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ON FISH REMAINS IN LACUSTRINE SEDIMENTS

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ABSTRACT. The uppermost 15 cm of the deep-water sediments of Little Round Lake, Ontario, contain an abundance of fish bones and scales mostly derived from *Perca flavescens*. The average numbers found per square meter of sediment surface were 16,000, 650, 400, and 205, for scales, vertebrae, arches (neural and hemal), and ribs, respectively. The deep-water sediments of two other lakes were devoid of fish remains. The number of scales found in the surface sediments of a fish hatchery pond was 6 percent of the number expected from fish that had died in the pond.

INTRODUCTION

Literally thousands of sediment cores have been collected from lakes and bogs, but only in one instance have these been reported to contain fish remains.[1] The one published case on record is that of Lagler and Vallentyne (1956) who found two isolated fish scales in 7,000 to 8,000 year old sediments from Linsley Pond, Connecticut. These scales were found by accident, and not as the result of premeditated search. From these single findings we suspected that fish remains might be more common in the deep water sediments of lakes than had hitherto been thought. The work here reported was undertaken to determine the abundance of fish remains in the deepest surface sediments of three lakes and one pond.

METHODS AND MATERIALS

The water-bodies selected for study were: Fayetteville Green Lake, located about 10 miles east of Syracuse, New York; Lake Opinicon, situated near the town of Chaffey's Lock in eastern Ontario; Little Round Lake, about 3 miles north of the town of Sharbot Lake in eastern Ontario; and Pond H, one of a series of artificial ponds at the Cornell Fish Hatchery. Fayetteville Green Lake is meromictic, and was examined precisely for that reason. It has a maximum depth of 59 m, with the level of the chemocline at 19-20 m (Eggleton 1931, 1956). Lake Opinicon is a shallow, holomictic, eutrophic lake with a maximum depth of 11 m (Curran, et al., 1947). The lake supports high populations of large-mouth bass, *Micropterus salmoides*, and the sunfish, *Lepomis macrochirus* and *L. gibbosus*. Serious limnological studies of Little Round Lake have not been made. Preliminary studies have shown that the maximum depth is about 16 m, and the mid-summer level of the thermocline about 7-8 m. Pond H is approximately 30 × 33 m in area, with a maximum depth of 2 m. The pond was constructed in 1949 and stocked in 1952 with large-mouth bass, and one year later with blue-gills (*L. macrochirus*).

The lake sediments were collected with a 15 × 15 cm Ekman dredge. Ten samples were taken from Lake Opinicon at 9-10 m depth in the main basin of the lake: 25 samples from Fayetteville Green Lake at 50 m depth; and 23 samples from Little Round Lake at 15-16 m depth. The samples from Little Round Lake were collected in two series, one (samples 1-12) from the central part of the deep-water plateau, and the other (samples 13-23) from the southern edge of the deep-water plateau. It was necessary to use an orange-peel

[1] Dr. Winnifred Frost (personal communication) is currently examining salmonid scales and vertebrae found in a sediment core taken from Esthwaite Water, England.

sampler to penetrate the silty sediments of Pond H. Twenty-five samples were collected.

The lake sediment samples were sieved through an 80 mesh (to the inch) brass screen with openings of 0.2 × 0.4 mm. The sediment from Pond H was sieved through a coarser screen with openings of 1.1 × 1.4 mm. The individual samples from Lake Opinicon and Little Round Lake were examined separately, whereas those from Fayetteville Green Lake were combined before sieving as was the case for Pond H. The materials retained by the sieves were examined under water in a white enamelled tray with a 6X hand lens. For closer examination of some of the fish remains a binocular microscope (magnification up to 120X) was used.

The sediments of Fayetteville Green Lake and Lake Opinicon did not contain any macroscopic remains of fishes and will not be discussed further.

LITTLE ROUND LAKE

The results for Little Round Lake are summarized in table 1. Most of the scales and bones were identified as belonging to the yellow perch, *Perca flavescens*, a known inhabitant of the lake.

Three general types of scale were present: (a) ctenoid scales resembling those of *Perca flavescens*, with only marginal ctenii; (b) ctenoid scales resembling those of centrarchid fishes, with the ctenii extending anteriorly to the focus of the scale; and (c) small cycloid scales. The cycloid scales might have originated from brook trout, *Salvelinus fontinalis*, that have been stocked in the lake. The scales were identified with the aid of Lagler's "Lepidological studies I" (1947) and by comparison with the scales of known fishes. Both the bones and scales were excellently preserved, and of a beautiful amber color. There was no evidence of muscle tissue attached to the bones, indicating death of the fish some (unknown) time previously.

