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A STUDY OF NATIVE MUSKELLUNGE POPULATIONS IN EASTERN KENTUCKY STREAMS

by

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C O N T E N T S

A B S T R A C T

Native populations of muskellunge (Esox masquinongy ohioensis) *eleven Kentucky streams were investigated during 1967-1971 in respect to the following: the size and structure of such populations; the minimum size of the musky at maturity; the time, places, and duration of musky spawning; the success of reproduction and the survival of young musky; the growth rate; and an evaluation of factors limiting musky populations. Musky were collected by use of electrofishing gear, sodium cyanide, and hoop nets. Musky were usually found to occur at rates of 1.5 to 2.0 pounds per acre of pool habitat. And population sampling showed that musky comprised 5.4% of the existing fish weight at such pools. Young-of-year musky generally occurred at a rate of about one fish per every 2.0 acres of pool habitat; sub-legal musky (10.5 to 29.9 inches) occurred at rates of about one per every 2.0 to 2.5 acres of pool habitat; and, legal musky occurred at rates of about one per every 12 to 14 acres of pool habitat. Musky in the streams generally spawned at Age IV. The average length of musky at Age IV was 29.4 inches, and the prevailing 30-inch size limit protected most musky through their first spawning season. As far as could be determined, spawning took place at those shallow waters located at either the upper or lower ends of low-gradient pools. Musky began their initial pre-spawning movements near the end of March. Musky generally spawned during the last half of April or early May when water temperatures were averaging 55°-60° F. Adult musky made post-spawning movements and, by June, they were found as far as 12 miles from their spawning habitat. Growth in length as calculated by the Lee Method was 10.4 inches at Age I, 18.0 inches at Age II, 24.4 inches at Age III, 29.4 inches at Age IV, 32.7 inches at Age V, and*

35.5 inches at Age VI. Tagging studies showed that about 33% of all tagged musky were creeled within a year after tagging. Prevailing springtime water temperatures and discharges evidently had a decided impact on musky reproduction success, with low discharges and seasonable temperatures during late April and early May being favorable, and high discharges and low temperatures during the same period being unfavorable. A number of collected musky were removed from the study streams for use as broodstock at a state hatchery. The final activity involved a determination of the amount of musky stream habitat present in the state. As of 1974, Kentucky had 14 streams with appreciable musky populations, and such streams provided about 6,600 acres of musky pool habitat. Several other streams had either small, remnant, or extinct musky populations. The available evidence indicated that considerable musky stream habitat in the state had been destroyed or degraded by the impoundment and/or pollution of musky streams. It was recommended that data from this investigation be used for the purpose of abating or litigating further encroachments on musky stream habitat. It was also recommended that most musky streams in the state receive maintenance stockings of large musky fingerlings. The recommended stocking rate for most musky streams was one fingerling per every two acres of pool habitat, but stocking rates for a few streams could be as high as one fingerling per acre of pool habitat. Maintenance stockings were recommended on the basis that certain environmental factors limit inherent musky recruitment at the streams.

INTRODUCTION

The geographic subspecies of muskellunge found in Kentucky is the Ohio muskellunge, Esox masquinongy ohioensis. Clark (1941) stated that musky were present in several eastern Kentucky streams including North Fork of Triplett Creek, Beaver Creek, Kinniconick Creek, and Tygarts Creek. Clay (1962) reported that musky were present in the Kentucky, Licking, and Green River systems as well as Kinniconick Creek and Tygarts Creek. Until 1967, no scientific work concerning the life history of musky had been done in Kentucky and a review of Kentucky Fisheries Division publications revealed that less than a dozen musky had been collected by division personnel. Parsons (1959) had studied the life history of muskellunge in Tennessee streams and his work provided the most applicable basis for musky management in Kentucky.

Actually, prior to 1967, little management work with musky had been accomplished in the state. The only musky stocking occurred in 1966, when 25,000 one-inch fry were placed into Lake Cumberland; these fry were obtained from West Virginia. In the years before 1952, Kentucky had either no musky size limit or an 18-inch limit. From 1952 to 1967, there was no size limit. And, in early 1967, the state adopted a 30-inch limit.

Two factors prompted the musky studies project. First, the impoundment and/or pollution of many musky streams appeared to be resulting in a declining statewide musky population. Secondly, the state was planning a fingerling musky production and stocking program. In order to evaluate musky habitat degradation and to efficiently use hatchery-reared musky, more knowledge of the musky's life history was needed.

This project was initially set up to determine:

1) the size and structure of the musky population in each of several study streams,
2) the minimum size of musky at maturity,
3) the time, places, and duration of spawning,
4) the success of reproduction and the survival of young musky,
5) the growth rate,
6) any possible physical, chemical, or biological factors which may limit musky populations in the study streams.

Another project goal was to determine what effect the impoundment of Cave Run Reservoir on the Licking River would have on musky reproduction and fry survival. Unfortunately, the impoundment of Cave Run Lake was delayed until 1974 and the above goal had to be abandoned.

The original project (1967) included six study streams: Kinniconick Creek, Licking River, North Fork of Triplett Creek, Beaver Creek, North Fork Creek, and Red River. Later, the Little Sandy River (1969) and Tygarts Creek (1970) were added; these two were primarily added so that more musky and thereby more data could be collected. None of the above listed streams was adversely affected by coal-mining pollution; therefore, Big Goose Creek (1969) was added so that a musky stream receiving coal-mining pollution could be studied. Sexton Creek was added in 1970 because it was an unpolluted musky stream located near Big Goose Creek and could therefore serve as a comparison stream with Big Goose Creek. Unfortunately, Sexton Creek also became polluted by coal-mining wastes in 1970. As a result another musky stream, Sturgeon Creek, was added in 1971 to serve as a comparison stream with both Big Goose Creek and Sexton Creek.

During the project years, three management-oriented jobs were incorporated into the project. The first (1970, 1971) involved collecting musky from the study streams and transporting them to temporary holding ponds so that they could later be transferred to Minor Clark Hatchery as a native musky broodstock. The second (1970), involved evaluating musky fry stockings since such fry introductions continued during the years of the project. The last (1972) dealt with tabulating the number of miles and acres of musky pool habitat present in every native musky stream in the state so that a basis could be evolved for later stream maintenance stockings of fingerling musky.

M E T H O D S

Selection of Study Stations

Each stream was first visited with the aid of county conservation officers. Then study stations were selected for fish population studies, physicochemical studies, and zooplankton sampling studies.

Fish population study stations were selected on the basis of two principal criteria: first, that the study waters be considered by the conservation officers as being at least nominal musky waters; and, that the study waters be accessible in regards to a boat-mounted electrofishing unit. In regards to the first criterion, all study waters selected were pools generally having depths averaging at least three feet deep and generally having lengths of one-fifth mile or longer. Relating to the second criterion, we generally studied every accessible pool on each study stream, even up to the point of considering accessibility as meaning that the electrofishing boat might have to be carried a short distance to the stream.

Physico-chemical sampling stations had to be located at riffles so that stream discharges could be efficiently sampled. Such stations also had to be readily accessible throughout the year. After all readily-accessible riffle areas were known, we then selected the available area which most closely approximated the mid-length of each stream.

Zooplankton sampling studies were not started until 1968, and then zooplankters were studied only in their relation as being a food source for musky fry. By 1968, we had a fair idea where musky fry might be found in the study streams and consequently zooplankton sampling stations were selected at suspected musky fry habitats, i.e., the shallow areas of pools.

Fish Population Studies

A project prerequisite mandated that any fish population sampling techniques employed should enable the collection of musky but should also render as little harm to the collected musky as possible. Sodium cyanide and electrofishing were used for fish sampling.

Sodium Cyanide Sampling

In each sodium cyanide study, 100 to 300 feet of a study pool were blocked off with 1/2-inch-mesh block nets. The size of each enclosed area was determined by measuring its length and width with a steel tape and then soundings were made to determine the average depth.

The necessary amount of sodium cyanide and the manner of distributing that amount were learned largely by experience. The amount used depended on: 1) the acre-feet of water to be sampled, and 2) the prevailing water temperature. At the following water temperatures, the corresponding rates of application were necessary to sufficiently affect all species throughout each study area:

Surface water temperature (°F.)	Application rates (ppm)
68-76	1.0-1.5
55-65	1.5-2.0
50-55	2.0-2.5
40-50	2.5-3.0

In distributing the chemical, the necessary weight of cyanobriks (97% NACN) was placed in dip nets and towed through the water. If stream flows were visibly noticeable, the chemical was distributed in a narrow band paralleling the upper net. If no appreciable flow was apparent, the chemical was distributed throughout the study area except in that area just above the lower net. Usually, the immediate area of distribution was stirred utilizing the wake action of the boat's motor to achieve better overall chemical distribution.

Muskies collected were processed (measured, weighed, tagged, and scale sampled) immediately and quickly released a reasonable distance upstream from the study area. Other fishes were measured and weighed at the end of each study and survivors were returned to the stream. After the study, the entire sample area was thoroughly stirred to dilute the chemical over a somewhat larger area.

While it is probably generally true that sodium cyanide does not provide as complete a quantitative sample as rotenone (Charles, 1964), our sodium cyanide studies were generally satisfactory in terms of quantitative sampling without appreciable downstream kills. Initial sodium cyanide studies were attempted on Licking River and Red River but prevailing current velocities made it difficult to correctly distribute the chemical and consequential downstream kills occurred; as a result, further river studies were regarded as infeasible.

By 1970, the author believed that sodium cyanide posed too much of a health risk to the project crew and therefore the project use of sodium cyanide was discontinued.

