In George and Corrine Lakes, the largemouth congregate in the very same areas that are preferred by the muskellunge. Under less strenuous circumstances, that is, where densities of muskellunge were substantially lower or where a greater number of individuals of another species were available, much better survival of the young largemouth bass would be expected. Under the conditions which prevailed, however, the advantage of increased survival of largemouth bass which resulted from the reduction in the numbers of perch was apparently nullified a short time later through predation by the muskellunge. It is remarkable, nevertheless, that there was such a complete elimination of young largemouth bass as there appears to have been. With essentially no recruitment, it is not surprising that the largemouth bass populations declined.

Smallmouth bass, on the other hand, increased in numbers, probably because of a net increase in recruitment, although, as it has already been mentioned, no exceptionally large year classes were observed. It seems that here, too, the reduction in the numbers of perch aided the survival of bass fry and that the different habits of smallmouth bass acted in such a manner as to diminish contact between them and the muskellunge.

It is obvious that in this experiment more muskellunge were stocked than were necessary to markedly reduce the number of perch. At the end, both populations had literally eaten themselves "out of house and home." Ideally, enough predators should be stocked to reduce the density of perch to a level which would allow a greater percentage of bass fry to survive but not to such a low level that the bass fingerlings would be extensively eaten later on. Under these conditions, the muskellunge would be able to grow normally and reach catchable size at the normal age.

One approach toward the establishment of an appropriate stocking density is to construct a population model. A suitable model approximating the conditions in George, Corrine or any similar lake would consist of a population of perch ranging in age from 1 to 6 years with constant annual recruitment, a natural annual mortality rate of 0.5, and a total weight of about 50 pounds per acre. It is possible to interject into this scheme different densities of muskellunge which are growing and dying at normal rates and to study the effect on the perch population. Under the conditions postulated, stocking muskellunge at three or four large fingerlings per acre would reduce adequately the numbers of larger perch and lead to a better-balanced ratio of predator to prey.

Table 27: Estimates of muskellunge production and prey consumption by periods.

Date	N	Mean weight (g.)	g	Standing crop (kg.)	Mean standing crop-(kg.)	Production (kg.)	Food conversion factor	Quantity of prey consumed (kg.)
				GEORGE LAKE				
May 1956	400	90		36.0				
			0.288		36.0	10.37	4.0	41.48
June 1956	300	120		36.0				
			0.875		54.0	47.25	4.0	189.00
June 1957	250	288		72.0				
			0.442		72.6	32.09	5.0	160.45
May 1958	175	418		73.1				
			0.567		87.9	49.84	5.0	249.20
May 1959	130	790		102.7				
			0.038		78.0	3.00	5.0	15.00
June 1960	65	821		53.4				
				CORRINE LAKE				
Oct. 1956	395	90		35.5				
			0.228		36.1	8.22	4.0	32.88
June 1957	325	113		36.7				
			0.477		46.6	22.20	4.0	88.80
May 1958	310	182		56.4				
			0.704		73.3	51.60	5.0	258.00
May 1959	245	368		90.2				
			0.920		114.3	105.07	5.0	525.35
June 1960	150?	923		138.5				

N = estimated number of muskellunge
g = instantaneous growth rate = $(\ln \text{mean weight})_t - (\ln \text{mean weight})_{t+1}$
Production = g x mean standing crop

Table 28: Summary of vital statistics concerning the fish populations of George Lake from 1951 through 1960.

Year	Estimated Population	Mean Length (mm.)	Mean Weight (g.)	Standing Crop Total Weight (kg.)	Standing Crop kg./ha.	Standing Crop lbs./ac.
			LARGEMOUTH BASS			
1951 *	97	-	-	48.55	2.80	2.48
1952 *	77	-	-	48.55	2.80	2.48
1953 *	-	-	-	48.55	2.80	2.48
1954	115	236	192	22.08	1.27	1.14
1955	147	226	142	20.87	1.20	1.08
1956	115	242	174	20.01	1.16	1.03
1957	220	229	157	34.54	1.99	1.78
1958	94	310	372	34.97	2.02	1.80
1959	101	348	503	50.80	2.93	2.62
1960	76	332	483	36.71	2.12	1.89
			SMALLMOUTH BASS			
1951 *	87	-	-	22.59	1.30	1.15
1952 *	97	-	-	22.59	1.30	1.15
1953 *	90	-	-	22.59	1.30	1.15
1954	97	206	127	12.32	0.71	0.63
1955	94	225	146	13.72	0.79	0.71
1956	195	213	118	23.01	1.33	1.91
1957	250	225	152	38.00	2.19	1.96
1958	233	249	208	48.46	2.80	2.50
1959	211	303	345	72.79	4.20	3.75
1960	132	318	417	55.04	3.18	2.84
			PERCH			
1951-3 *	147,000	127	18	2639.00	152.37	135.65
1954 **	107,700	126	23	2643.80	152.64	135.89
1955	90,720	-	17	1578.50	91.14	81.14
1956	31,200	-	22	447.40	27.56	24.54
1957	-	-	-	-	-	5.00 ?
1958	-	-	-	-	-	1.00 ?
1959	-	-	-	-	-	1.00 ?
1960	-	-	-	-	-	1.00 ?
			MUSKELLUNGE			
1956(May)	400	266	90	36.00	2.08	1.85
1956(June)	300	292	120	36.00	2.08	1.85
1957	250	400	288	72.00	4.16	3.70
1958	175	448	418	73.15	4.22	3.76
1959	130	541	790	102.70	5.93	5.28
1960	65	568	821	53.36	3.08	2.74

* Johnson (1954)
** Stross (1954)

Table 29: Summary of vital statistics concerning the fish populations of Corrine Lake from 1954 through 1960.

Year	Estimated Population	Mean Length (mm.)	Mean Weight (g.)	Standing Crop: Total weight (kg.)	Standing Crop: kg./ha.	Standing Crop: lbs./ac.
			LARGEMOUTH BASS			
1954 *	325	229	155	50.37	3.45	3.08
1956	230	232	114	26.22	1.79	1.60
1957	100	239	167	16.70	1.14	1.02
1958	90	293	308	27.72	1.90	1.70
1959	90	332	511	45.99	3.15	2.81
1960	40	381	747	39.72	2.72	2.43
			PERCH			
1954 *	7,600	152	34	258.40	17.69	15.78
1956	10,000	168	44	440.00	30.12	26.87
1957	10,000	172	51	510.00	34.91	31.15
1958	9,500	175	45	427.50	29.26	26.11
1959	1,900	162	48	91.20	6.24	5.57
1960	-	-	-	10.00 ?	1.00 ?	1.00 ?
			MUSKELLUNGE			
1956(Oct.)	395	253	90	35.55	2.43	2.17
1957	325	293	113	36.72	2.51	2.24
1958	310	351	182	56.42	3.86	3.44
1959	245	423	368	90.16	6.17	5.50
1960	150 ?	543	923	138.45	9.48	8.46

* Durkin, (1955)

P A R T I I

MOVEMENTS AND HOME RANGE OF YOUNG MUSKELLUNGE

The use of numbered tags made it possible to identify individually each muskellunge. In order to determine the site of capture as closely as possible, map grids consisting of 30' x 30' squares were used with a system of coordinates (Figures 2 and 4). Satisfactory precision was attained by using these in conjunction with land marks. The place of capture of any marked fish was easily described by a pair of coordinates tallied on the field record sheet. The maps were also used as permanent recording forms to construct the recapture history of individual fish.

As mentioned previously, three different types of collecting apparatus were utilized, two of which (the boom shocker and angling gear) permitted equivalent sampling effort over each unit of shore line. Once processed, each muskellunge was returned to the lake not far from the place of capture.

The straight-line distance between the place of capture and the place of subsequent recapture was selected as a crude measure of the area traversed by the muskellunge. It is obvious that this has some deficiencies. In the first place, muskellunge are fish of the littoral regions. As such, they would be expected to travel in the proximity of the shoreline rather than to swim out across deeper water. Observations accrued during the investigation indicate the presence of such a behavior. The minimum distance between the points of capture and recapture is not necessarily the shoreline distance. Trial calculations using actual data indicate that, on the average, the magnitude of the discrepancy between the two quantities increases directly as the minimum distance. That is, when short distances are involved, the minimum distance and the shoreline distance are the same, while at long distances the minimum distance may be only half as much as the shoreline distance. The use of minimum distance, therefore, serves as a built-in transformation. While the values obtained do not allow statements concerning the size of the "home range," they are convenient for comparing annual trends within each separate population and, since the size and shape of the two lakes are similar, for comparing the two populations with each other.