The manner in which the scales and bones are distributed over the floor of the lake is a question of prime importance. In rare samples, such as no. 6 and no. 14, most of the bones (disarticulated) of separate perch heads were found. The skull bones had apparently remained more or less in place. Most of the other samples showed rather peculiar distributions of parts indicating that the various fish remains had been to some extent scattered around the lake bottom. An intact perch has roughly 2700 scales, 40 vertebrae, 40 neural arches, 40 ribs, and 20 hemal arches, i.e. a ratio of 68 scales: 1 vertebra: 1.5 arches (neural and hemal): 1.0 ribs. The corresponding ratio for the combined sediment samples was 24 scales: 1 vertebra: 0.6 arches: 0.3 ribs. The ratios of scales: vertebrae and ribs: vertebrae were found to differ significantly ($P << 0.01$) from the ratios expected of an intact perch, but the scale: rib ratio showed no significant difference. The above data together with the manner of occurrence of the ribs suggest selective sorting and/or decomposition of the fish parts.

Correlation coefficients (*r*'s) were determined for scales and vertebrae and for scales and arches (neural and hemal), separately for the two series of samples as well as for the combined set of 23 samples. The relevant data are presented in table 2. The correlation coefficient for vertebrae and arches was not determined because in many cases the neural and hemal arches were still attached to the vertebrae. The negative values of $r_{\text{scales-vertebrae}}$ and $r_{\text{scales-arches}}$ for samples 1-12 certainly do not support a hypothesis of a strong marked positive correlation. In samples 13-23 there was a significant ($P = .05$) correlation between scales and vertebrae, but when all samples were combined no statistically significant relationships emerged.

In one sample (no. 10) a complete examination was made of all the scales using a binocular microscope with a magnification up to 120X. Of 148 scales determinable as to type, 134 were ctenoid and 14 cycloid. Most of the ctenoid scales were from *Perca flavescens*; however, it was impossible to make out the distinguishing characteristics on the smaller scales, and some of these may have been derived from other species of fish. Table 3 shows the frequencies of the different size classes of ctenoid scales in the sample. The smallest scales were of about the same dimensions as the openings of the sieve. Of 139 scales that were determinable as to age, 128 were definitely from fish in their first year of life, and 6, 4, and 1, probably from fish in their second, third, and fourth years of life, respectively. The annuli showed no tendency to be near the edges of the scales, suggesting that the mortality was not the result of a *late* winter kill. It would be fallacious to assume that the age distribution of the scales corresponds to that of the fishes that gave rise to the scales. This would be justified only in the absence of sorting and selective decomposion, or, in the presence of sorting if the entire lake had been randomly sampled.

In addition to fish remains the samples contained large numbers of cladoceran ephippia; some unidentified, amber-colored, doughnut-shaped objects that ranged up to 1 mm in diameter and were about one-half as abundant as the scales; occasional twigs and leaves of both deciduous and gymnospermous trees; and a few floatoblasts of the bryozoan *Cristatella*. Living chironomid larvae were not observed in any of the 23 samples. This notable fact suggests a severe oxygen depletion in the bottom waters, and may thus be indirectly correlated with the abundance of fish remains. Little more can be said until the detailed limnology of the lake is known.

POND H[2]

From the records kept by Cornell Fish Hatchery workers it was clear that approximately 350 centrarchid fish (large-mouth bass and blue-gills) had "disappeared" in the pond in the two years prior to the time of sampling (November, 1958). That is to say, this number of fish was not accounted for in terms of stocking, repeated population cenuses, and human removal. It was assumed that these fish died in the pond, and that their scales were not removed from the pond.

The orange-peel sampler penetrated the sediment to an average depth of 2-3 cm. This depth corresponds roughly to the annual thickness of sediment deposited in the pond. We therefore expected to find the remains of about 175 centrarchids in the uppermost 2-3 cm of the entire pond. The number of scales

[2] This section is written in collaboration with Mr. George Tanner.

on a bass or blue-gill is slightly over 2,000. The total area of the pond is about 1,000 m^2. The combined 25 dredge samples covered an area of 1.75 m^2, i.e. about 0.175 percent of the surface area of the pond. *Assuming* that the sampling was random with respect to the scales in the sediment and that no destruction of scales had occurred, we expected to find 610 centrarchid scales in the total of 25 dredge samples. Actually only 26 centrarchid scales were found, suggesting that only about 6 of every 100 original scales had been preserved. Two considerations suggest that this estimate is low: (a) some of the blue-gills were doubtless eaten by the bass, and their scales destroyed in the gastro-intestinal tract of the predator; and (b) the coarse-mesh sieve probably retained only the larger scales present in the sediment. In view of a number of uncertainties that are involved in the calculation, the value of 6 percent is taken only to indicate the general order of magnitude. The preservation in this case pertains to a period of one year in a pond with a relatively high rate of sedimentation. The short time and rapid burial would both tend to favor scale preservation.