Electrofishing

The electrofishing unit was mounted on a 16-foot, square-end aluminum boat having a 40-inch guard rail at the bow. A Homelite, 230-volt AC, 110-volt DC, generator served as a power source. Output was controlled by a variable-voltage transformer (Variac) which was in turn controlled by a 12-volt relay system. Eight electrodes were attached to a forward boom and one electrode was attached to a man-held "probe". The probe consisted of a 12-foot fiberglass pole with a 2-foot circular section of copper mounted at the end. A microswitch on the probe was part of the 12-volt relay system and enabled a rapid output shutdown.

This electrofishing unit required a 3-man crew. The boat operator manipulated the generator and control box. At the bow, one man netted fish. At his side, the third man held the probe and maneuvered it so that brushy areas along the stream banks could be efficiently sampled.

Shoreline electrofishing was conducted along the entire length of both banks of each study pool. With few exceptions, the perimeter of each pool was shocked twice. At the wider pools, we occasionally electrofished the mid-water areas but were generally successful only in the sense that we apparently sometimes drove musky toward the banks where they could be collected on the second perimeter trip. Captured muskies were placed in the live well of the boat. To better insure survival, most musky were processed immediately and released.

Throughout the project, it was apparent that electrofishing success was more limited at the wider, deeper study pools, e.g., at Kinniconick Creek, Red River, and Licking River. During 1969-1970, an "intensive" electrofishing method was employed at Kinniconick Creek. This method involved the partitioning off of short stream sections (300-600 feet long) with 1/2-inch-mesh block nets; the enclosed area was then thoroughly electrofished three or more times. The same technique was tried at Licking River but leaves and debris carried by the prevailing current continuously fouled the block nets making the effort too consuming to be worthwhile.

On one occasion (1971), three electrofishing units were employed at a large pool on Kinniconick Creek. The units were operated in parallel courses with a unit along each bank and one in the mid-water area.

Spawning Studies

Methods used to capture adult musky during the spawning season included using hoop nets with single leads, hoop nets with leads stretched to each bank entirely blocking the stream width, trammel-netting, and electrofishing. As would be expected, high spring discharges generally limited the extent of spawning studies.

The author presumed, based on the literature (Clay, 1962), that Licking River musky must often use the tributary streams, i.e., North Fork of Triplett Creek, North Fork Creek, and Beaver Creek, as spawning grounds. Therefore, netting efforts were concentrated at the lower reaches of the tributary streams. Hoop nets with single leads were fished both day and night at Beaver Creek in 1967. Such netting was not particularly successful and in 1969 trammel netting was carried out at North Fork of Triplett Creek, North Fork Creek, and Beaver Creek. Three-inch bar mesh trammel nets were fished from bank to bank both day and night. Trammel netting yielded only one musky which died and such netting was discontinued after 1969. During 1970-1971, hoop nets with wing leads stretched to each bank were fished at North Fork Creek and Beaver Creek. Such nets were fished continuously day and night as long as discharges were suitable.

Electrofishing as described (p. 8) was conducted during the 1968-1971 spawning seasons. Pools were shocked on Kinniconick Creek, Licking River, North Fork of Triplett Creek, North Fork Creek, Beaver Creek, and Red River.

All muskies captured during the spawning season were measured, weighed, scale sampled, tagged, checked for sex and degree of ripeness, and released. Since there was small chance that the project crew would actually observe musky spawning, the author queried all possible county conservation officers, local residents, and musky fishermen as to whether they had observed spawning and, if so, the locale, time, and events of spawning.

In order to evaluate the success of reproduction, we conducted searches for musky fry with a seine during 1968-1969 at several study streams. Seining for musky fry was completely unsuccessful. During 1969-1971, project personnel quietly waded several suspected fry habitats and were successful in collecting several musky fry with dip nets.

During 1967, searches for musky fingerlings were conducted by spot-sampling with sodium cyanide; the method was unsuccessful. Summer and fall fish population studies (p. 6) yielded information regarding the survival of the various musky year classes.

Age and Growth Studies

Analytical methods were employed to determine the growth in length and the length-weight relationship of musky in the study streams. Growth was further checked by tagging studies. And, as far as possible, checks were made on the food habits of musky.

A total length, weight and scale sample were obtained from each musky collected during fish population studies and spawning studies. Length was measured to the nearest 0.5 inch and weight to the nearest 0.01 pound. Scales were taken from that region just posterior to the operculum and lying between the lateral and mid-dorsal lines. Scales, just slightly wet, were mounted between glass slides and read with the aid of an Eberbach microprojector at a magnification of 42X.

Growth in length was determined by the Lee Method (Lagler, 1956) which introduces a correction factor to the direct proportion method. To determine the correction factor, the author extrapolated the regression line represented by plotting the scale measurement against the body length (see Rounsefell and Everhart, 1953). Lagler (1956) states that the "age and length distribution of the sample must influence estimation of the constant (i.e. correction factor)". The author attempted to reduce the bias caused by unequal age distribution of the sample by arranging samples into eight age groups of 0 through VII. The average anterior scale radius and the average total body length were found for each age group. The regression of the average total body length on the average anterior scale radius was determined by the method of least squares (see Goulder, 1952). The resultant correction factor was substituted into the formula $L' = a + S'/S\ (L-a)$ where:

L' = length of fish at annulus
a = correction factor
S' = length of scale radius at annulus
S = length of total scale radius
L = total fish length

The length-weight relationship was determined as described by Lagler (1956) utilizing the equation Log W = log a + n Log L where W equals weight, "a" and "n" are constants, and L equals total length.

During 1967-1971, tagging generally consisted of clamping metal clip-on tags at the anterior insertion of the dorsal fin. During 1969 and 1970, musky were also tagged with anchor tags using the Floy tagging gun (see Dell, 1968). Anchor tags were inserted into the dorsal musculature just below the dorsal fin. Overall, the anchor tags seemed to result in more fish injury and less tag returns than did the metal tags and anchor tag use was discontinued after 1970. Throughout the project many musky, especially the smaller ones, were marked only by fin-clipping. Fin clipping was more-or-less adequate for the project studies but provided no fishermen tag returns.

Stomach contents were examined for those few musky which died as a result of project studies. During 1968, a stomach pump similar to that used by Seaburg (1957) was utilized for a short time but was abandoned to avoid overhandling musky.

Physical-Chemical-Biological Studies

Physical characteristics measured for the study streams included gradient, discharge, temperature, turbidity, and conductivity. Chemical parameters studied were dissolved oxygen, total alkalinity, and pH. Biological studies involved zooplankton sampling during that time period when musky fry were suspected to be in the zooplankton-feeding stage.

Stream gradients were determined by the use of topographic maps and a topographic map measurer. Stream discharges were obtained by using a current meter. A conductivity meter was used to measure conductivities. A Hach colorimeter was employed to determine turbidity and pH. Dissolved oxygen was measured by the azide modification of the Winkler method. And, total alkalinities were determined by titration with bromcresol green-methyl red as an indicator.

Physico-chemical studies including discharge, temperature, turbidity, dissolved oxygen, total alkalinity and pH were conducted once a month from March, 1967 through February, 1969 at one station on each of the following streams: North Fork of Triplett Creek, North Fork Creek, Beaver Creek, and Kinniconick Creek. Similar studies were conducted once a month from January, 1968, through December, 1968, at Red River and Licking River. Also, such studies were conducted quarterly during 1969 at Big Goose Creek and Little Sandy River.

Zooplankton samples were collected during May and early June for the years 1968-1971. Samples were obtained at two stations on each of the following streams: North Fork of Triplett Creek, North Fork Creek, Beaver Creek, and Kinniconick Creek. During 1968, zooplankters were sampled by the sand filtration method as described in Standard Methods for the Examination of Water and Wastewater (1965). So few zooplankters were collected by this quantitative method that it became necessary to abandon the method. Rather, a more practicably comparative but less strictly quantitative method incorporating the use of a plankton net was adapted. At each station, a Ward's coarse plankton tow net was towed through 30 feet of shallow pool waters with the entire net always submerged. Each sample was preserved with formalin in a separate vial. At the lab, zooplankters were enumerated by the use of field counts employing a compound microscope at 100X magnification and a Sedgewick-Rafter counting cell. Zooplankters counted included cladocerans, copepods, nauplii larvae, annelids, aquatic insect larvae, and the larger rotifers.

Management Activities

Procurement of Musky Broodstock

During 1970, two temporary holding ponds for musky broodstock were selected in Nicholas County; one pond served as a municipal water reservoir and the other was operated by a 4-H club. During this phase of the project, fishing was not allowed at either pond and owning-agency personnel maintained some degree of guardian care for the ponds. In June, 1970, both ponds were electrofished to check the existing fish populations.

Throughout 1970-1971, many of the musky collected during fish population studies were transferred in a small distribution truck to the holding ponds. Each musky received a dip treatment with malachite green before release.

During 1970-1971, the holding ponds were electrofished several times to check on available forage and on the survival and condition of the stocked musky. An additional holding pond was selected and stocked with musky during 1971; however, the pond developed a serious seepage problem and the stocked musky had to be transferred to the two original holding ponds.

(Further work with the broodstock was conducted under F-31-D and is reported under Development Section - Work Plan Segment 6, dated April 10, 1973.)

Evaluation of Musky Fry Stockings

During the years of the project, all musky fry stocked came from West Virginia, which in turn received them from New York State. Before 1969, musky fry had been stocked into two lakes with established fish populations, i.e., Lake Cumberland (1966) and Dewey Lake (1968); by 1969, the author recommended that musky fry be stocked only into recently-impounded waters. Grayson Lake, impounded during the latter half of 1968, was stocked with 20,000 fry (13 per acre) by the project crew in May, 1969. Lake Linnville, which was impounded in early 1970, was stocked with 20,000 fry (40 per acre) by the project crew in May, 1970. Also, Benson Creek was stocked with 1,000 fry (56 per mile) by the project crew in 1970. Benson Creek was stocked so that the author could evaluate early fry survival.