In working with a mixture of age groups of this same species, Crossman (1956) noted "a greater amount of travel for greater numbers of days out, but (that) the relation here seems to be more one of distance travelled to season." He found that fish captured in the fall and recaptured in the fall had moved about considerably, while fish captured during the summer and recaptured in either the same or the following summer remained in the same place.

The data collected from Corrine Lake in 1958 (Table 30) were analyzed by plotting the minimum distance traveled against the time lapsing between capture and recapture using Olmstead and Tukey's (1947) quadrat sum test (see Steel and Torrie 1960). There was no strong relation between the two. Muskellunge that have roamed about for several months tend to be no farther from the place of original capture than muskellunge that are recaptured after a very few days. This simplifies group comparisons since no adjustments for the "time out" factor need be made.

The frequency distributions of the minimum distances traveled by muskellunge during the different years are presented in Tables 31 and 32. These were tested by the non-parametric median test (Steel and

Torrie, pg. 405), and it was found that, within each population, there were no great differences between any two distributions. Nevertheless, if the mean of each distribution is computed (Table 33), several interesting comparisons may be made:

1.) The mean minimum distance traveled by muskellunge captured, marked, and recaptured within a single summer is very similar to that of muskellunge which were not recaptured until the following summer. This corresponds with Crossman's findings. No fall collections were made during this investigation, so there is no information to compare with the results he obtained at that time of the year.

2.) The mean minimum distances traveled by muskellunge of the same age are similar in both populations.

3.) The mean minimum distance traveled decreased with increasing age of the muskellunge.

A reversal of this last trend occurred with the muskellunge in George Lake captured in 1959 and recaptured in 1960. Crossman found that an increase in the distance traveled occurred between the ages of three and seven, but that does not appear to be the case here. The sudden increase in distance traveled by George Lake muskellunge in 1960 may possibly be associated with the onset of maturity, but gonads were not examined, and it is not known if the majority matured in 1960 or not. Although they were old enough, nutrition was poor, and growth was very slow from 1959 on, and this may have served to delay maturation.

While these observations are interesting in themselves, the question of whether these fish truly are restricted in their movements or whether they move freely around the lake has not been answered. It is generally assumed that "if a marked fish is caught two or more times in a restricted area, it is very likely that the fish has occupied the area for a substantial period" (Gerking 1959). There is evidence here that a bare majority of the muskellunge captured three or more times over periods of from one to three years - 11 of 18, or 61%, in George Lake and 11 of 20, or 55%, in Corrine Lake - remained in the same general area of the lake. On the basis of the above assumption, muskellunge do have a home range as defined by Hayne (1949). Funk (1957) has noted the presence of a sedentary group and a mobile group in the same population, and it seems that a similar situation occurs here since a substantial proportion of each population roamed about considerably.

Further information was needed to discover whether or not the population movements noted here represented differences from random movements. For comparison, the random movements of a hypothetical fish (or population) were studied in the following way:

On an outline map of Corrine Lake, a series of 57 equally-spaced stations were marked off on the shoreline and numbered clockwise from 1 through 57 beginning at the northerly-most point. A series of 201 pairs of digits from 01 through 57 were selected by means of a table of randomly-assorted digits (Snedecor, 1956). It was assumed that any two adjacent pairs represented the station of capture and the station of re-capture of a hypothetical fish, and the minimum distance between the two was measured. Proceeding down the list, a series of 200 observations were accumulated. The frequency distribution of these is presented in Table 34.

When this random distribution is compared to the actual distribution obtained in 1958 from Corrine Lake muskellunge by means of the median test, a very high chi-square of 9.95 is obtained. From this it can be concluded that muskellunge do not move freely around the lake but confine their movements to smaller areas.

This restricted area is a home-range rather than a territory in the sense used by Nice (1941), since numerous observations indicate that these immature muskellunge are gregarious. In using the boom shocker at night, groups of two or three individuals were commonly caught in the electrical field at the same time. Also, while skin diving, groups of two, three or more individuals were frequently seen swimming near the same small brush pile. It seems doubtful, in view of these observations, that a territory is defended by muskellunge in this age bracket.

No attempt was made to investigate success of homing in this species because of the scarcity of individuals.

Table 30: 1958 data for Corrine Lake muskellunge showing the number of days lapsing between capture and recapture and the minimum distance traveled.

Days Out	Minimum Distance Traveled - feet
1	0
1	0
1	0
1	480
3	870
3	1600
4	80
6	1300
6	830
7	840
7	250
12	150
12	960
14	130
17	1140
17	340
17	0
18	150
21	1430
28	180
28	700
28	960
28	1100
32	0
33	1040
33	0
37	1270
41	250
45	240
45	0
49	1720
52	160
53	550
53	740
56	220
59	1360
61	1350
67	340
70	1770
73	320
75	1580
87	830
97	870
98	1550
98	460
100	300
103	1150
110	870

Table 31: Frequency distribution of the distances between the place of capture and the place of recapture of muskellunge in George Lake. (Columns headed by two years indicate capture in the first and recapture in the second.)

	Year(s) of capture and recapture					
Interval - feet	1957	1957-58	1958	1958-59	1959	1959-60
0 - 99	2	1	4	3	5	1
100 - 199	-	-	3	2	-	-
200 - 299	-	2	2	3	-	-
300 - 399	-	-	3	1	1	1
400 - 499	-	-	3	-	-	-
500 - 599	-	1	-	1	1	1
600 - 699	1	-	-	5	-	1
700 - 799	-	-	1	-	-	2
800 - 899	-	-	-	1	-	-
900 - 999	1	1	2	-	1	1
1000 - 1099	-	2	-	1	-	-
1100 - 1199	-	1	-	-	-	1
1200 - 1299	-	-	1	-	-	-
1300 - 1399	-	-	-	-	-	-
1400 - 1499	2	1	-	-	-	-
1500 - 1599	-	-	-	-	-	-
1600 - 1699	-	-	-	-	-	1
N =	6	9	19	17	8	9

Table 32: Frequency distribution of the distances between the place of capture and the place of recapture of muskellunge in Corrine Lake. (Columns headed by two years indicate capture in the first and recapture in the second.)

Interval - feet	Year(s) of capture and recapture: 1958	1958-59	1959	1959-60
0 - 99	8	5	3	-
100 - 199	5	2	2	2
200 - 299	5	4	1	1
300 - 399	3	-	1	1
400 - 499	2	1	1	-
500 - 599	1	2	-	-
600 - 699	1	-	-	-
700 - 799	1	-	-	1
800 - 899	6	-	-	-
900 - 999	2	2	-	-
1000 - 1099	1	3	2	-
1100 - 1199	3	1	-	1
1200 - 1299	2	-	2	-
1300 - 1399	2	3	-	-
1400 - 1499	1	1	-	-
1500 - 1599	2	1	-	-
1600 - 1699	1	-	1	-
1700 - 1799	2	-	-	-
N =	48	25	14	6

Table 33: Mean minimum distance traveled (MMDT) by muskellunge in George and Corrine Lakes.

Year(s)	Average Age (years)	No.	MMDT - feet
	GEORGE LAKE		
1957	2.5	6	750
1957-58	3.0	9	851
1958	3.5	19	384
1958-59	4.0	17	421
1959	4.5	8	253
1959-60	5.0	9	756
	CORRINE LAKE		
1958	2.5	48	673
1958-59	3.0	25	665
1959	3.5	14	593
1959-60	4.0	6	439

Table 34: Frequency distribution of minimum distances between a series of randomly selected points situated equidistant from each other around the shoreline of Corrine Lake.

Interval - feet	Frequency
0 - 99	10
100 - 199	6
200 - 299	5
300 - 399	7
400 - 499	7
500 - 599	10
600 - 699	7
700 - 799	14
800 - 899	15
900 - 999	10
1000 - 1099	12
1100 - 1199	12
1200 - 1299	16
1300 - 1399	23
1400 - 1499	11
1500 - 1599	15
1600 - 1699	8
1700 - 1799	9
1800 - 1899	2
1900 - 1999	1

PART III

THE CYCLE OF SPERMATOGENESIS IN THE MUSKELLUNGE
Esox masquinongy immaculatus Garrard

INTRODUCTION

The literature describing the seasonal changes in the gonads of different species of fish is sparse, but growing. Much of it is presented not so much for its histological significance as for its value in connection with some other problem. This investigation is no exception since the study was originally begun to ascertain the importance of spermatozoa production in male muskellunge as a factor which might be involved in controlling the density of muskellunge in lakes and other bodies of water. The ecological part of the investigation is incomplete at this time, and only the descriptions of the spermatogenetic cycle, the relationship of testes weight to body weight, and the estimation of the quantitative production of spermatozoa in male muskellunge will be presented here.