In addition to the 26 centrarchid scales isolated from the sediment of this pond. nine other scales were found. one of which appeared to have come from the minnow *Notemigonus crysoleucas*. Thirty-six opercula of the snail *Viviparus contectoides*. a known inhabitant of the pond, were also found. A single pectoral spine of the channel catfish. *Ictalurus punctatus*. was the only non-scaley fish part that was found in the collected sediment. The catfish (or the spine) must have entered from Cascadilla Creek which supplies the water for the pond.

DISCUSSION AND CONCLUSIONS

The above results indicate that fish remains do occur in some lake and pond sediments; however. the data are inadequate to formulate any general statement on the probability of finding such remains in any particular body of water. Attention was focussed on deep water sediments because it is in such locations that limnologists are prone to take sediment cores. Shallow water lacustrine sediments may contain more abundant remains of fishes. It would appear that in Little Round Lake, some specific and perhaps catastrophic phenomenon was responsible for the death of the perch. In the case of Pond H it is possible that some of the scales entered the pond as such from the waters of Cascadilla Creek; however, in such a case one would not have expected such a high proportion of centrarchid scales. It seems more likely that these were derived tfrom the bass and blue-gills resident in the pond.

In closing, it is instructive to calculate the frequency with which various fish parts might be expected to occur in the uppermost 15 cm (the depth to which the dredge penetrated the sediment) of a core from Little Round Lake. Given a corer of 4 cm diameter, one would expect to find an average of 19 scales, 0.5 vertebrae, and 0.5 neural and hemal arches, with occasional evidence of other bones in the top 15 cm. The conclusion from this preliminary work is that fish remains can be expected to be found in cores of lake sediments, but only in certain lakes and perhaps only during certain stages of a lake's history.

TABLE 1

Numbers of scales, vertebrae, neural and hemal arches, and ribs in 23 Ekman dredge (15 × 15 cm) samples from the deep water sediments of Little Round Lake, Ontario (see text for explanation).

Sample	Scales	Vertebrae	Neural and Hemal Arches	Ribs	Other
1	282	4	4	0	
2	271	6	3	0	
3	185	16	11	0	
4	147	13	4	0	
5	108	25	7	0	
6	173	8	5	35	Skull and opercular bones abundant
7	154	10	4	1	
8	273	10	1	1	
9	175	16	1	0	
10	180	72	41	0	
11	153	2	3	0	
12	497	7	8	0	
Av. 1-12	217	16	8	3	
13	228	12	6	2	
14	898	15	4	30	Skull and opercular bones abundant
15	1345	40	37	35	
16	630	8	3	0	
17	291	8	1	0	
18	376	8	3	0	
19	271	8	6	1	Some opercular bones
20	231	10	5	0	
21	267	3	5	0	
22	500	33	43	0	
23	667	5	2	1	
Av. 13-23	519	14	10	6	
Av. 1-23	361	15	9	5	

TABLE 2

Correlation coefficients for scales-vertebrae and scales-arches (neural and hemal) in two series of sediment samples from Little Round Lake, Ontario.

Correlation between:	*r* (samples 1-12)	significant at P = .05 ?	*r* (samples 13-23)	significant at P = .05 ?	*r* (samples 1-23)	significant at P = .05 ?
scales-vertebrae	−.23	no	+.67	yes*	+.19	no
scales-arches (n. & h.)	−.07	no	+.49	no	+.36	no

* Just significant at P = .05; not significant at P = .02.

TABLE 3

Frequencies of scale size-classes in sample #10 from Little Round Lake, Ontario. The distance from the focus to the anterior margin was determined for each scale, and the scales then grouped according to successively increasing 0.16 mm size intervals. The scales in size class 1 (0.00 – 0.16 mm) would have been too small to be retained by the sieve used to concentrate the scales.

size class	frequency	size class	frequency
1	.00	9	.04
2	.38	10	.00
3	.27	11	.00
4	.11	12	.00
5	.09	13	.00
6	.03	14	.01
7	.04	15	.01
8	.02		1.00

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