Electrofishing was conducted at Grayson Lake and Lake Linnville in an effort to recover stocked musky. Grayson Lake was shocked twice during October, 1969, and once during October, 1970; Lake Linnville was shocked twice during November, 1970. The Clifty Creek headwaters of Grayson Lake were seined during October, 1969, also in an effort to locate stocked musky.

Immediately after musky fry were stocked into Benson Creek, the author waded the stream to observe any predation on stocked musky fry. Three days after stocking, and again six days after stocking, the author again waded the stream to locate any surviving musky. During August and September, 1970, division personnel (Jones, 1973) chemically sampled two of the three areas stocked on Benson Creek; in all, they sampled 419 feet, or 0.43 acre.

Over the years, the author contacted local conservation officers in regards to whether any musky were creeled from those waters stocked with musky fry.

Estimation of the Miles and Acres of Musky Pool Habitat present in Native Musky Streams

Survey letters were sent during 1967 to all county conservation officers who might have musky streams in their counties. Appropriate county officers were personally contacted in 1972 to determine the amount of musky waters present in each musky stream in the state. The 1972 survey involved a visit to each musky stream, with county officers providing the following information: the extent of musky range in each stream; and the percentage of that range which was made up of musky pool habitat. Musky range was generally defined as that area from which musky had been creeled. Musky pool habitat was regarded as any substantial pool falling within the general range. Based on five years experience and familiarity with musky streams, the author generalized that musky primarily inhabited pools having a minimum length of 0.2 mile and a maximum depth of at least four feet. During each stream visit, project personnel also measured representative stream widths.

After the stream visits, topographic maps and a topographic map measurer were used to measure the range of musky distribution in each stream as described by local officers. Then, for each stream, the determined miles of range was multiplied by the percentage of musky pool habitat within that range so that the miles of musky pool habitat in each stream could be determined. The miles of musky pool habitat present in each stream was then multiplied by the appropriate average stream width so that the acreage of musky pool habitat in each stream could be tabulated.

During the aforementioned stream visits, officers assisted in locating potential stocking sites and also described any prevalent pollution occurring at musky streams.

F I N D I N G S

Fish Population Studies

Stream population studies were conducted only at suspected musky habitats, i.e., the larger pools in each stream. Therefore, fish population data for each stream cannot be regarded as representative for that stream's entire length. For example, North Fork Creek is 21.4 miles long but musky occur only in the lower 10 miles of stream and are actually concentrated in only 3 miles or 22 acres of musky pool habitat. In this regard, the author has listed, Table 1, p. 18, the total length of each stream, the miles of musky range for each stream, and the miles and acres of musky pool habitat for each stream. The study streams and all fish population sampling stations are mapped on page 19, and the stations are described in Table 2, pp. 20-21.

General Fish Populations

Sodium cyanide studies conducted on six study streams during 1967-1969 yielded the following fish standing crops:

Stream	Acres sampled by NACN	Standing crop (lb/a)
Big Goose Creek	0.63	89.5
Beaver Creek	1.96	35.6
North Fork Creek	2.55	34.7
Red River	1.00	34.0
Kinniconick Creek	5.09	31.6
North Fork Triplett Creek	2.59	25.3

The comparatively low standing crop measured at North Fork of Triplett Creek can be attributed in part to interstate highway construction work along that stream beginning in late 1967 and extending through much of 1968. During construction work, turbidities at this stream averaged almost five times the

Table 1. The total length of each study stream; the miles of musky range for each stream; and, the miles and acres of musky pool habitat for each stream.

Stream	Total length (miles)	General musky range (mile 0 is at the mouth)*	Miles of musky pool habitat	Acreage of musky pool habitat
North Fork Cr.	21.4	mile 0 to mile 10	3	22
N.F. Triplett Cr.	31.8	mile 0 to mile 15	7	76
Beaver Cr.	19.3	mile 0 to mile 7	2	13
Kinniconick Cr.	49.0	mile 0 to mile 38	19	195
Red River	93.5	mile 25 to mile 66	21	168
Licking River	299.5	mile 131 to mile 240	68	783
Little Sandy River	82.5	mile 0 to mile 50	30	400
Tygarts Cr.	87.5	mile 0 to mile 75	43	413
Big Goose Cr. and Collins Fork of Big Goose Cr. **	43.1	mile 0 to mile 33	12	112
Sexton Cr.	23.0	mile 0 to mile 12	4	28
Sturgeon Cr.	33.8	mile 0 to mile 12	5	41

* Range as reported by local conservation officers.

** Big Goose Creek and Collins Fork are combined as one stream unit since Collins Fork is the only tributary to Big Goose Creek which contains a musky population.

preconstruction levels (see Brewer, 1969). In late 1967, this stream's standing crop measured 10 ppa (0.36-acre sample); in June, 1968, the standing crop measured 18.7 ppa (0.83-acre sample); and, in late 1969, the standing crop measured 33.2 ppa (1.40-acre sample). During 1959-1963, Turner (1960, 1963,

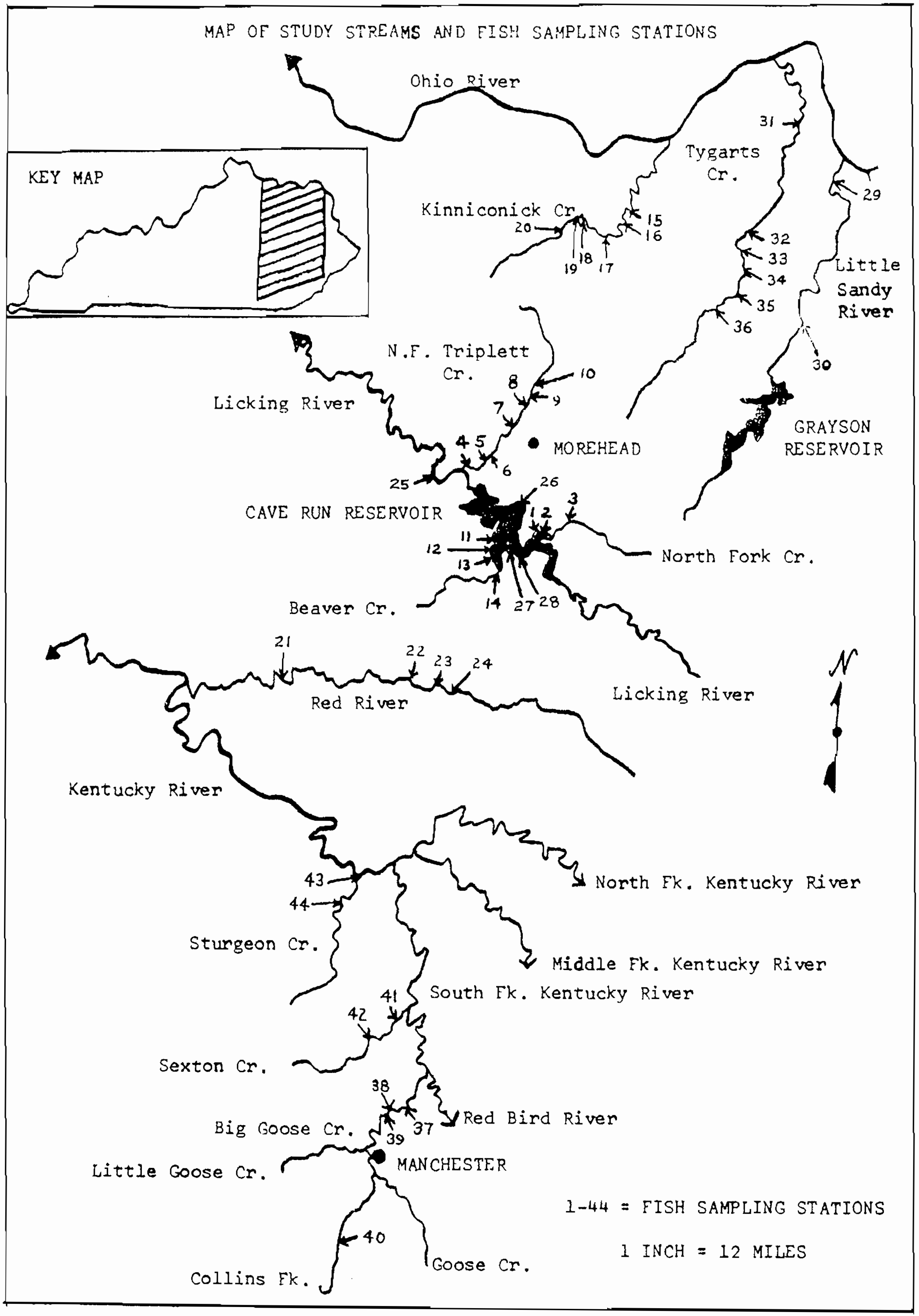

MAP OF STUDY STREAMS AND FISH SAMPLING STATIONS
Ohio River
KEY MAP
Tygarts Cr.
Kinniconick Cr.
Little Sandy River
N.F. Triplett Cr.
Licking River
MOREHEAD
GRAYSON RESERVOIR
CAVE RUN RESERVOIR
North Fork Cr.
Beaver Cr.
Red River
Licking River
Kentucky River
North Fk. Kentucky River
Sturgeon Cr.
Middle Fk. Kentucky River
South Fk. Kentucky River
Sexton Cr.
Red Bird River
Big Goose Cr.
Little Goose Cr.
MANCHESTER
1-44 = FISH SAMPLING STATIONS
1 INCH = 12 MILES
Collins Fk.
Goose Cr.
N

Table 2. Location and description of fish sampling stations.