These processes and relationships in the muskellunge are compared wherever possible to those in its close relative, the northern pike, *Esox lucius*, L. Two recent papers by Zaitzev (1955) and Lofts and Marshall (1957) have greatly facilitated the comparisons, but new material is presented in several areas.

MATERIALS AND METHODS

Muskellunge testes were collected in each month of 1960 except for the months of June, November and December. Residents of the Chippewa Indian Reservation near Hayward, Wisconsin collected muskellunge testes from January through March. The assistance of Mr. Steve Taylor of

Reserve, Wisconsin, was invaluable in securing samples at this time of the year. From August to October, samples of muskellunge testes were secured through anglers vacationing at the Resort of the Woods, Boulder Junction, Wisconsin, with the cooperation of Mr. Herb Sahar.

A total of 2[illegible] specimens of muskellunge testis were examined histologically. Whenever possible, northern pike testes were also examined microscopically.

Material prepared for histological examination was fixed in Bouin's fixative, embedded in paraffin, sectioned at 6 microns, and stained with Harris' hematoxylin and eosin. All measurements given are from fixed and stained sections of testis.

The methods used in the non-histological sections of the report will be elaborated at the appropriate place.

ANATOMY OF THE TESTES

The testes of muskellunge and northern pike are very similar. They consist of two separate, elongated bodies which are suspended ventrally from the swim bladder and which extend along the entire length of the body cavity. Over much of their length they are, in cross section, triangular in shape. At maximum size, northern pike testis tapers only slightly from the posterior end to the anterior end, while muskellunge testis is much more attenuated.

The internal structure of northern pike testis has been described by Turner (1919), who used one of its common local names, the "pickerel," and by Lofts and Marshall (1957). The body of the testes of northern pike and muskellunge consists of a complex of many interbranched, blindly-ending lobules, with thin walls of fibrous connective tissue. The entire structure is enveloped by a sheath of fibrous connective tissue.

The lobules are most apparent at the termination of spermatogenesis when the lumen of each lobule is filled with spermatozoa. Weisel's (1943) illustrations of the lobules of the sockeye salmon adequately describe the tortuously interconnecting lobules of the northern pike and muskellunge as well.

At spawning, the sexual products eventually drain into several very large channels which are found on the ventral edge of the posterior third of each testis. Along part of their length, these channels, like the sperm ducts into which they lead, are lined by a cuboidal to low columnar epithelium.

THE CYCLE OF SPERMATOGENESIS IN MUSKELLUNGE

The northern pike spawn immediately after the ice has melted in the spring of the year, usually in April throughout Wisconsin. Muskellunge generally spawn somewhat later, usually in May, after the temperature of the water reaches 48° to 56° F. (Johnson 1958). The spawning behavior of northern pike has been thoroughly described by Fabricius and Gustafson (1958). In both species of Esox, the sexual products are gradually shed in many separate, coordinated spawning acts. Ordinarily, the spawning period lasts from one to two weeks, but cold and cloudy weather may cause a decrease in the spawning intensity and an increase in the length of the spawning period. Such inclement weather may also be responsible for incomplete spawning with the result that not all of the spermatozoa and eggs are released. Zaitzev (1955), on the other hand, believes that the male pike normally retain some spermatozoa after spawning as do some other species of fish (Foley 1926, Mann 1927).

Small quantities of mature unspawned spermatozoa are found in the lumen of the lobules of muskellunge testes in late July, over two and one-half months after spawning. At this time the walls of the lobules are lined by nests of spermatogonia. Some of the lobules in the peripheral regions of the testis also contain groups of primary spermatocytes surrounded by a thin, nucleated membrane. These groups of cells, always in the same stage of spermatogenesis, are known as cysts. Only spermatogonial cysts are found in the central part of the testis. No later stages were noted, however, and it appears certain that the mature spermatozoa in the lumen of the lobules remained from the previous spawning period.

The channels on the edge of the testes not only contain spermatozoa but also contain cells with nuclei averaging about 4.3 microns in diameter and with abundant, often granulated, cytoplasm. The reticulated nuclei vary in shape from sperical to oblong. Very few of the cells are to be found among the masses of spermatozoa in the lobules themselves. These cells may be phagocytes, but no evidence was noted.

By early August, most of the mature spermatozoa which remained from the previous spawning period have disappeared. Each lobule is now somewhat enlarged and is composed of numerous, thin-walled cysts. All of the cells within each cyst divide at nearly the same time so that cells of one stage only are found within each cyst. There is no antero-posterior gradient of spermatogenesis in the testis of muskellunge.

Spermatogenesis is well under way by late August, and cysts at different stages of development are abundant everywhere. Some of these have already produced mature spermatozoa and have ruptured and released their contents into the lumen of the lobules. The various stages found in the testis of muskellunge at this time are similar to those described and illustrated by Hann (1927) for *Cottus bairdii* and by Robertson (1958) for the rainbow trout, *Salmo gairdnerii*.

Throughout the month of September, spermatogenesis proceeds at a high rate, and the lobules enlarge as mature spermatozoa fill the lumen. No estimates of the chromosome number were made because no well-defined mitotic figures were found. Secondary spermatocytes are relatively more scarce than either primary spermatocytes or spermatids, probably because this stage passes rapidly.

By October, cysts containing intermediate stages of spermatogenetic cells are not as abundant as they formerly were. The lumen of the lobules are already filled with mature spermatozoa. Spermatogonia are common, as are 'lobule boundry cells'. Lofts and Marshall (1957) have described the 'lobule boundry cells' for northern pike and some salmonids and found that, beginning in September, they accumulate cholesterol-positive lipids in their cytoplasm which is released into the lumen of the lobule at spawning. It is believed by these biologists that the 'lobule boundry cells' are homologous to the Leydig cells of higher vertebrates.

No samples of testes were obtained during November or December, but presumably the intensity of spermatogenesis diminishes rapidly because of gradually-decreasing water temperatures.

In the northern pike, all of the cysts have matured and ruptured by January, and the lobules are filled exclusively with mature spermatozoa. Spermatogenesis has also ceased in muskellunge by or before mid-January. However, many cysts are still present, the cells of which have not completed their development into spermatozoa. Most of these cells were

arrested as primary spermatocytes, although some spermatids were observed. Judging from the appearance, shape and staining qualities of the nuclei, these cells are now degenerating. The cysts of degenerating cells are by no means uncommon, and it is estimated that they made up from 3% to 7% of the total volume of the testis in several different muskellunge. Germ cells or spermatogonia are common as are 'lobule boundry cells.' Numerous cells of spermatogonia appear to contain two or more nuclei.

From January until the spawning period in late April or early May, there is little change within the testis. The cysts of degenerating cells become smaller and appear more infrequently and, at the time of spawning, make up only about 1.5% of the volume of the testis. Throughout this period, spermatogonia are plentiful, many of which have divided to form two separate cells and many of which appear to have two or four nuclei within the cell. The spermatogonia lie in the now-thin layer of connective tissue of the lobule walls and protrude into the lumen. They frequently have two or three small cells closely applied to their cytoplasmic membrane, usually on the same plane as the lobule wall. These small "cap" cells can be found later throughout the summer and fall near the lobule wall between the developing cysts. Apparently these cells are responsible for the thin walls of the individual cysts.

As the spermatozoa are shed over the eggs during spawning, the testes diminish greatly in size. The posterior part of the testes becomes smaller more rapidly than the anterior part, but eventually most of the spermatozoa are expelled.

Reorganization follows spawning, and the cycle is repeated.

Except for two specific, marked differences, the cycle of spermatogenesis in the muskellunge is very similar to that which occurs in the northern pike in Europe as described by Zaitzev (1955) and Lofts and Marshall (1957).

The first major variation is the incomplete transformation of many of the cysts which contain intermediate spermatogenetic stages. It appears as though the cells within the cysts are prevented from developing further by cold water temperatures and that they subsequently degenerate and are resorbed. There is a complete transformation of all of the stages to spermatozoa by January in northern pike.

In centrarchids and other species of fish with a prolonged period of spawning, spermatogenesis proceeds in the fall until the water temperature becomes cold. During the winter, spermatogenesis ceases or continues very slowly, but the cells at intermediate stages of development do not degenerate. With the coming of spring, spermatogenesis is accelerated, and the intermediate stages develop into spermatozoa (James 1946). In some species spermatogenesis continues throughout the summer (Putskaya 1955).

All of the muskellunge testes examined during the winter and early spring have these degenerating cells, and it is apparently a characteristic of this species rather than a temporary abnormality. However, no samples of northern pike testes were obtained during the critical period, and the possibility of this phenomenon being geographic rather than species specific is not ruled out.

