	38	.222
3. Pumpkin seed, *Eupomotis gibbosus*	110 m.m.	7-10 ft.	28	.164
4. Pickerel-pike, *Esox lucius*	440 m.m.	20-40 ft.	21	.123
5. Catfish, *Amieurus melas*	320 m.m.	At all depths	17	.099
6. Small-mouthed black bass, *Micropterus salmoides*	380 m.m.	20-40 ft.	10	.058
7. Yellow perch, *Perca flavescens*	160 m.m.	10-20 ft.	3	.017
8. Large-mouthed black bass, *Micropterus salmoides*	300 m.m.	20-40 ft.	2	.012

Aside from the fishes taken in the trammel net at a depth exceeding 20 feet, and listed in Table No. 6, the lake whitefish, *Argyrosomus artedi cisco* and the ling, *Lota maculosa*, are known to occur in very deep water. During the summers of 1913 and 1914, dead lake whitefish were found. Each had an injury on the ventral side of the body, near the caudal fin. This injury resembled the scar made by the lake lamprey. Many other species of fish were taken, as will be seen later, with the same type of injury. At the close of the 1914 session of the Biological Station a large specimen of the ling, *Lota maculosa*, was found almost dead under a beached boat near the Station dock after a heavy wind storm. This species belongs to the deep water near the thermocline, at a depth varying from 35 to 40 feet or more.

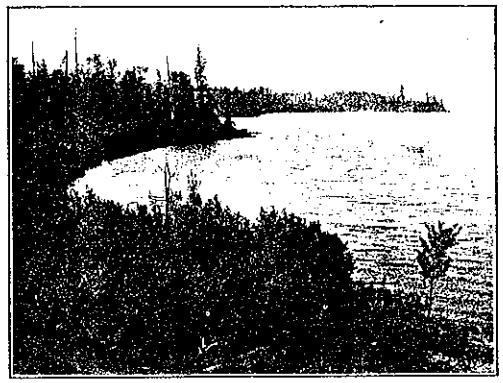
In addition to the lake itself, Bessey Creek, the other smaller inlets and the outlet, Maple River, are important habitats for fishes. Bessey Creek is a sluggish stream varying from one to eight feet in depth. The bottom is covered with a deep layer of loose decayed vegetable matter and ooze. A considerable amount of high grass, rushes, *Scirpus americanus*, and white water lilies, *Castalia odoratum*, grow in the shallow water near the bank, and in many places in mid-stream. The banks are well wooded and shady. By frequent observations and seining it was found that the mud minnow, *Umbra limi*, is the dominant species of this habitat. The creek was seined several times and the combined data of the seinings are given below:

TABLE NO. 7.

Species.	Number	Average size.	Frequency.	Place in stream.
1. Mud minnow, *Umbra limi*....	190	85 m.m. (adults)	.626	Distributed over bottom.
2. Yellow perch, *Perca flavescens*.	30	100 m.m. (young)	.099	Near surface, mid-stream.
3. Blue gill, *Lepomis pallidus*....	18	60 m.m. (young)	.060	Mid-stream.
4. Pumpkin seed, *Eupomotis gibbosus*.....	17	62 m.m.	.057	Mid-stream.
5. Cayuga shiner, *Notropis cayuga*	13	25 m.m.	.043	Mid-stream.
6. Rock bass, *Ambloplites rupestris*.	12	102 m.	.040	Mid-stream.
7. Catfish, *Amiurus melas*.....	8	142 m.m.	.026	At bottom of mid-stream.
8. Pickerel-pike, *Esox lucius*....	8	145 m.m. (young)	.026	Under grass along bank.
9. Large-mouthed black bass, *Micropterus salmoides*.....	4	30 m.m. (young)	.014	Mid-stream.
10. Sculpin, *Cottus ictalops*.....	1	48 m.m.	.004	Mid-stream.
11. Iowa darter, *Etheostoma iowae*.	1	14 m.m.	.004	Mid-stream.

As shown by the table *Umbra limi* is by far the most frequent species in this habitat.

Maple River and the small streams coming into the lake, other than Bessey Creek, have been placed in the same group as regards type of habitat because they are more or less swift and clear, and offer about



GENERAL VIEW OF EAST SHORE OF SOUTH TWIN LAKE, LOOKING SOUTH FROM STATION 1.

SOUTH TWIN LAKE, LOOKING NORTHWEST, SHOWING BROAD SHOAL WITH A SCANT RUSH GROWTH AND THE ZONES OF SHORE VEGETATION.

the same sort of conditions. These stream beds are gravel or clear sand, and if a mucky bottom exists at all, it is near the banks or in holes and bayous along the stream. In these places the *Umbra limi* and small *Amieurus melas* are abundant. Aside from these situations, however, Maple River and the small clear streams afford a group of species different from those found in any other habitat of the region. The brook trout, *Salvelinus fontinalis*, is abundant along the small inlets and in Maple River five miles down stream from the lake. Besides *Salvelinus fontinalis*, several other species, which did not occur in the other habitats, were found in Maple River in abundance. *Etheostoma iowae*, *Notropis whipplii*, *Semotilus atromaculatus*, and *Rhinichthys atronasus* were taken in numbers. *Coltus ictalops* is also more abundant in Maple River than in Bessey Creek.