Stream	Station	Distance from mouth (miles)	Length (miles)	Width (feet)	Acreage
North Fork Creek	1	1.3	0.20	35-55	1.1
	2	2.0	1.12	35-55	6.1
	3	6.0	0.94	30-70	5.3
North Fork of Triplett Creek	4	0.0	0.65	70-80	5.9
	5	5.0	0.47	45-80	3.1
	6	6.0	0.31	50-70	2.3
	7	10.0	0.23	60-85	1.8
	8	13.0	0.44	60-85	3.7
	9	13.5	0.36	50-110	3.9
	10	14.0	0.42	60-110	4.2
Beaver Creek	11	0.4	0.23	30-40	0.9
	12	0.8	0.35	40-60	2.1
	13	2.0	0.36	35-55	1.7
	14	6.0	0.42	30-65	2.2
Kinniconick Creek	15	15.5	0.80	80-150	11.2
	16	17.0	0.89	75-110	10.8
	17	27.0	1.50	75-105	15.6
	18	30.0	0.09	80-110	1.0
	19	32.0	0.32	50-70	2.3
	20	34.0	1.50	55-65	11.8
Red River	21	29.0	0.69	65-75	5.8
	22	50.1	0.70	50-100	5.1
	23	54.3	0.55	50-90	5.0
	24	55.4	0.95	50-90	8.7
Licking River	25	160.0	2.50	90-175	38.0
	26	177.0	1.50	70-135	21.0
	27	184.0	0.90	90-110	10.9
	28	185.0	2.80	90-135	33.0
Little Sandy River	29*	6.5	-	-	-
	30	32.5	1.20	85-125	13.8
Tygarts Creek	31	29.5	0.90	70-110	9.3
	32	48.7	0.97	65-95	8.8
	33	50.1	0.60	60-85	5.1
	34	55.3	0.42	70-100	4.0
	35	59.4	0.70	60-95	6.3
	36	64.8	0.93	50-90	6.8

Table 2. (continued)

Stream	Station	Distance from mouth (miles)	Length (miles)	Width (feet)	Acreage
Big Goose Creek and	37	5.4	0.38	60-85	3.4
Collins Fork of Big	38	6.8	0.50	80-100	5.4
Goose Creek	39	7.5	0.51	70-90	4.1
	40	32.0	0.60	40-60	3.5
Sexton Creek	41	3.5	0.20	40-70	1.3
	42	9.8	0.53	60-90	4.8
Sturgeon Creek	43	0.0	0.47	70-90	4.6
	44	5.0	0.42	60-80	3.5

* The lower part of this river is a continuous pool formed by a navigation dam on the Ohio River.

and 1964) conducted rotenone population studies on the following streams; Tygarts Creek, Licking River, and Little Sandy River. Rotenone studies on Tygarts Creek yielded fish at rates of 39, 72, 89.5, and 134 ppa at four collection sites. At the Licking River, rotenone yielded fish at a rate of 55.4 ppa (0.5-acre sample); and at Little Sandy River, rotenone yielded fish at a rate of 35.6 ppa (2.16-acre composite sample). In summary, the study streams had existing standing crops ranging from 25.3 to 89.5 ppa during the 1960's; and levels of 31 to 56 ppa were predominant.

Sodium cyanide studies conducted at the study streams during 1967-1969 yielded 475.7 pounds of fish from 13.82 acres or at an overall rate of 34.4 ppa. A composite summary of all sodium cyanide studies is presented in the Appendix, Table A-1, pp. 94-95. Fishes dominating the composite chemical sample by weight were redhorses, 23.7%, gizzard shad, 15.6%, longear sunfish, 10.8%, rock bass, 8.1%, bluegill, 5.7%, muskellunge, 5.4%, and spotted bass, 3.8% (black basses as a group comprised 8.1% of the composite sample weight).

The composite A_{T1} value, or percent of weight comprised of harvestable-sized fishes, was 58 (see Charles and McLemore, 1973, for a description of the Kentucky-version of the "legal A_T" or A_{T1}). The only fishes collected having a legal size limit were the musky (30") and the black basses (10"); but the relatively high size limit on musky obviously contributed to a somewhat lowered A_{T1} value. Together, harvestable-sized suckers (12") and shad (8") comprised about 53% of the total harvestable weight and further comprised almost 32% of the total collected fish weight.

During 1967, a total of 12 shallow stream sections composed of riffles and potholes were spot-sampled with sodium cyanide; streams sampled were North Fork of Triplett Creek, Beaver Creek, Kinniconick Creek, and Red River. Of the 1,440 fish collected, 68.5% were cyprinids, 16.7% were centrarchids and 8.0% were percids. The most abundant species collected were, respectively, common shiner, bluntnose minnow, longear sunfish, stoneroller, river chub, rosefin shiner, and rock bass; musky were not collected from such areas.

The 81 fish species collected from the original six study streams during 1967-1971 are listed in the Appendix, Table A-2, pp. 96-98. Less comprehensive fish sampling was conducted at the five appended study streams and a list of fishes collected from each appended stream has been stored in the possession of the Kentucky D-J Coordinator.

Musky Populations

For this report, musky are categorized as follows: legal musky include those fish 30.0 inches or longer; sub-legal musky include fish 10.5 to 29.9 inches long; and young-of-the-year musky which generally included fish less than 10.5 inches long. This categorization generally coincides with the terminology - young, juvenile, and adult - except that in our case, we collected four adult musky which were less than 30 inches long. As regards to musky populations, data were combined wherever possible to depict general conditions, since it was most difficult to obtain sufficient data for each stream and/or year in regards to so uncommon a fish as the musky.

Sodium cyanide studies conducted during 1967-1969 produced quantitative data in regards to musky populations. The physical data associated with sodium cyanide studies are listed in Table 3, p. 24. The number and weight of musky collected from each stream are presented in Table 4, p. 25, and the length and weight of each musky collected during the chemical studies are listed in Table 5, p. 26.

Overall, sodium cyanide studies yielded 14 musky with a composite weight of 25.70 pounds from 1.71 miles, or 13.82 acres of pool habitat. Musky were collected at an overall rate of about eight per mile, or about one per acre of pool habitat. Young-of-the-year and sub-legal musky were respectively collected at rates of one per 2.0 and one per 2.3 acres of pool habitat. Legal musky averaged about one per 14 acres of pool habitat. In terms of weight, musky were collected at an overall rate of 1.86 pounds per acre of pool habitat. In all, musky comprised 5.4% of the total collected fish weight.

Summer and fall electrofishing studies carried out during 1967-1971 provided extensive but somewhat subjective data in regards to musky populations. As would be expected with electrofishing studies, not all muskies sighted were captured. Capture success generally improved over the study years with the percent of capture for each year as follows: 1967 - 43%; 1968 - 77%; 1969 - 87%; 1970 - 82%; 1971 - 87%. Rather than deleting well-sighted but uncaptured musky from the data, the author decided it would be more practical to project into the data estimated lengths and weights for those musky which were raised but not captured. A summary of all summer and fall electrofishing results is presented in Table 6, pp. 27-29. Of the 214 miles of musky pool habitat present in the

Table 3. Physical data associated with NACN studies conducted during 1967-9.

Stream	Study stations sampled*	Acres sampled	Acre-feet sampled	Month sampled	Surface water temperatures (°F)
			1967		
North Fork Cr.	2	0.29	0.84	June	72
N. F. Triplett Cr.	8	0.36	1.19	Nov.	40
Beaver Cr.	12	0.27	1.49	June	69
Kinniconick Cr.	17	0.45	4.95	Nov.	41
			1968		
North Fork Cr.	2,3	1.10	3.58	Oct.	55 - 60
N. F. Triplett Cr.	5,7,10	0.83	2.78	June	70 -76
Beaver Cr.	12,13,14	0.90	3.48	Oct.	48 - 55
Kinniconick Cr.	15,16,17,20	1.26	7.61	Nov.	40 - 45
Red River	22	1.00	-	Oct.	48 - 55
			1969		
North Fork Cr.	2,3	1.16	3.67	Sept.	60 - 65
N. F. Triplett Cr.	5,6,7,8,10	1.40	3.62	Oct.	54 - 60
Beaver Cr.	11,13,14	0.79	2.81	Sept.-Oct.	45 - 65
Kinniconick Cr.	15,16,17,18,20	3.38	19.15	Sept.-Nov.	43 - 72
Big Goose Cr.	38	0.63	2.35	Oct.	60 - 65
Total		13.82			

* The study stations' locations are listed on p. 20, and mapped on p. 19.

Table 4. Number and weight of musky collected by sodium cyanide sampling at each of six study streams during 1967-1969.

Stream	No. of studies	Stream miles sampled	Acres sampled	No. of musky collected	Wt. of musky collected (lbs.)	Lbs. of musky collected per acre	% of total fish wt. which was comprised of musky
North Fork Creek	10	0.46	2.55	6	6.35	2.49	7.2
N.F. Triplett Creek	10	0.30	2.59	2	2.46	0.95	3.8
Beaver Creek	9	0.36	1.96	1	0.19	0.10	0.3
Kinniconick Creek	12	0.45	5.09	3	13.02	2.56	8.1
Red River	1	0.08	1.00	2	3.68	3.68	10.6
Big Goose Creek	2	0.06	0.63	0	0.00	0.00	0.0
Totals	44	1.71	13.82	14	25.70	1.86	5.4

Table 5. Lengths and weights of the 14 musky collected from 44 NACN studies conducted on six study streams during 1967-69.