The second major variation is the ever-present abundance of spermatogonia at all times of the year in muskellunge. All spermatogonia in the testes of northern pike have disappeared by November. These do not reappear until after spawning in the spring when germ cells migrate into

the lobule walls from an as-yet-undetermined point of origin. The term "primary germ cells" as used by Lofts and Marshall (1957), following the example of Turner (1919), applies to large migratory cells which move into the lobule walls after spawning. These give rise to spermatogonia by growth and division. In muskellunge, as in _Cottus bairdii_ (Mann, 1927), these large cells are continuously present within the lobule and are here referred to as spermatogonia.

THE RELATIONSHIP OF TESTES WEIGHT TO BODY WEIGHT IN NORTHERN PIKE AND MUSKELLUNGE

Fifty-two northern pike and twenty-three muskellunge collected during the late winter and spring before the onset of spawning provided the data used to determine the relationship of testes weight to body weight for each species. Spermatogenesis is complete, and the testes are fully developed during this period. Seasonal variations in the average testes weight of northern pike are presented by Lofts and Marshall (1957), but the relationship of testes weight to the weight or length of the fish was not explored by these investigators.

Individual fish were measured to the nearest millimeter in total length, and both the fish and the testes were weighed to the nearest gram, usually on spring-type platform scales of different capacities. Both the right and left testis appeared to be of equal size and were weighed together. The above information, together with the time and place of capture, are presented in Tables 35 and 36.

The relationship of testes weight to body weight of both *E. lucius* and *E. m. immaculatus* is presented in Figure 16. Although much variation was encountered, it is apparent that the relationship is linear, hence a linear regression analysis was used.

Muskellunge and northern pike resemble each other physically, grow at about the same rate, and have other characteristics in common. In both species, males grow more slowly but mature about a year earlier than females. In Wisconsin, male northern pike spawn for the first time as two- and three-year olds while male muskellunge spawn as four- and five-year olds. The relationship of testes weight to the body weight in

each species is a reflection of the difference in the length of time required for the attainment of maturity.

Considering the weight of the testes at maximum development as a percentage of body weight, the testes of northern pike comprise about 2.5% of the total body weight in a pike weighing about 1.0 kg. and about 2.25% in a fish of 4.0 kg. The testes of mature muskellunge contribute even less to the total body weight. About 0.77% of a 3.0 kg. muskellunge and approximately 1.29% of a 7.0 kg. fish are testes.

The small size of the testes of both species is a cause for some concern in the artificial propagation of these fish. Huet (1953), referring to the artificial fertilization of northern pike eggs, writes:

> "Comparés aux Truites et à beaucoup d'autres espèces d'Europe occidentale, les Brochets mâles ont très peu de laitance, d'où la nécessité de faire très soigneusement la fécondation artificielle."

The problem is even more critical in the muskellunge where the size of the testes in relation to the body weight is only half of that in the northern pike. Johnson (1955) states, in reference to the volume of milt obtained by "stripping" the male on one occasion, "Male muskellunge produce only small quantities of milt, on the order of 0.2 to 0.3 cc., which is usually measured by the number of drops," and ". . . as many as six males may be needed to produce sufficient milt for the eggs from a single female."

In comparison, bluegill testes at maximum development comprise from 1.0% to 1.5% of the total body weight (James 1946). The testes weight of white bass, *Roccus crysops*, just before spawning in April averaged from 1.7% to 5.7% of the total body weight in fish which ranged from 258 to 623 grams in weight (Kilpatrick 1959). Turner (1919) states that the maximum testes weight of the yellow perch, *Perca flavescens*, represents from 4.58% to 5.9% of the entire gross weight of the body. A single male carp examined on 30 December 1960 weighed 4.25 kg. and had testes which weighed 392 grams or 9.2% of the total gross weight. Even more remarkable is the Pacific herring whose testes comprise nearly 25% of the entire gross body weight of the male (Wynne-Edwards 1929).

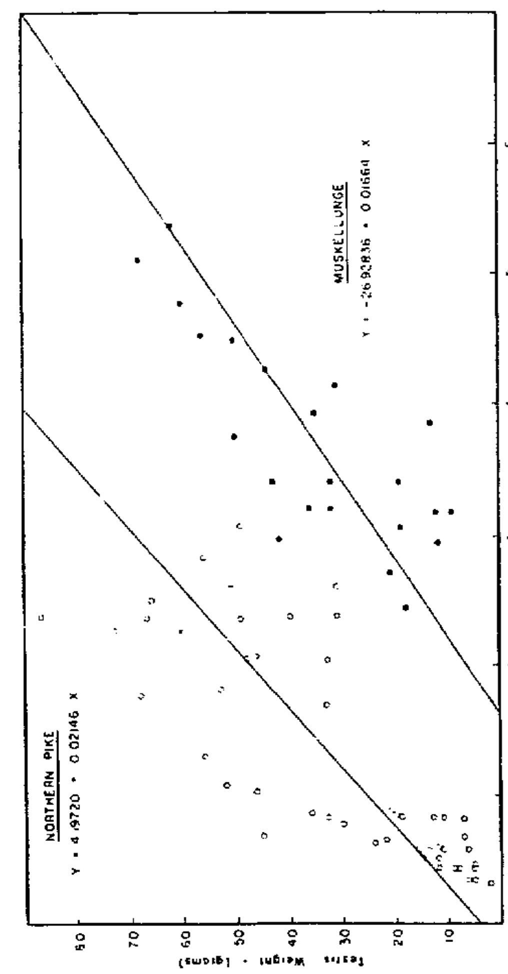

Figure 16 Regressions of testis weight (grams) prior to spawning on body weight (grams) for northern pike and muskellunge.

Table 35: Body length, weight and weight of testes of muskellunge collected from several Wisconsin lakes during late winter and early spring of 1960.

Date of Capture	Place of Capture	Total Length (mm.)	Weight (g.)	Testes Weight (g.)
19 Jan.	Chief Lake	838	3856	13
19 "	" "	883	4480	50
21 "	" "	762	2722	21
23 "	" "	775	3062	19
23 "	" "	762	2948	12
4 Feb.	" "	806	3402	19
4 "	" "	781	3176	9
6 "	" "	889	3912	35
30 March	Big Lac Court Oreilles	800	3176	12
6 April		813	4139	31
7 "	"	889	4762	60
10 "	"	781	3402	43
12 "	"	775	3750	50
22 "	Allequash Lake	813	2977	42
22 "	" "	914	5103	68
25 "	" "	810	3204	36
25 "	" "	840	4252	44
25 "	" "	808	3402	32
25 "	" "	807	3204	32
25 "	" "	890	4508	56
25 "	" "	940	5359	62
25 "	" "	742	2438	18
25 "	" "	1000	7429	92

Table 36: Body length, weight and weight of testes of northern pike collected from several Wisconsin rivers and lakes during late winter and early spring of 1960.

Date of Capture	Place of Capture	Total Length (mm.)	Weight (g.)	Testes Weight (g.)
18 March	Rock River	475	805	7
22 March	" "	460	670	7
2 April	Big Lac Court	686	2268	60
2 "	Oreilles	700	2381	40
3 "	"	813	4082	104
4 "	"	635	2070	46
4 "	"	640	2041	48
6 "	"	660	2268	61
6 "	"	686	2608	51
6 "	"	660	2381	67
6 "	"	673	2495	66
6 "	"	660	2381	49
7 "	"	610	1701	33
7 "	"	724	2835	56
7 "	"	660	2381	31
7 "	"	737	3062	49
7 "	"	673	2608	31
9 "	"	711	2268	73
9 "	"	660	1814	53
9 "	"	749	2605	51
9 "	"	673	2041	33
9 "	"	724	2381	87
20 "	Vance Lake	540	880	21
20 "	" "	645	1770	69
20 "	" "	490	680	45
21 "	" "	510	851	36
21 "	" "	560	1134	56
21 "	" "	460	567	16
21 "	" "	465	652	22
21 "	" "	563	1077	52
21 "	" "	507	624	24
21 "	" "	418	425	12
21 "	" "	435	510	15
21 "	" "	446	510	12
21 "	" "	505	765	30
21 "	" "	515	922	33
21 "	" "	568	1021	46
26 "	Kenu Lake	462	567	11
26 "	" "	460	567	6
26 "	" "	415	425	5
26 "	" "	395	340	5
26 "	" "	506	851	20
26 "	" "	430	454	5

Table 36: continued.