From the foregoing studies of the several habitats the fish fauna of Douglas Lake and connecting streams may be seen to include the following 26 species, of which 23 (marked *) occur in the lake proper:

TABLE NO. 8.

1. Bowfin, *Amia calva.**
2. Common sucker, *Catostomus commersonii.**
3. Catfish, *Amieurus melas.**
4. Hudson River shiner, *Notropis hudsonius.**
5. Common shiner, *Notropis cornutus.**
6. Cayuga shiner, *Notropis cayuga.**
7. Blue shiner, *Notropis whipplii.*
8. Horned dace, *Semotilus atromaculatus.*
9. Black-nosed dace, *Rhinichthys atronasus.*
10. Blunt-nosed minnow, *Pimephales notatus.**
11. Pickerel-pike, *Esox lucius.**
12. Mud minnow, *Umbra limi.**
13. Brook trout, *Salvelinus fontinalis.**
14. Lake whitefish, *Argyrosomus artedi cisco.**
15. Trout perch, *Percopsis gultatus.**
16. Log perch, *Percina caprodes.**
17. Iowa darter, *Etheostoma iowae.**
18. Johnny darter, *Boleosoma nigrum.**
19. Yellow perch, *Perca flavescens.**
20. Rock bass, *Ambloplites rupestris.**
21. Large-mouthed black bass, *Micropterus salmoides.**
22. Small-mouthed black bass, *Micropterus dolomieu.**
23. Pumpkin seed, *Eupomotis gibbosus.**
24. Blue gill, *Lepomis pallidus.**
25. Ling, *Lota maculosa.**
26. Sculpin, *Coltus ictalops.**

With this determination of the fish fauna of the Douglas Lake Region and the general distribution of the species in mind, the study of the mortality of the species was begun. To this end one mile of beach was laid off along the east side of South Fishtail Bay. (See map, Fig. 2). This section of beach was chosen because it receives the full sweep of the wind from across the entire lake, hence most floating fish, even on the far side of the lake, are eventually beached somewhere within this mile. This strip of beach was gone over each evening and all of the beached fish collected, identified, measured, examined, and buried. The study of the beached fish was continued for a period of 40 consecutive days (July 10 to August 19, 1913), and was supplemented by a study of the beached fish on all shores of the lake. The following table gives the results of the 40 days collecting on the mile of beach:

TABLE NO. 9.

Species.	Smallest.	Largest.	Size of majority of individuals.	Number injured.	Beached while feeding.	Other causes.	Total number beached.
1. Yellow perch, *Perca flavescens*	25 m.m.	280 m.m.	100 m.m.	11	71	2,782	2,864
2. Trout perch, *Percopsis guttatus*	30 m.m.	120 m.m.	80 m.m.	17	.....	701	718
3. Cayuga shiner, *Notropis cayuga*	30 m.m.	120 m.m.	70 m.m.	3	.....	88	91
4. Sucker, *Catostomus commersonii*	130 m.m.	400 m.m.	300 m.m.	1	.....	55	56
5. Rock bass, *Ambloplites rupestris*	70 m.m.	235 m.m.	140 m.m.	1	.....	29	30
6. Blue gill, *Lepomis pallidus*	60 m.m.	220 m.m.	90 m.m.	2	.....	28	30
7. Common shiner, *Notropis cornutus*	50 m.m.	105 m.m.	100 m.m.	.....	.....	19	19
8. Hudson River shiner, *Notropis hudsonius*	30 m.m.	70 m.m.	60 m.m.	1	.....	17	18
9. Small-mouthed black bass, *Micropterus dolomieu*	120 m.m.	220 m.m.	140 m.m.	.....	10	.....	10
10. Pumpkin seed, *Eupomotis gibbosus*	80 m.m.	130 m.m.	100 m.m.	1	.....	9	10
11. Catfish, *Amicurus melas*	150 m.m.	350 m.m.	200 m.m.	.....	.....	7	7
12. Lake whitefish, *Aggrosomus artedi cisco*	140 m.m.	210 m.m.	150 m.m.	3	.....	.....	3
13. Log perch, *Percina caprodes*	80 m.m.	80 m.m.	80 m.m.	1	.....	.....	1
14. Pickerel-pike, *Esox lucius*	165 m.m.	165 m.m.	165 m.m.	1	.....	.....	1
15. Large-mouthed black bass, *Micropterus salmoides*	120 m.m.	120 m.m.	120 m.m.	.....	1	.....	1
Total	.....	.....	.....	42	82	3,735	3,859

In looking for the causes of death of the fish listed in Table 9, the following are at least to be considered: (1) mechanical injury, (2) injury through attacks of other species, (3) the beaching of individuals while pursuing or swallowing prey, (4) accidental beaching while attempting to escape enemies, (5) disease and parasites.