Total length (in.)	Weight (lbs.)	Stream	Total length (in.)	Weight (lbs.)	Stream
9.3	0.12	North Fork Creek	17.0	0.84	North Fork Creek
9.5	0.12	North Fork Creek	21.0	1.72	Kinniconick Creek
9.5	0.15	North Fork Creek	22.0	2.32	N.F. Triplett Creek
9.5	0.15	North Fork Creek	26.0	3.52	Red River
9.8	0.14	N.F. Triplett Creek	29.0	4.94	North Fork Creek
10.0	0.16	Red River	29.0	5.30	Kinniconick Creek
10.3	0.19	Beaver Creek	30.4	6.00	Kinniconick Creek

eleven study streams, 31.5 miles or 15% were electrofished at least once during the study years.

At the smaller streams, i.e., North Fork of Triplett Creek, North Fork Creek, and Beaver Creek, electrofishing results for musky compared favorably with sodium cyanide study results except for young-of-the-year musky which were seldom raised by electrofishing. During 1967-1970, a composite total of 119.5 acres of pool habitat was electrofished at the above three streams and 217.0 pounds of musky were collected or at an overall rate of 1.8 ppa. The composite electrofishing studies at the three streams yielded sub-legal musky at a rate of one per every 2.4 acres and yielded legal musky at a rate of one per every 12.0 acres. The 1971 electrofishing results for the three streams were excluded from the above data since many of the musky collected from the

Table 6. Number and weight of musky collected by shoreline electrofishing at eleven study streams during 1967-1971; the lengths and weights of musky which were raised but not collected were estimated and included in these data.

Stream	Year	Study stations sampled*	Miles sampled	Acres sampled	Number of musky collected: y.o.y.	sub-legal	legal	Total weight of musky collected	Pounds per acre of musky collected
North Fork Cr.	1967	2,3	1.90	10.5	0	7	1	31.0	3.0
	1968	2,3	1.90	10.5	1	5	2	32.7	3.1
	1969	2,3	1.83	10.2	0	6	2	27.0	2.6
	1970	1,2,3	2.26	12.5	0	20	0	44.4	3.6
	1971**	2,3	2.06	11.4	0	8	0	24.5	2.1
N.F. Triplett Cr.	1967	5,7,8,10	1.57	12.8	0	2	2	28.0	2.2
	1968	5,7,8,10	1.57	12.8	0	6	1	29.7	2.3
	1969	5,6,7,8,9,10	2.23	19.0	0	0	0	0.0	0.0
	1970	5,6,10	1.20	9.6	0	0	0	0.0	0.0
	1971	4,5,6,9	1.79	15.2	0	4	1	18.7	1.2
Beaver Cr.	1967	11,13,14	1.01	4.8	0	1	2	20.0	4.2
	1968	12,13,14	1.13	6.0	0	0	0	0.0	0.0
	1969	11,13,14	1.01	4.8	0	0	0	0.0	0.0
	1970	12,13,14	1.13	6.0	0	3	0	4.2	0.7
	1971**	12,13,14	1.13	6.0	0	6	0	13.6	2.3
Kinniconick Cr.	1967	15,16,17,19,20	5.01	51.7	0	4	4	56.0	1.1
	1968	15,16,17,19,20	5.01	51.7	0	3	5	65.0	1.3
	1969	15,16,18,19	2.10	25.3	1	0	1	9.0	0.4
	1970	15,16,18,19,20	3.60	37.1	0	2	2	29.9	0.8
	1971	15,16,17,18,19,20	5.10	52.7	0	2	0	4.9	0.1

Table 6. (continued)

Stream	Year	Study stations sampled*	Miles sampled	Acres sampled	Number of musky collected: y.o.y.	Number of musky collected: sub-legal	Number of musky collected: legal	Total weight of musky collected	Pounds per acre of musky collected
Red River	1967	22,23,24	2.10	18.8	0	3	1	13.0	0.7
	1968	22,23,24	2.10	18.8	1	3	0	10.0	0.5
	----	---	----	----	-	-	-	----	---
	1970	21,22,23,24	2.79	24.6	0	3	2	21.9	0.9
	1971**	21,22	1.39	10.9	0	1	0	5.5	0.5
Licking River***	1967	25,26,28	6.80	92.0	0	3	3	----	---
	1968	25,26,28	6.80	92.0	1	0	4	----	---
	1969	27	0.90	10.9	2	0	0	----	---
	1970	27,28	3.30	37.1	0	4	2	36.8	1.0
	1971**	27,28	3.30	37.1	0	6	0	18.0	0.5
Little Sandy River	1969	30	1.20	13.8	0	0	0	0.0	0.0
Tygarts Cr.	1970	31,32,33,34,35,36	4.52	40.9	0	5	2	41.4	1.0
	1971**	31,32,33,34,35,36	4.52	40.9	0	4	3	45.4	1.1
Big Goose Creek and	1969	37,38,39,40	1.99	16.4	0	3	0	3.0	0.2
Collins Fork of	1970	37,38,39,40	1.99	16.4	0	0	0	0.0	0.0
Big Goose Creek****	1971	37,38,39,40	1.99	16.4	0	0	0	0.0	0.0
Sexton Cr.	1970	41,42	0.73	6.2	0	0	0	0.0	0.0
	1971	41	0.20	1.3	0	0	0	0.0	0.0
Sturgeon Cr.	1971	43,44	0.89	8.1	0	3	0	6.0	0.7

* Because of varying accessibility, it was not possible to electrofish the same study stations at every stream each year.

** At these streams, some of the musky collected during 1970 were removed from the streams and placed in holding

Table 6. (continued)

ponds for future hatchery broodstock; therefore the 1971 electrofishing studies sampled artificially altered musky populations (i.e., depleted populations).

*** Since few musky were actually captured from the Licking River during 1967-1969, the author refrained from making estimates of the weight of musky raised by electrofishing.

**** No musky were collected from the 3 study pools on Big Goose Creek during 1969; however, 3 yearling muskies weighing a total of 3.00 pounds were collected from a 3.5-acre pool on Collins Fork of Big Goose Creek.

streams in 1970 were removed from the streams as part of a broodstock collection effort. Each of the above three streams is a tributary to the Licking River and each serves as a spawning ground for Licking River musky (see p. 33). In essence, each tributary also serves as a rearing area for young and juvenile musky; and, when muskies in the tributaries approach adult size they surely tend to move into the larger, deeper pools present in the Licking River.

At the larger streams, e.g., Kinniconick Creek, Tygarts Creek, Red River, and Licking River, shoreline electrofishing was relatively ineffective because of the size (width and depth) of the associated study pools. Electrofishing studies at these streams generally yielded musky at rates of only 0.5 to 1.0 pound of musky per acre of pool habitat. Sodium cyanide study results at Kinniconick Creek and Red River indicated substantially higher musky poundage rates for these two streams than did shoreline electrofishing results; and, although sodium cyanide studies were not conducted at Tygarts Creek and Licking River, it was assumed that electrofishing results were also limited at these streams[1].

[1] As of 1973, there were about 34 miles or 433 acres of musky pool habitat present in the tailwaters of Cave Run Dam on the Licking River. During 1973-1974, division hatchery personnel collected and removed 28 legal-sized musky from the tailwaters immediately below Cave Run Dam. By back-calculation, the author determined that all of these collected musky would have been legal-sized during the spring of 1973 and their total approximate weight at that time would have been 316 pounds. This weight alone would have accounted for somewhat over 0.7 pound of musky per acre of pool habitat in the tailwaters as of the spring of 1973. In addition, the author estimated that fishermen creeled about 20 legal musky from the tailwaters during early 1973. The total of the above collection and creel would account for somewhat over one pound of legal musky per acre of pool habitat in the tailwaters during early 1973. Considering uncollected and/or uncreeled legal musky plus any sub-legal musky present in the tailwaters during early 1973, one would assume that musky in the Licking River occurred at poundage rates similar to those determined for the smaller study streams.

During 1969-1971, several efforts were made to improve upon the electrofishing technique. These efforts were concentrated at Kinniconick Creek where some of the project's widest and deepest study pools were located and where shoreline electrofishing success seemed to be the most limited. During 1969-1970, intensive electrofishing (see p. 9) was conducted at study pools #17 and #20 on Kinniconick Creek. In all, 2.13 miles or 23.0 acres were sampled; and, two legal and one sub-legal musky were collected. Intensive electrofishing studies during 1969-1970 yielded musky at a rate of 1.0 pound per acre, whereas shoreline electrofishing studies at this stream during 1969-1970 yielded musky at an average rate of only 0.6 pound per acre of pool habitat. During 1971, three electrofishing units were employed at study pool #15 on Kinniconick Creek. From 0.8 mile or 11.2 acres of pool, we collected one musky weighing 23.85 pounds and raised at least three other muskies, one being legal-sized and two being sub-legal. The actual weight collected accounted for 2.1 pounds of musky per acre and the total estimated weight raised and/or collected would have accounted for at least 3.5 pounds of musky per acre. During the summer of 1971, regular shoreline electrofishing at this pool yielded only one sub-legal musky weighing 2.28 pounds or a rate of 0.2 pound of musky per acre. A composite summary of the 1969-1970 intensive electrofishing studies plus the 1971 multiple-unit electrofishing study on Kinniconick Creek showed that a total of 2.93 miles or 34.3 acres of pool habitat were sampled and musky were raised and/or collected at an estimated rate of 1.8 pounds per acre with legal musky occurring at a rate of about one per 9 acres and sub-legal musky occurring at a rate of about one per 11 acres (shoreline electrofishing studies, sodium cyanide studies, and creel reports indicated a downtrend in musky population numbers at this stream during the late 1960's, due apparently to low recruitment over that period).