Date of Capture	Place of Capture	Total Length (mm.)	Weight (g.)	Testes Weight (g.)
26 April	Kenu Lake	432	567	14
26 "	" "	447	822	11
26 "	" "	394	340	6
26 "	" "	420	425	8
26 "	" "	432	822	13
26 "	" "	408	425	9
26 "	" "	465	595	12
26 "	" "	375	312	2
26 "	" "	515	822	19

THE PRODUCTION OF SPERMATOZOA BY NORTHERN PIKE AND MUSKELLUNGE

Since the process of spermatogenesis in the male northern pike and muskellunge is, for the most part, complete by January and does not commence again until after spawning, it is possible to make estimations of the total quantity of spermatozoa elaborated during the process. This quantity also represents the total amount of spermatozoa available for the fertilization of eggs during the spawning period.

The procedure followed in making these estimations was, first, to remove a small piece of testis by carefully slicing the testis transversely. The piece was usually taken from the middle of the testis, but it was soon discovered that the exact area of sampling was not important. The piece of testis, usually weighing between 0.5 and 1.0 grams, was weighed immediately (wet wt.) to the nearest ten-thousandths of a gram on a triple beam balance. It was then macerated thoroughly in a Potter-Elvehjem homogenizer which contained a small volume of normal saline solution. This was diluted to 100 ml., and 10 ml. of this suspension was diluted further to 100 ml.

A 0.75% solution of sodium chloride was usually used as a diluent, but tap water was used under field conditions without difficulty.

The concentration of spermatozoa in each of 10 drops of the final dilution was estimated by means of a hemacytometer. When estimates were conducted in the field, only five drops were used because of time limitations. These estimates were then based on the number of spermatozoa per gram of whole testis.

In addition, the concentration of spermatozoa within the testis, exclusive of the connective tissue, was also estimated but on the basis of volume rather than weight. The contents of the lobules, the lobular fluid, was expressed by lacerating the testis longitudinally and applying digital pressure. A small quantity was drawn into a micropipette and measured out. This was then processed in the same manner as the pieces of whole testis.

Estimates of the mean density of spermatozoa and its confidence interval in both whole testis and lobular fluid appear in Tables 37 and 38. The individual estimates of the mean concentration of spermatozoa in the testes of each species of Esox are, in general, similar. More variation is found among the individual estimates of spermatozoa concentration in the lobular fluid. There is no correlation between the size of the testes and the mean concentration of spermatozoa. The density is apparently similar throughout the testis since, as mentioned earlier, spermatogenesis seems to proceed at the same rate along the entire length of the testis. This would be expected in a species which has a single, short, well-defined spawning period each year. Some direct evidence comes from the statistically-similar estimates of spermatozoa density in the anterior, middle and posterior portions of one muskellunge testis (Table 37).

There is a relationship, statistically significant at the 0.02 level as tested by the "corner test" (Olmstead and Tukey, 1947), between the density of spermatozoa within the lobules and the density of spermatozoa in whole testis. High densities in the testis are accompanied by high densities in the lobules of the testis.

The overall mean density of spermatozoa in the testes of northern pike is approximately 12% greater than that of the muskellunge, while the concentration of spermatozoa within the lobules of muskellunge is considerably higher (13%) than that in the northern pike. The former confirms the impression gained during the histological examination of

the sections of testis that the interlobular connective tissue is thicker in testes of muskellunge than it is in testes of northern pike.

Table 37: Estimates of the density of mature spermatozoa in the testes of muskellunge following the completion of spermatogenesis.

Date of Capture	Testes Weight (g.)	Density of Spermatozoa: Whole Testis, Mean ± 95% C. I. (sperm x 10^{10}/gram)	Density of Spermatozoa: Lobular Fluid, Mean ± 95% C. I. (sperm x 10^{10}/ ml.)
6 Feb. 1960	35	3.333 ± 0.193 *	- -
		3.242 ± 0.144 **	- -
		3.562 ± 0.237 ***	- -
30 March 1960	12	3.013 ± 0.138	- -
6 April 1960	31	3.231 ± 0.175	4.944 ± 0.382
7 " "	60	3.348 ± 0.154	4.960 ± 0.232
10 " "	43	3.101 ± 0.181	6.392 ± 0.537
22 " "	42	2.873 ± 0.244	4.592 ± 0.479
22 " "	68	2.780 ± 0.246	4.768 ± 0.374
	average	= 3.019	average = 5.131

* Anterior testis
** Middle testis
*** Posterior testis

Table 38: Estimates of the density of mature spermatozoa in the testes of northern pike following the completion of spermatogenesis.

Date of Capture	Testes Weight (g.)	Density of Spermatozoa: Whole Testis, Mean ± 95% C. I. (sperm x 10^{10}/gram)	Density of Spermatozoa: Lobular Fluid, Mean ± 95% C. I. (sperm x 10^{10}/ ml.)
18 March 1960	7	3.343 ± 0.129	4.640 ± 0.255
22 " "	7	3.523 ± 0.200	5.184 ± 0.332
2 April 1960	60	3.069 ± 0.215	3.816 ± 0.504
2 " "	40	3.529 ± 0.172	4.160 ± 0.372
3 " "	104	3.767 ± 0.168	5.728 ± 0.438
4 " "	46	3.425 ± 0.172	4.072 ± 0.312
4 " "	48	3.964 ± 0.162	4.696 ± 0.446
6 " "	61	3.879 ± 0.199	5.040 ± 0.590
6 " "	51	3.138 ± 0.195	- -
6 " "	67	3.402 ± 0.127	- -
6 " "	66	4.036 ± 0.199	5.712 ± 0.479
6 " "	49	3.710 ± 0.199	4.600 ± 0.390
7 " "	33	2.300 ± 0.170	3.864 ± 0.374
7 " "	56	3.424 ± 0.164	4.360 ± 0.343
7 " "	31	3.501 ± 0.161	3.596 ± 0.446
7 " "	49	3.349 ± 0.245	4.224 ± 0.475
7 " "	31	- -	5.528 ± 0.563
9 " "	73	3.065 ± 0.167	3.208 ± 0.380
9 " "	53	3.275 ± 0.245	5.256 ± 0.541
9 " "	51	3.444 ± 0.224	4.512 ± 0.419
9 " "	33	3.326 ± 0.209	5.968 ± 0.508
9 " "	87	2.137 ± 0.190	2.744 ± 0.316
	average	= 3.386	average = 4.560

SUMMARY

1. George and Corrine Lakes, two small northern Wisconsin lakes containing resident populations of perch and bass, were stocked with young muskellunge (*Esox masquinongy immaculatus* Garrard).
2. Within a year after the introduction, the perch population in George Lake decreased from about 31,000 individuals to a density which was too low to estimate. In Corrine Lake, three years lapsed before a comparable reduction occurred.
3. The growth rate of one- and two-year-old perch increased after the reduction in the number of perch. The length-weight relationship, as analyzed by an analysis of covariance, remained unchanged.
4. Population levels of largemouth bass decreased because virtually no small bass survived to the third summer of life, although good numbers of fry were observed in most years.
5. During the study, the population level of smallmouth bass increased significantly because of a net increase in recruitment, although no rich year classes were observed.
6. The difference in the response of the population levels of largemouth and smallmouth bass appears to be related to a difference in the schooling tendencies and the habitat preferences of the young. Young largemouth bass school near the same type of habitat - usually vegetation - which is preferred by muskellunge, while young smallmouth bass scatter over sandy and rocky areas.
7. Little change in the growth rate and the length-weight relationship of either smallmouth or largemouth bass occurred after the reduction in the number of perch.

8. About 25% of the muskellunge stocked in the spring in George Lake was unaccounted for after one and a half months, but there was no evidence of a similar high, initial mortality of the muskellunge stocked in the fall in Corrine Lake. After the initial loss, a relatively constant annual mortality rate of 20% to 25% was observed in both populations.
9. The course of events which followed the introduction of the predator is discussed in relation to a postulated cycle of abundance of the perch. For some intervals within the study it was possible to compare quantitatively the decrease in the abundance of the prey with the production of the predator.
10. Large young-of-the-year muskellunge gain approximately one gram in weight for each 2.72 grams of fish eaten.
11. The cycle of spermatogenesis in the muskellunge is described and compared to that in the northern pike.
12. The relationship of testes weight to total body weight is described by the equations: $Y(\text{testes wt. in g.}) = -26.92836 + 0.01664\, X(\text{body wt. in g.})$ for the muskellunge and $Y = 4.19720 + 0.02146\, X$ for the northern pike.
13. After the completion of spermatogenesis and before spawning, the density of spermatozoa in the testes is 3.019×10^{10} spermatozoa per gram in muskellunge and 3.386×10^{10} spermatozoa per gram in northern pike. Within the lobules of the testes, the density of mature spermatozoa is about 5.131×10^{10} per ml. in muskellunge and 4.560×10^{10} per ml. in northern pike.

APPENDIX

Table A: [illegible] from 1963 through 1967.