The total number of individuals of all species showing definite external injuries was low, something less than one-tenth of one per cent, and as may be seen in Table 9 these were distributed rather evenly among the several species in proportion to the total number beached. Many apparently normal fish, free from parasites and without any sign of injury, were beached which may have been killed by wave action either well out in the lake or at the edge of the shoal water where the high waves break.

Few if any specimens showed unmistakable injuries due to the attacks of other species. A few suckers bore circular wounds resembling lamprey marks but these wounds were of such a nature that they might have been due to any of several other causes.

In the "beached while feeding" column only those individuals were listed which were found with prey in the mouth. *Perca flavescens* was the heaviest loser in this way. Seventy-one beached specimens of this species had half-swallowed individuals of *Percopsis guttatus* in their mouths, and the Percopsidae in almost every case were adults. In addition to the specimens taken with prey in the mouth undoubtedly other individuals are beached while pursuing prey. *Catostomus commersonii*, a bottom feeder, is known to come into shallow water at night while feeding and individuals of this species might easily be beached by a sudden storm.

The beaching of small fishes while attempting to escape larger pursuing fishes was on more than one occasion observed. The young suckers, Notropi, and other young fishes are constantly preyed upon by the larger carnivorous species and schools of the small fish are often forced to the shore line by the pursuers. Here an incoming wave completes the beaching.

Parasites certainly play an important part in the death of a large number of the individuals reaching the beach. With very few exceptions all of the *Centrarchidae* beached, i. e. *Ambloplites rupestris*, *Lepomis pallidus* and *Eupomotis gibbosus* were infected in the gill chambers with parasitic Copepods. Often this infection was very heavy although some specimens bore but a few of the gill parasites. Many suckers and Cyprinids contained worm cysts in the body wall and in the skin. The parasitic worms were not examined, but Dr. La Rue (see report of the Director of the Biological Station for 1912) reports a variety of forms and a heavy infection of several species of fish.

It is understood that Table No. 9 does not give complete data on the death rate of the species of the lake but it is considered suggestive. In spite of the fact that many dead fish are eaten by water birds before reaching shore and that the fish successfully caught and eaten by other species can not be estimated, the data in Table 9 indicate a critical size in the life of several species of fishes. Those fishes about two-thirds grown (see table for length of majority of individuals) were most often beached. Again, as might be expected, the species most abundant in the lake proper were represented on the beach by the largest number of individuals. On the other hand those species found in the more restricted habitats were represented by fewer individuals, and those confined to streams by none.

In order that these data might be verified a trip was made covering the entire shore line of the lake of 15 miles in a single day. On this trip all beached fishes were measured, examined and identified. The data collected are given in Table 10.

TABLE NO. 10.

Including a study of the shores about the whole lake (Aug. 3, 1913).

Species.	Average size.	Number.
1. Small-mouthed black bass, *M. dolomieu*	240 m.m.	1
2. Large-mouthed black bass, *M. salmoides*	350 m.m.	1
3. Yellow perch, *Perca flavescens*	103 m.m.	551
4. Pumpkin seed, *Eupomotis gibbosus*	105 m.m.	1
5. *Notropus cayuga*	110 m.m.	2
6. Hudson River shiner, *Notropus hudsonius*	78 m.m.	10
7. Common shiner, *Notropus cornutus*	107 m.m.	7
8. Cat fish, *Amiurus melas*	204 m.m.	11
9. Common yellow sucker, *Catostomus commersonii*	290 m.m.	177
10. Rock bass, *Ambloplites rupestris*	132 m.m.	31
11. Log perch, *Percopsis guttatus*	97 m.m.	72
12. Pike-pickerel, *Esox lucius*	537 m.m.	5
13. Blue gill, *Lepomis pallidus*	98 m.m.	10
14. Lake whitefish, *A. n. cisco*	140 m.m.	2
Total		881

NOTE:—Several dead specimens of "Johnny darter" (*Boleosoma nigrum*) were observed lying among the pebbles in the shallows about Grape-vine Point and Fairy Island. Because of their lack of an air-bladder they are not thrown upon the beach as are the other species of dead fish, but they remain in their habitat and are for the most part eaten by the crayfish.

The figures in Table 10 show the same relations of species as those in Table 9, the true lake forms being the ones most often beached.

In conclusion it may be said that *Perca flavescens*, *Percopsis guttatus*, *Catostomus commersonii* and *Notropis cayuga* were the forms most often beached.

The writer wishes to thank Dr. Max M. Ellis for suggestions and help in this work.

DRAGONFLIES OF THE DOUGLAS LAKE REGION, MICHIGAN.

ARTHUR T. EVANS