Determinations of the size and structure of musky populations in the larger streams were difficult to access due to the lack of sufficient reliable data. Indications were that musky in these streams occurred at poundage rates nearly similar to those more accurately determined for the smaller streams. As shown previously, musky poundage at the smaller streams was comprised primarily of young and sub-legal musky; this was less the case at the larger streams where young and sub-legal musky were not quite so abundant and where legal musky were somewhat more abundant than at the smaller streams. At the larger streams, there were indications that legal musky often occurred at rates of one per every 7-10 acres of pool habitat.

Big Goose Creek, Sexton Creek, and Sturgeon Creek are all relatively small musky streams located in the upper Kentucky River drainage. Several fish kills attributed to coal-mining wastes occurred at Big Goose Creek and Sexton Creek during the period 1969-1973, while Sturgeon Creek remained unpolluted. Shoreline electrofishing studies at these three streams during 1969-1971 showed at least a fair musky population in Sturgeon Creek but showed almost no musky population at either Sexton Creek or Big Goose Creek. Such studies did show a small musky population at Collins Fork of Big Goose Creek, which was the only sizeable tributary to Big Goose Creek which remained unaffected by pollution during 1969-1973.

Spawning Studies

During the spawning seasons of 1967-1971, extensive efforts were conducted to collect adult musky by netting, Table 7, p. 34, and by electrofishing, Table 8, p. 35. The results of these efforts are presented in Table 9, pp. 36-39.

Pre-Spawning Movements of Musky

Netting and electrofishing efforts showed that musky in the Licking River exhibited pre-spawning movements in search of suitable spawning habitat. Evidently, some of the musky in the Licking River remained in the river to spawn, while others ascended tributaries, e.g., North Fork of Triplett Creek, North Fork Creek, and Beaver Creek, for spawning. Generally, initial movement into the tributaries began during the last week of March when water temperatures typically began warming towards 50°F.; netting efforts at the tributaries during the first three weeks of March, with prevailing water temperatures in the upper 30s and low 40s, yielded no musky[2]. During the first 2-3 weeks of April, the streams generally had temperatures warming towards the low and middle 50s and during this time the greater part of musky movement into the tributaries transpired. On April 20, 1970, a 30.3-inch musky was caught in a hoop net at the lower reaches of North Fork Creek, and on April 14, 1971, the same fish (but 32.0 inches long) was recaptured in a hoop net at the selfsame site.

As far as could be determined, the range of musky movement into the tributaries was limited to the downstream low-gradient section of each tributary.

[2] Electrofishing efforts by division hatchery personnel during March and April of 1973-1974 immediately below Cave Run Dam on the Licking River showed a limited concentration of musky below the dam during the first three weeks of March with a much larger concentration during later March and early April.

Table 7. Time periods for springtime netting efforts at the study streams.

Year	Netting method	Streams netted	Location of nets	Time periods of netting
1967	Hoop nets with single leads	Beaver Creek	Lower six miles of each stream	Mar. 28-30 Apr. 4-6 Apr. 20-21
1969	Trammel nets	Beaver Creek North Fork Creek N.F. Triplett Creek	Lower six miles of each stream	Mar. 4-7 Mar. 12-14 Mar. 18-25 Apr. 1-5 Apr. 7-9
1970	Hoop nets with leads stretched to each bank	Beaver Creek North Fork Cr.	Lower two miles of each stream	Mar. 9-12 Mar. 15-16 Mar. 23-30 Apr. 9-23
1971	Hoop nets with leads stretched to each bank	Beaver Creek North Fork Cr.	Lower two miles of each stream	Mar. 22 - Apr. 16

Time of Spawning

During 1970, two very ripe females and two nearly ripe females were collected from North Fork Creek on April 22. Evidently, these fish should have spawned during the last week of April. Local residents and fishermen reported several sightings of musky spawning at the study streams about May 1, 1970. On May 6, 1970, a pool on Kinniconick Creek was electrofished and, at the upper shallow reaches of this pool, two muskies were stunned but not collected; the muskies were apparently swimming side by side when stunned and evidently were spawning. From the above, musky spawning at the streams during 1970 occurred during the last week of April and the first week of May. Over that time period, daily water temperatures averaged 55-63°F. with the overall average being 59°F.

Table 8. Study pools electrofished during the musky spawning seasons of 1968-1971.

Year	General time period	Streams sampled	Study pools sampled*
1968	Apr. 2 - May 8	N.F. Triplett Cr.	5, 7, 9, 10
		North Fork Cr.	2
		Beaver Creek	12
		Kinniconick Cr.	17, 20**
		Licking River	28
1969	Apr. 8 - May 1	N.F. Triplett Cr.	5, 10
		North Fork Cr.	2**, 3
		Beaver Cr.	13
		Kinniconick Cr.	17
		Red River	22
		Collins Fork of Big Goose Cr.	40
1970	Apr. 7 - May 6	N.F. Triplett Cr.	5, 7, 10
		North Fork Cr.	1, 2, 3
		Beaver Cr.	13
		Kinniconick Cr.	16, 18**, 19**, 20**
1971	Apr. 20 - Apr. 28	N.F. Triplett Cr.	5
		North Fork Cr.	2**, 3
		Kinniconick Cr.	19

* See page 20 for a description of all study pools.

** Study pools so marked were electrofished twice during the respective spawning season.

Table 9. Adult muskies collected during the spawning seasons of 1967-1971.

Collection date	Method of collection	Stream	Pool*	Length (inches)	Age	Prevailing mean daily water temperatures (°F.)	Spawning condition
3/27/1967	Hook-and-line fishing	Beaver Creek	11	39.0	-	46-54	Reportedly eggs inside of fish but eggs could not be stripped
4/6/1967	Hoop-netting	Beaver Creek	11	31.5	4	55-58	Stripped a small quantity of milt
4/24/1968	Electrofishing	Kinniconick Creek	20	35.0	6	57-59	Could strip neither eggs nor milt
4/28/1968	Hook-and-line fishing	North Fork Creek	8	32.0	4	54-56	Reportedly had eggs inside of fish
5/8/1968	Electrofishing	Licking River	28	31.0	4	58-61	Relatively large quantity of milt stripped
4/1/1969	Trammel netting	North Fork Triplett Cr.	-	36.0	6-7	40-42	Eggs inside of fish but eggs still firmly attached to egg sacs
4/8/1969	Electrofishing	North Fork Creek	2	31.5	5	52-58	Eggs inside of fish but eggs could not be stripped
4/8/1969	Electrofishing	North Fork Creek	2	35.0	6	52-58	Stripped a small quantity of milt
4/8/1969	Electrofishing	North Fork Creek	2	37.0	6-7	52-58	Stripped a relatively large quantity of milt, fish very ripe

Table 9. (continued)

Collection date	Method of collection	Stream	Pool*	Length (inches)	Age	Prevailing mean daily water temperatures (°F.)	Spawning condition
4/10/1969	Electrofishing	North Fork Triplett Cr.	5	34.0	5	54-58	Stripped a small quantity of milt
4/29/1969	Electrofishing	North Fork Creek	2	39.0	9	58-59	Stripped a small quantity of milt
3/27/1970	Hook-and-line fishing	North Fork Creek	-	36.5	-	40-43	Reportedly started releasing milt about 3 hours after caught
3/27/1970	Hoop-netting	Beaver Creek	11	33.0	6	40-43	Trace of milt with good pressure applied
4/7/1970	Electrofishing	Kinniconick Creek	19	37.5	7	43-46	Stripped a small quantity of milt
4/13/1970	Electrofishing	North Fork Creek	2	30.5	4	49-54	Stripped a small quantity of milt
4/15/1970	Hoop-netting	Beaver Creek	11	34.0	6	50-54	Stripped a small quantity of milt
4/15/1970	Hoop-netting	Beaver Creek	11	40.0	6	50-54	Female but no eggs could be pressed
4/15/1970	Electrofishing	North Fork Triplett Cr.	5	37.5	7	50-54	Stripped a small quantity of milt
4/20/1970	Hoop-netting	North Fork Creek	2	30.5	4	55-59	Stripped a relatively large amount of milt
4/22/1970	Hoop-netting	North Fork Creek	2	36.0	6	55-60	Very ripe male

Table 9. (continued)

Collection date	Method of collection	Stream	Pool*	Length (inches)	Age	Prevailing mean daily water temperatures (°F.)	Spawning condition
4/22/1970	Hoop-netting	North Fork Creek	2	38.0	8	55-60	Very ripe female; eggs exuded without any pressure
4/22/1970	Hoop-netting	North Fork Creek	2	47.0	12	55-60	Very ripe female; eggs exuded without any pressure
4/22/1970	Electrofishing	North Fork Creek	1	29.0	4	55-60	Relatively large quantity of milt stripped
4/22/1970	Electrofishing	North Fork Creek	1	36.5	6	55-60	Eggs exuded with slight pressure
4/22/1970	Electrofishing	North Fork Creek	1	45.0	11	55-60	Eggs exuded with slight pressure
3/28/1971	Hook-and-line fishing	Beaver Creek	11	43.0	--	39-44	-----
4/6/1971	Found dead near hoop net	North Fork Creek	2	28.0	3	46-48	Eggs inside of fish; egg sacs about 4 inches long
4/13/1971	Hoop-netting	North Fork Creek	2	38.0	7	46-54	Female but no eggs could be pressed.
4/14/1971	Hoop-netting	North Fork Creek	2	32.0	5	50-56	Stripped a very small quantity of milt
4/15/1971	Hoop-netting	North Fork Creek	2	34.0	5	52-56	Ripe female; eggs exuded without pressure
4/26/1971	Electrofishing	North Fork of Triplett Cr.	5	37.0	8	56-62	Stripped a small amount of milt

Table 9. (continued)

Collection date	Method of collection	Stream	Pool*	Length (inches)	Age	Prevailing mean daily water temperatures (°F.)	Spawning condition
4/26/1971	Electrofishing	North Fork Triplett Cr.	5	45.0	-	56-62	Female; appeared to be spent
4/27/1971	Electrofishing	North Fork Creek	2	33.0	5	56-62	Female; could press some eggs but appeared to be spent

* See page 20

During 1971, a ripe female was collected from North Fork Creek on April 15, and by April 26-27, two apparently spent females were collected from the study streams. The limited available evidence indicated that musky spawned about the third week of April in 1971; at that time, daily water temperatures averaged 55-62° F., with the overall average being 57° F.