Length Interval (cm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50- 59	-	-	-	-	-	-	1	-
60- 69	-	-	-	-	-	-	5	-
70- 79	-	-	-	-	-	-	15	-
80- 89	-	-	-	-	-	-	12	2
90- 99	2	-	-	5	-	-	2	-
100-109	10	8	2	7	-	-	2	2
110-119	16	17	3	6	-	-	-	-
120-129	10	15	6	2	-	-	-	-
130-139	5	3	2	1	-	-	-	-
140-149	-	5	6	7	-	-	-	2
150-159	2	5	2	2	-	1	-	-
160-169	14	4	1	1	-	-	-	-
170-179	12	1	-	2	-	-	-	-
180-189	6	1	4	1	2	-	-	-
190-199	3	4	5	-	15	-	-	-
200-209	10	5	25	-	17	-	-	-
210-219	11	8	27	1	5	1	-	-
220-229	5	6	24	2	2	1	-	-
230-239	7	4	17	7	1	2	-	-
240-249	6	2	12	3	1	3	-	-
250-259	2	5	3	12	2	4	1	-
260-269	6	1	2	7	7	5	-	-
270-279	4	4	4	6	3	5	1	-
280-289	-	2	17	4	2	7	-	3
290-299	2	-	2	1	-	8	5	1
300-309	1	2	2	2	4	8	8	6
310-319	1	-	4	1	6	2	1	2
320-329	1	-	2	2	-	2	1	3
330-339	1	-	-	-	1	5	6	-
340-349	1	-	1	3	1	4	3	2
350-359	1	-	-	-	1	7	2	1
360-369	-	-	1	-	1	4	3	1
370-379	1	1	-	-	-	1	1	3
380-389	5	1	2	-	-	-	-	1
390-399	3	1	1	-	-	2	-	-
400-409	2	-	1	-	-	-	-	1
410-419	1	-	1	-	1	-	1	1
420-429	-	-	-	-	-	-	1	2
430-439	-	-	1	1	-	1	-	2
440-449	-	-	-	-	-	-	-	-
450-459	1	-	-	-	-	-	1	-
460-469	-	-	-	-	-	1	-	-
470-479	1	-	-	-	-	-	-	-
480-489	-	-	-	-	-	1	-	1
N =	121	90	170	97	64	53	54	37

Table [illegible]: Annual catch of [illegible] largemouth bass in [illegible] Lake from 1954 through 19[illegible].

Length Interval (mm)	1954 June	1954 Sept.
100-124	-	4
125-149	3	1
150-174	25	11
175-199	20	71
200-224	1	37
225-249	2	9
250-274	13	1
275-299	2	6
300-324	5	5
325-349	5	6
350-374	7	4
375-399	5	4
400-424	1	-
425-449	1	1
450-474	4	-
N =	120	198

Length Interval (mm)	1960	1967	[illegible]	1979	1980
70- 79	-	-	-	2	3
80- 89	-	-	-	-	1
90- 99	-	-	-	-	1
100-109	-	-	-	-	-
110-119	-	-	-	-	-
120-129	-	-	-	-	-
130-139	2	-	-	-	-
140-149	-	-	-	-	-
150-159	2	1	-	-	-
160-169	3	2	-	-	-
170-179	11	-	-	-	-
180-189	14	-	1	-	-
190-199	14	1	-	-	-
200-209	11	7	-	1	-
210-219	15	1	-	-	-
220-229	15	6	-	-	-
230-239	20	2	1	-	-
240-249	22	7	1	-	-
250-259	14	2	3	-	-
260-269	6	2	1	1	-
270-279	5	3	5	4	-
280-289	4	1	9	4	-
290-299	2	1	7	3	-
300-309	1	-	3	7	-
310-319	1	1	4	1	1
320-329	-	1	3	3	-
330-339	1	-	2	1	-
340-349	7	1	1	3	1
350-359	2	1	1	-	-
360-369	2	2	1	1	1
370-379	2	2	4	1	-
380-389	-	-	2	4	-
390-399	-	1	2	2	1
400-409	1	1	2	-	-
410-419	-	-	3	4	-
420-429	-	1	2	2	-
430-439	-	-	1	2	2
440-449	-	-	-	-	1
450-459	-	-	-	-	-
460-469	-	-	1	-	1
470-479	-	-	2	2	-
480-489	-	-	-	-	-
N =	139	54	73	45	13

Table [illegible]: Annual catch of smallmouth bass in [illegible] Lake from 1953 through 1980.

Length Interval (mm)	Year 1953	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1979	1980
60- 69	-	-	-	-	-	-	4	-
70- 79	-	-	1	-	-	-	7	-
80- 89	5	-	16	-	-	-	14	-
90- 99	4	1	16	5	-	-	5	-
100-109	2	4	40	3	-	2	2	-
110-119	5	1	7	11	-	1	-	-
120-129	-	1	2	3	-	2	-	-
130-139	5	1	-	3	-	2	-	1
140-149	32	-	-	2	-	8	2	1
150-159	24	-	-	-	1	3	-	-
160-169	6	-	2	-	3	7	1	1
170-179	2	2	5	4	3	2	2	-
180-189	-	3	13	17	12	3	3	-
190-199	-	10	5	4	4	1	1	-
200-209	-	5	3	23	7	2	3	-
210-219	-	2	2	2	1	1	1	-
220-229	1	-	1	6	15	3	2	-
230-239	-	-	1	2	2	4	1	-
240-249	-	-	3	2	2	13	1	-
250-259	7	-	12	5	5	3	1	1
260-269	3	-	7	5	7	5	4	1
270-279	2	1	2	1	2	1	4	3
280-289	4	-	2	3	2	6	5	1
290-299	1	-	-	-	1	1	1	1
300-309	5	-	1	-	3	7	6	1
310-319	4	-	1	-	1	6	7	2
320-329	4	1	-	3	-	5	7	4
330-339	2	-	-	2	1	1	1	6
340-349	6	-	-	1	1	-	3	11
350-359	-	-	1	-	-	2	-	7
360-369	5	-	-	2	-	1	1	3
370-379	-	-	-	2	-	2	-	5
380-389	1	1	1	-	2	-	1	-
390-399	1	-	2	1	1	-	1	-
400-409	-	-	-	-	-	2	-	-
410-419	-	-	-	-	-	-	2	2
420-429	-	-	-	1	2	1	-	-
430-439	-	-	-	-	-	1	-	-
440-449	-	-	-	-	-	2	-	-
450-459	-	-	-	-	-	2	-	1
460-469	-	-	-	-	-	-	-	-
470-479	-	-	-	-	-	2	-	-
N =	171	35	155	152	170	113	94	57

Table 1: Length frequencies of the catch of perch in George Lake from 1953 through 1960.

Length Interval (mm)	Year 1953	1954	1955	1956	1957	1958	1959	1960
40- 49	-	-	-	-	-	4	-	-
50- 59	-	-	-	-	-	12	-	-
60- 69	-	-	2	-	-	26	21	1
70- 79	4	-	51	3	-	15	30	9
80- 89	19	27	131	7	-	13	55	68
90- 99	46	113	212	6	-	12	17	65
100-109	143	80	123	37	-	4	11	35
110-119	215	32	146	173	-	7	4	15
120-129	113	56	213	178	1	7	3	[illegible]
130-139	51	63	242	132	-	5	1	5
140-149	26	54	113	136	-	2	1	2
150-159	35	43	65	61	2	-	2	-
160-169	30	29	37	41	2	6	2	-
170-179	41	17	30	21	3	1	-	-
180-189	14	11	17	14	3	-	1	-
190-199	20	13	9	15	1	-	-	-
200-209	10	9	6	6	2	-	-	-
210-219	5	6	2	-	1	-	-	-
220-229	3	1	2	-	1	-	-	-
230-239	-	-	-	1	-	-	-	-
240-249	-	-	1	-	-	-	-	-
N =	900	575	1407	835	23	108	203	202

Table 2: Length frequencies of the catch of perch in Corrine Lake from 1954 through 1960.

Length Interval (mm)	Year 1954	1956	1957	1958	1959	1960
50- 59	-	-	-	-	-	57
60- 69	-	-	-	-	411	112
70- 79	-	-	1	-	274	67
80- 89	-	-	1	-	13	26
90- 99	-	-	-	2	20	4
100-109	-	-	-	-	48	14
110-119	14	-	-	-	71	8
120-129	20	-	6	-	31	5
130-139	172	5	12	6	0	0
140-149	75	42	12	41	9	-
150-159	53	111	87	125	2	-
160-169	42	141	90	293	11	-
170-179	33	113	64	150	40	-
180-189	31	46	63	143	51	-
190-199	14	30	40	73	30	-
200-209	3	16	15	47	16	-
210-219	1	7	5	13	30	-
220-229	5	-	2	5	12	-
230-239	2	-	2	1	7	-
240-249	-	-	-	-	1	-
250-259	1	1	-	-	-	-
260-269	-	-	-	1	-	-
N =	460	550	410	1106	1039	311

Table F: Mean, back-calculated lengths, in millimeters, at time of annulus formation of largemouth bass in George Lake.

Year Class	No. fish 58	59	60	Mean calculated length in mm. at end of year 1	2	3	4	5	6	7	8	9	10	11	12	13
1959	-	-	4	69												
1958	-	-	1	70	119											
1957	1	-	-	73	-	-										
1956	-	1	1	70	175	223	263									
1955	-	4	2	95	193	255	295	305								
1954	-	1	4	72	164	207	254	283	292							
1953	-	4	4	76	158	210	253	283	305	320						
1952	-	4	2	93	175	236	271	304	336	345	349					
1951	-	3	3	60	103	213	240	273	308	337	350	361				
1950	-	2	2	72	131	182	214	238	270	305	320	331	[illegible]			
1949	-	1	1	95	164	240	270	305	322	344	367	355	372	400		
1948	1	1	-	96	171	201	235	265	294	316	336	347	365	380	-	
1947	-	1	1	71	173	193	220	259	302	330	335	358	363	372	313	442

Table G: Mean, back-calculated lengths, in millimeters, at time of annulus formation of largemouth bass in Corrine Lake.

Year Class	No. fish 1959	1960	Mean calculated length in mm. at end of year 1	2	3	4	5	6	7	8	9	10	11	12
1953	8	-	73	141	162	205	275	304	-					
1952	7	3	79	147	169	207	251	275	290	330				
1951	2	-	92	172	214	235	274	302	327	344	-			
1950	2	-	97	155	195	255	320	353	383	403	413	-		
1949	2	1	80	175	225	262	317	354	383	394	405	419	450	
1948	1	-	80	146	161	217	255	296	335	361	394	403	411	-
1947	1	-	76	170	193	230	273	294	309	347	360	356	372	374

Table H: Mean, back-calculated lengths, in millimeters, at time of annulus formation of smallmouth bass in George Lake.

Year Class	No. fish 58	59	60	Mean calculated length in mm. at end of year 1	2	3	4	5	6	7	8	9	10	11	12
1959	-	-	1	81											
1958	-	1	4	67	151										
1957	4	15	1	97	163	225									
1956	4	3	4	91	154	210	261								
1955	-	5	7	90	153	224	263	291							
1954	-	10	6	91	157	219	261	298	339						
1953	-	18	10	90	155	202	244	282	315	335					
1952	-	6	4	88	172	200	247	283	315	336	345				
1951	-	3	1	84	145	191	236	263	291	322	339	345			
1950	-	4	-	90	140	197	251	296	332	350	381	401	-		
1949	1	2	1	92	156	209	252	295	340	364	377	389	413	455	
1946	3	-	-	81	152	225	272	333	369	390	414	430	442	455	490

Table I: Mean, back-calculated lengths, in millimeters, at time of annulus formation of perch in George Lake.

Year Class	No. fish 58	59	60	Mean calculated length in mm. at end of year 1	2	3	4	5	6	7	8
1959	-	-	2	77							
1958	-	7	11	65	90						
1957	1	20	2	53	97	114					
1956	13	1	-	58	85	105	-				
1955	5	6	-	53	73	113	134	-			
1954	1	1	-	52	84	111	155	165	-		
1953	4	-	-	58	88	116	149	160	-	-	

Table J: Mean, back-calculated lengths, in millimeters, at time of annulus formation of perch in Corrine Lake.

Year Class	No. fish 58	59	60	Mean calculated length in mm. at end of year 1	2	3	4	5	6	7	8	9
1958	-	1	17	69	96							
1957	-	10	-	61	93							
1956	1	8	-	65	87	123						
1955	2	5	-	66	95	124	161					
1954	3	1	-	74	101	131	145	160				
1953	4	6	-	63	103	126	141	160	174			
1952	9	-	-	66	112	135	151	166	175	-		
1951	3	1	-	69	105	131	148	165	177	191	215	
1950	2	-	-	62	95	115	132	144	154	192	173	-

Table K: Calculated mean length ($\bar{x}$), variance (s^2) and 95% confidence interval ($t_{05}s_{\bar{x}}$) of largemouth bass in George Lake at the time of annulus formation before and after the introduction of the muskellunge.

	Period of Observation									
	Pre-treatment					Post-treatment				
Age	No.	s^2	$\bar{x}$	±	$t_{05}s_{\bar{x}}$	No.	s^2	$\bar{x}$	±	$t_{05}s_{\bar{x}}$
1	42	284.3	82.80	±	5.25	8	35.4	70.75	±	4.98
2	36	1115.6	159.60	±	11.32	9	1058.9	181.11	±	25.01
3	31	1452.3	212.48	±	13.97	13	2033.7	231.54	±	27.25
4	23	1561.9	246.43	±	17.20	20	1496.2	266.65	±	18.14
5	17	1793.7	269.06	±	21.78	21	1246.5	293.19	±	16.07
6	11	1378.9	295.55	±	24.94	24	1432.7	311.50	±	15.99
7	7	1317.3	332.43	±	33.57	20	1443.3	330.95	±	17.78
8	5	1477.7	348.20	±	47.72	14	1650.6	342.50	±	23.46
9	3	2863.0	378.00	±	132.93	11	1024.7	345.63	±	21.50
10	-	-	-		-	8	1866.0	351.62	±	36.12

Table L: Calculated mean length ($\bar{x}$), variance (s^2) and 95% confidence interval ($t_{05}s_{\bar{x}}$) of untagged largemouth bass in Corrine Lake at the time of annulus formation, before and after the introduction of the muskellunge.

	Period of Observation									
	Pre-treatment					Post-treatment				
Age	No.	s^2	$\bar{x}$	±	$t_{05}s_{\bar{x}}$	No.	s^2	$\bar{x}$	±	$t_{05}s_{\bar{x}}$
1	27	127.7	79.48	±	4.47	-	-	-		-
2	27	586.5	151.85	±	9.58	-	-	-		-
3	27	859.6	194.48	±	11.60	-	-	-		-
4	19	1033.6	239.26	±	15.50	7	446.3	222.42	±	19.54
5	9	1132.6	297.11	±	25.87	10	615.6	266.70	±	17.75
6	7	1363.5	336.86	±	34.15	10	1261.1	309.00	±	25.40
7	5	1163.7	361.80	±	42.35	4	2035.7	343.50	±	71.79
8	2	98.0	354.00	±	88.94	4	988.3	379.50	±	50.02
9	-	-	-		-	3	276.5	411.67	±	41.31
10	-	-	-		-	2	761.0	424.50	±	247.66

Table M: Calculated mean length ($\bar{x}$), variance (s^2) and 95% confidence interval ($t_{05}s_{\bar{x}}$) of untagged smallmouth bass in George Lake at the time of annulus formation, before and after the introduction of the muskellunge.

	Period of Observation									
	Pre-treatment					Post-treatment				
Age	No.	s^2	$\bar{x}$	±	$t_{05}s_{\bar{x}}$	No.	s^2	$\bar{x}$	±	$t_{05}s_{\bar{x}}$
1	81	59.0	89.69	±	1.70	40	153.2	93.15	±	3.96
2	69	361.2	153.98	±	4.58	46	344.4	155.80	±	5.53
3	53	544.1	202.00	±	6.43	38	479.6	218.60	±	7.19
4	25	722.2	253.96	±	11.09	35	777.4	265.50	±	7.22
5	15	1122.4	295.53	±	18.56	19	725.7	304.80	±	12.99
6	11	1020.1	345.09	±	21.46	10	1121.9	332.20	±	23.96
7	7	1655.2	378.00	±	37.63	7	845.3	348.60	±	26.89
8	3	250.5	414.33	±	39.32	6	1493.4	384.00	±	40.56
9	3	90.5	430.33	±	23.64	2	1478.0	429.00	±	345.40
10	3	212.5	442.67	±	36.21	-	-	-		-

Table N: Calculated mean length ($\bar{x}$), variance (s^2) and 95% confidence interval ($t_{.05}s_{\bar{x}}$) of yellow perch in George Lake at the time of annulus formation, before and after the introduction of the muskellunge.