Considering temperature records for the study streams (see Table 20, pp. 62-67), it seems evident that musky in the study streams typically spawned sometime during the last half of April and the first week of May, when water temperatures were averaging 55-60° F. When springtime temperatures were unseasonably warm, musky may have spawned during the first half of April[3].

Places of Spawning

During 1970, at Kinniconick Creek, the author briefly sighted two musky which evidently were spawning. The location was at the upper shallow reaches of a sizeable pool. The depth of the spawning area averaged about two feet and the bottom was composed of sandstone-based rubble and bedrock. Spawning, as reported by conservation officers and local residents, usually took place at those shallow waters located at either the upper or lower ends of low-gradient pools. The author inspected most described spawning sites and found that most had some organic matter in the form of decaying leaves and/or rooted aquatic vegetation, and had substrates comprised primarily of rubble and gravel. The character of the described spawning sites varied, however, and some almost lacked organic matter and a very few had substrates with considerable sand or mud or bedrock.

[3] On April 1, 1973, division hatchery personnel collected a nearly-ripe female and a ripe male from a hoop net on North Fork Creek; these fish spawned in a hatchery pond on April 6, 1973.

All indications were that the spawning action transpired much as described by Buss (1960). Apparently, the spawning action occasionally occurred in such shallow waters that local residents were able to hand-capture the musky, since the author heard of such hand-captures almost every year of the study.

Age and Size of Musky at Sexual Maturity

Data presented in Table 9, pp. 36-39, indicated that both male and female musky in the study streams usually reached sexual maturity in their fourth summer and first spawned at Age 4. On the average, musky in the streams were 29.4 inches long and weighed 6.0 pounds at Age 4. Since 1967, Kentucky has had a 30-inch musky size limit; of the musky collected from the streams, 69% were less than 30 inches long and legally protected at Age 4 (90% were under 32 inches and 96% were under 33 inches at Age 4).

Neither eggs nor milt could be obtained from a total of twelve two- and three-year-old musky collected during the spawning seasons of 1967-1971. However, at North Fork Creek, in April, 1971, project personnel found a dead three-year-old musky which had egg sacs about four inches long; this fish was 28 inches long and had exhibited greater than average growth. So there was some evidence that fast-growing musky may have spawned at Age 3. Growth data showed that about 7% of the study stream musky would have been 28 inches long at Age 3 as was the aforesaid musky. (Of course, most of these three-year-old sexually mature musky would have been legally protected through their first spawning season and their inclusion would increase the overall percentage of musky legally protected through their first spawning season from 69% to 77%.)

During 1969, a 12-pound musky which died in a trammel net was found to contain about 115,000 eggs or at a rate of about 8,800 per pound of female.

Post-Spawning Movements of Musky

A number of adult musky was tagged in the Licking River tributaries during the spawning seasons of 1967-1971; six of these adults were later creeled by fishermen and all six were caught from the Licking River. A summary of post-spawning movements for these creeled musky is presented below:

Date tagged	Date creeled	Summary of post-spawning movements
April, 1969	October, 1969	Two miles downstream to river and then 15 miles down river
April, 1970	May, 1970	One-half mile downstream to river and then 2 miles up river
April, 1970	June, 1970	Two miles downstream to river and then 10 miles down river
April, 1970	July, 1970	One and one-half miles downstream to river and then 3 1/2 miles up river
April, 1970	October, 1970	Two miles downstream to river and then 15 miles up river
April, 1971	November, 1971	Five miles downstream to river and then eight miles up river

The above fish had respectively moved 17, 2 1/2, 12, 5, 17 and 13 miles since tagging in April. It was assumed that these musky moved out of the tributaries soon after spawning since reports of creeled musky from the tributaries during May were rare.

Chronology of Egg, Sac Fry, and Advanced Fry Stages

The lengths for all young-of-the-year musky collected during late May and early June are listed in Table 10, p. 43. During the period May 25-29 of 1969 and 1970, young musky were 0.8 - 1.2 inches long. Armbruster (1966) reported that musky (at an Ohio hatchery) were 0.9 inch in length at 18 days after hatch-

Table 10. List of advanced musky fry collected from the study streams.

Year	Stream	Number of advanced fry collected	Size of advanced fry (in.)	Date collected
1969	Kinniconick Cr.	2	0.8 - 1.0	May 28
	Beaver Cr.	3	0.9 - 1.2	May 29
1970	Beaver Cr.	1	1.0	May 25
1971	N.F. Triplett Cr.	1	1.5	June 2

ing. Riethmiller (1958) further reported that musky eggs (at an Ohio hatchery) hatched in 8 to 15 days and yolk sac absorption was achieved in about 10 days. Therefore, data from Ohio indicated that the total time for hatching and subsequent growth to 0.9 inch was 26-33 days. Utilizing the Ohio data, the author determined that, during 1969 and 1970, musky spawned during the period April 23 - May 4 and eggs hatched during the period May 7 - May 12; the yolk sac should have been absorbed and swim-up achieved by May 17 to May 22 and a length of 0.9 inch achieved by May 24 to May 29.

Bishop (1966) reported a musky egg incubation time of approximately 12 days at 59°F. hatchery water in Tennessee. Water temperature records for the study streams, Table 20, pp. 62-67, indicated a general musky egg incubation time of about 12 days in those streams; but in unseasonably cool years or during those years when musky spawned early, the incubation time should have been closer to 15 days.

Success of Reproduction

The data presented in Table 11, p. 44, indicate the relative success of musky reproduction at nine streams during the years 1961-1971. Evidently, 1967

Table 11. Number of musky collected from each year class, year classes 1961-1971 included, from each of nine study streams. Only musky collected by the project crew are included; recaptures and musky less than 2 inches long at capture are excluded. Most streams were sampled every year from 1967 through 1971*.

Stream	Year Class											
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Total
North Fork Creek	-	-	-	5	2	8	-	30	18	2	-	65
N.F. Triplett Creek	-	1	-	-	2	6	1	2	1	1	-	14
Beaver Creek	-	-	-	-	-	-	-	2	6	3	-	11
Kinniconick Creek	-	2	4	4	3	1	-	-	1	-	-	15
Red River	-	-	1	-	5	1	-	4	1	-	-	12
Licking River**	1	-	-	2	-	-	-	3	8	1	-	15
Tygarts Creek	-	-	1	1	-	5	-	2	1	1	-	11
Big Goose Creek + Collins Fork of Big Goose Creek	-	-	-	-	-	-	-	3	-	-	-	3
Sturgeon Creek	-	-	-	-	-	-	-	1	-	1	-	2
Total for all nine study streams	1	3	6	12	12	21	1	47	36	9	-	148

* Red River was not sampled during 1969; Big Goose Creek (+Collins Fork of Big Goose Creek) was sampled during 1969-1971; Tygarts Creek was sampled during 1970-1971; and Sturgeon Creek was sampled during 1971.

** North Fork Creek, North Fork of Triplett Creek and Beaver Creek are all tributaries to the Licking River and each spring musky apparently move from the river into the three tributaries in order to spawn (see p.33); for this reason, adult musky collected during the spring in the tributaries were not listed in the above table. These adult musky may have originated their life cycle in either the river or the tributaries. These adult musky belonged to the following year classes: 1958 (1 musky); 1959 (0); 1960 (1); 1961 (0); 1962 (1); 1963 (4); 1964 (8); 1965 (0); 1966 (7).

was a very poor musky reproduction year; on the other hand, 1968 and 1969 were successful musky reproduction years with recruitment at almost all study streams (although not listed, a musky obviously belonging to the 1968 year class was raised but not collected by electrofishing at Kinniconick Creek during 1969). The data collected were insufficient for an evaluation of musky reproduction success during 1970 and 1971; this was particularly true for the year 1971, since our primary fish collecting method was electrofishing which seldom yielded young-of-the-year musky.

North Fork Creek was definitely the best study stream in terms of musky population recruitment on a per-acre basis. The other streams apparently occasionally failed to produce a year class, e.g., Beaver Creek during 1966, or more often produced only moderate or weak year classes, e.g., North Fork of Triplett Creek and Kinniconick Creek during the years 1968 and 1969.

The study's most reliable data concerning y.o.y. musky population levels were obtained by sodium cyanide sampling during the years 1967-1969; a summary of y.o.y. musky population levels on both a per year basis and a per stream basis is presented in Tables 12 and 13, p. 46. During 1967 to 1969, North Fork Creek yielded large fingerling musky at a rate of 1.6 per acre of pool habitat. During 1968, the study streams as a group yielded large fingerling musky at a rate of 1.0 per acre of pool habitat. Such levels, i.e., 1.0 - 1.6 large musky fingerlings per acre, occurred either at a very good musky reproduction stream, i.e., North Fork Creek, or during a very good musky reproduction year, i.e., 1968; overall, during 1967-1969, the streams as a group yielded large musky fingerlings at a rate of only 0.5 per acre of pool habitat.