	Period of Observation									
	Pre-treatment					Post-treatment				
Age	No.	s^2	$\bar{x}$	±	$t_{.05}s_{\bar{x}}$	No.	s^2	$\bar{x}$	±	$t_{.05}s_{\bar{x}}$
1	31	33.1	55.35	±	2.11	43	127.0	62.02	±	3.47
2	17	148.9	81.94	±	6.28	47	129.2	93.13	±	3.35
3	6	115.8	114.83	±	11.30	14	189.8	112.78	±	7.95
4	4	220.7	149.00	±	23.64	8	368.3	139.50	±	15.65
5	-	-	-		-	5	75.8	161.20	±	10.81

Table O: Calculated mean length ($\bar{x}$), variance (s^2) and 95% confidence interval ($t_{.05}s_{\bar{x}}$) of yellow perch in Corrine Lake at the time of annulus formation, before and after the introduction of the muskellunge.

	Period of Observation									
	Pre-treatment					Post-treatment				
Age	No.	s^2	$\bar{x}$	±	$t_{.05}s_{\bar{x}}$	No.	s^2	$\bar{x}$	±	$t_{.05}s_{\bar{x}}$
1	50	46.8	67.64	±	1.95	31	60.8	65.68	±	2.86
2	41	130.2	103.61	±	3.60	39	72.5	92.97	±	2.76
3	34	132.9	129.70	±	4.04	15	285.4	124.20	±	9.39
4	30	194.3	145.77	±	5.21	9	569.2	154.77	±	18.34
5	20	197.4	163.40	±	6.58	11	288.7	160.45	±	11.41
6	11	271.0	172.82	±	11.06	15	132.7	174.40	±	6.38
7	2	800.0	162.00	±	254.12	9	161.7	191.30	±	9.78
8	-	-	-		-	3	1072.0	167.00	±	81.34

Table P: Comparison of mean, back-calculated lengths of tagged and untagged largemouth bass in George Lake.

	Tagged Bass		Untagged Bass	
Age	No.	Mean Length (mm)	No.	Mean Length (mm)
4	4	231.7	[illegible]	[illegible]
5	7	[illegible]	14	291.9
6	12	[illegible]	[illegible]	[illegible]
7	5	[illegible]	[illegible]	[illegible]
8	6	[illegible]	6	347.4
9	4	[illegible]	7	[illegible]
10	5	[illegible]	5	[illegible]

Table Q: Comparison of mean, back-calculated lengths of tagged and untagged largemouth bass in Corrine Lake.

	Tagged Bass		Untagged Bass	
Age	No.	Mean Length (mm)	No.	Mean Length (mm)
4	1	241.0	7	[illegible]
5	8	254.9	10	[illegible]
6	10	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	4	343.5
8	5	[illegible]	4	372.5
9	3	[illegible]	3	411.7

Table R: Comparison of mean, back-calculated lengths of tagged and untagged smallmouth bass in George Lake.

	Tagged Bass		Untagged Bass	
Age	No.	Mean Length (mm)	No.	Mean Length (mm)
3	3	210.0	36	213.6
4	25	242.7	[illegible]	[illegible]
5	42	[illegible]	19	304.8
6	33	310.1	10	[illegible]
7	21	333.1	7	348.6
8	10	[illegible]	[illegible]	364.0
9	7	[illegible]	[illegible]	429.0

Table S: Frequency of occurrence of food items in the stomachs of muskellunge in George and Corrine Lakes.

	GEORGE LAKE				CORRINE LAKE			
	1958		1959		1958		1959	
Number empty	27		13		75		31	
Number containing food	18		6		38		12	
Food Items	f	%	f	%	f	%	f	%
Perch								
- fingl. & yrls.	6	33.3	4	66.7	10	26.3	6	50.0
- larger	2	11.1	-	-	13	34.2	4	33.3
Largemouth Bass								
- fingl. & yrls.	7	38.9	-	-	2	5.3	-	-
- larger	-	-	-	-	-	-	-	-
Smallmouth Bass								
- fingl. & yrls.	-	-	-	-	-	-	-	-
- larger	-	-	1	14.3	-	-	-	-
Unidentified fish	3	16.7	1	14.3	12	31.6	5	41.7
Coleoptera								
- adult	1	5.6	-	-	-	-	-	-
- immature	-	-	-	-	1	2.6	-	-

Table T: Frequency of occurrence of food items in the stomachs of largemouth and smallmouth bass in George and Corrine Lakes during the summer of 1958.

	GEORGE LAKE				CORRINE LAKE	
	Smallmouth Bass		Largemouth Bass		Largemouth Bass	
Number empty	26		15		24	
No. containing food	81		20		21	
Food Items	f	%	f	%	f	%
Fish						
Perch						
- fingl. & yrls.	20	24.7	6	30.0	7	33.3
- larger	-	-	2	10.0	2	9.5
Largemouth Bass						
- fingl. & yrls.	11	13.6	7	35.0	1	4.8
- larger	-	-	-	-	-	-
Unidentified	15	18.5	3	15.0	2	9.5
Crustaces						
Insects - adult						
Odonata	4	4.9	-	-	-	-
Coleoptera	5	6.2	-	-	-	-
Hemiptera	2	2.5	1	5.0	5	23.8
Hymenoptera	2	2.5	-	-	-	-
Ephemeroptera	2	2.5	-	-	-	-
Diptera	-	-	-	-	1	4.8
Unidentified	11	13.6	3	15.0	3	14.4
Insects - immature						
Odonata	20	24.7	-	-	2	9.5
Coleoptera	1	1.2	-	-	-	-
Ephemeroptera	6	7.4	-	-	-	-
Diptera	2	2.5	1	5.0	-	-
Trichoptera	2	2.5	-	-	-	-
Unidentified	2	2.5	2	10.0	1	4.8
Amphipods	2	2.5	-	-	-	-
Decapods	10	12.3	7	35.0	1	4.8
Molluscs	3	3.7	2	10.0	-	-
Annelids	3	3.7	-	-	1	4.8

Table U: Mean weight and length and associated statistics of the muskellunge captured in George Lake from 1956 through 1960.

Mid-date	No.	Mean Weight (g.)	Length mean (mm.)	Length range (mm.)	Length s^2	$t_{.05}s_{\bar{x}}$
1956						
4 May	12	90	266	244 - 287	234	8.6
27 June	61	-	292	170 - 353	729	6.8
9 July	74	124	308	223 - 368	565	5.4
1957						
22 June	29	288	400	348 - 477	1382	13.5
30 June	24	317	416	357 - 483	1449	15.2
12 July	20	318	412	353 - 474	1616	17.5
6 Aug.	28	351	420	365 - 549	2010	16.5
22 Aug.	17	479	451	323 - 607	5370	34.8
19 Oct.	6	330	435	406 - 470	67	5.8
1958						
14 May	34	418	448	354 - 563	6064	26.1
22 June	13	461	470	422 - 565	1805	23.0
6 July	18	445	477	427 - 545	1772	19.5
20 July	18	530	477	421 - 563	2401	22.6
10 Aug.	13	582	508	437 - 566	2798	28.8
1959						
23 May	13	790	541	490 - 588	773	16.8
8 June	7	815	545	495 - 594	933	28.3
22 June	9	755	547	495 - 610	1388	28.6
9 July	7	-	549	515 - 605	1105	30.7
23 July	11	803	558	530 - 625	690	17.7
25 Aug.	5	880	566	547 - 605	581	29.9
1960						
16 June	6	821	568	540 - 628	1338	38.4
25 June	5	808	560	536 - 585	535	28.7
15 July	5	799	557	533 - 587	387	24.5
8 Aug.	3	945	593	584 - 602	81	22.5

Table V: Mean weight and length and associated statistics of the muskellunge captured in Corrine Lake from 1957 through 1960.

Mid-date	No.	Mean Weight (g.)	Length mean (mm.)	Length range (mm.)	Length s^2	$t_{.05}s_{\bar{x}}$
1957						
24 June	14	111	293	272 - 331	261	8.43
4 July	20	114	296	278 - 331	215	6.41
1958						
14 May	39	182	351	313 - 390	299	5.33
21 June	21	209	367	337 - 405	388	8.41
8 July	24	265	382	343 - 484	1418	15.07
24 July	30	289	408	347 - 486	1265	12.72
9 Aug.	20	342	415	336 - 580	2324	21.11
21 Aug.	30	313	403	345 - 494	948	11.00
7 Sept.	21	323	417	348 - 481	958	13.73
1959						
23 May	19	368	423	396 - 480	590	11.70
7 June	35	451	461	395 - 604	2378	16.70
23 June	22	425	441	371 - 487	874	13.10
23 Aug.	12	614	497	433 - 631	239	9.83
1960						
21 June	8	923	543	446 - 605	3208	48.01
10 July	6	1114	565	409 - 818	16960	144.28
17 July	7	1344	591	480 - 851	17741	123.18
17 Aug.	5	-	589	559 - 635	1095	41.11

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