Table 12. Number of young-of-the-year musky captured each year, years 1967-1969, during sodium cyanide studies; y.o.y. musky ranged in size from 9.3 to 10.3 inches.

Year	Stream	Acres sampled	No. of y.o.y. musky collected	No. of y.o.y. musky collected per acre
1967	North Fork Creek	0.29	0	0.0
	N.F. Triplett Creek	0.36	0	0.0
	Kinniconick Creek	0.45	0	0.0
	Beaver Creek	0.27	0	0.0
	Subtotal	1.37	0	0.0
1968	North Fork Creek	1.10	4	3.6
	N.F. Triplett Creek	0.83	0	0.0
	Kinniconick Creek	1.26	0	0.0
	Beaver Creek	0.90	0	0.0
	Red River	1.00	1	1.0
	Subtotal	5.09	5	1.0
1969	North Fork Creek	1.16	0	0.0
	N.F. Triplett Creek	1.40	1	0.7
	Kinniconick Creek	3.38	0	0.0
	Beaver Creek	0.79	1	1.3
	Big Goose Creek	0.63	0	0.0
	Subtotal	7.36	2	0.3
	TOTAL	13.82	7	0.5

Table 13. Number of young-of-the-year musky captured from each stream during sodium cyanide studies (1967-1969); y.o.y. musky ranged in size from 9.3 to 10.3 inches.

Stream	Acres sampled	No. of y.o.y. musky collected	No. of y.o.y. musky collected per acre
North Fork Creek	2.55	4	1.6
Red River	1.00	1	1.0
Beaver Creek	1.96	1	0.5
N.F. Triplett Creek	2.59	1	0.4
Kinniconick Creek	5.09	0	0.0
Big Goose Creek	0.63	0	0.0
TOTAL	13.82	7	0.5

Age and Growth

Growth in Length

Over the period 1967-1971, satisfactor scale sample readings were recorded for 151 musky which were Age I or older when captured. In addition, scales were read for several young-of-year musky.

The body-scale relationship of the collected musky is presented in Table 14, p. 48; and the regression line of body length against anterior scale radius is plotted in Figure 1, p. 49. The determined relationship between body length and scale length was expressed by the equation $L = 4.5 + 3.6S$.

The growth of musky as calculated by the Lee Method is shown in Table 15, p. 50. The growth of 12 known males and 10 known females was further checked and there appeared to be little difference between the growth of the sexes up to Age IV; however, there was some indication that females grew somewhat faster from Age IV up to Age VII, with Age VII females being perhaps one inch longer than similar-aged males. Scale samples were collected from 14 large musky, 37.5 to 47 inches long, but the outer annuli were generally too obscure for satisfactory scale sample readings. The most readable of these scales showed a 37.5-inch musky almost at Age IX, a 40-inch musky almost at Age X, a 45-inch musky almost at Age XII, and, a 47-inch musky almost at Age XIII. These fish showed yearly increments of only about one inch during the latter years of life. During the years of the project, several 48-inch musky were creeled from the study streams indicating that 15-year-old musky were of occasional occurrence in the streams. Both a 52-inch and a 54.5-inch musky were creeled from the streams during the period 1961-1973 indicating that 20-year-old musky had a rare occurrence in the streams.

Table 14. Body-scale relationship of 152 musky collected from 9 eastern Kentucky streams; musky are arranged into 8 age groups of 0 through VII.

Age group	No. of fish in age group	Average anterior scale radius for age group (in. x 42)	Average total body length for age group (in.)
0	5	1.4	9.2
I	32	3.4	16.6
II	48	4.8	21.9
III	23	6.2	26.4
IV	21	7.3	30.9
V	10	8.0	33.5
IV	9	8.9	36.4
VII	4	9.1	36.8

The growth of young-of-the-year musky at the study streams is presented below:

Time collected	Number collected	Length (in.)
May 25-29 (1969 and 1970)	5	0.8 - 1.2
June 30 (1970)	1	3.0
July 25 (1969)	1	4.5
August 7 (1968)	1	6.5
Sept. 11-18 (1968 and 1969)	3	8.0 - 10.3
Oct. 9-29 (1968 and 1969)	8	9.3 - 11.0

Length - Weight Relationship

The lengths and weights of 181 collected musky were used to calculate a length-weight relationship expressed by the equation Log W = -4.11002 + 3.32788 log L.

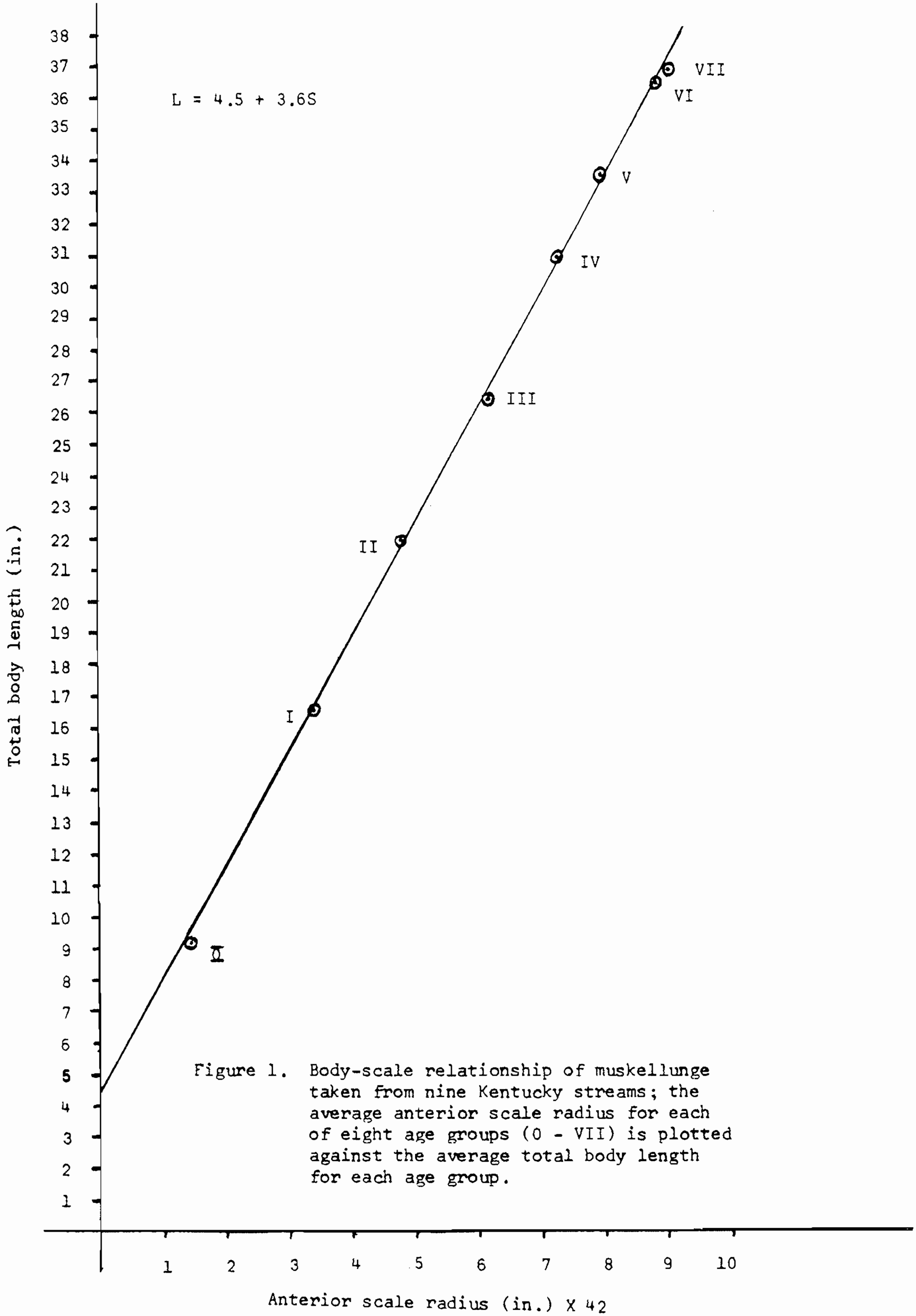


Figure 1. Body-scale relationship of muskellunge taken from nine Kentucky streams; the average anterior scale radius for each of eight age groups (0 - VII) is plotted against the average total body length for each age group.

Table 15. Growth of musky collected from nine Kentucky streams as calculated by the Lee method; data from all streams combined.

No. of fish	Age group	Calculated total lengths (inches) at end of year						
		1	2	3	4	5	6	7
32	I	10.6						
48	II	10.1	17.5					
23	III	10.2	18.1	23.7				
21	IV	10.4	18.4	25.1	29.0			
10	V	9.9	17.0	23.8	29.2	32.0		
9	VI	11.4	19.4	24.7	30.3	33.8	35.7	
4	VII	10.9	20.1	25.6	30.0	32.1	34.4	35.9
Average total length (in.)		10.4	18.0	24.4	29.4	32.7	35.3	35.9
Average annual increment (in.)		10.4	7.7	6.1	4.7	2.9	2.0	1.5
Sum of increments		10.4	18.1	24.2	28.9	31.8	33.8	35.3

The length-weight relationship of musky from the study streams is plotted in Figure 2, p. 51. The total lengths and empirical weights of all collected musky are listed in the Appendix, Table A-3, pp. 99-100; Table A-3 also lists calculated weights for musky ranging in length from 1.0 to 55.0 inches. The calculated weights compared well with empirical weights. Musky over 47 inches in length were not collected from the streams, but a 52-inch, 42-pound musky was creeled from the Licking River in 1973, and a 54.5-inch, 48-pound musky was creeled from the same river in 1961; reported weights for these large musky appeared to agree well with calculated weights for musky of similar lengths.

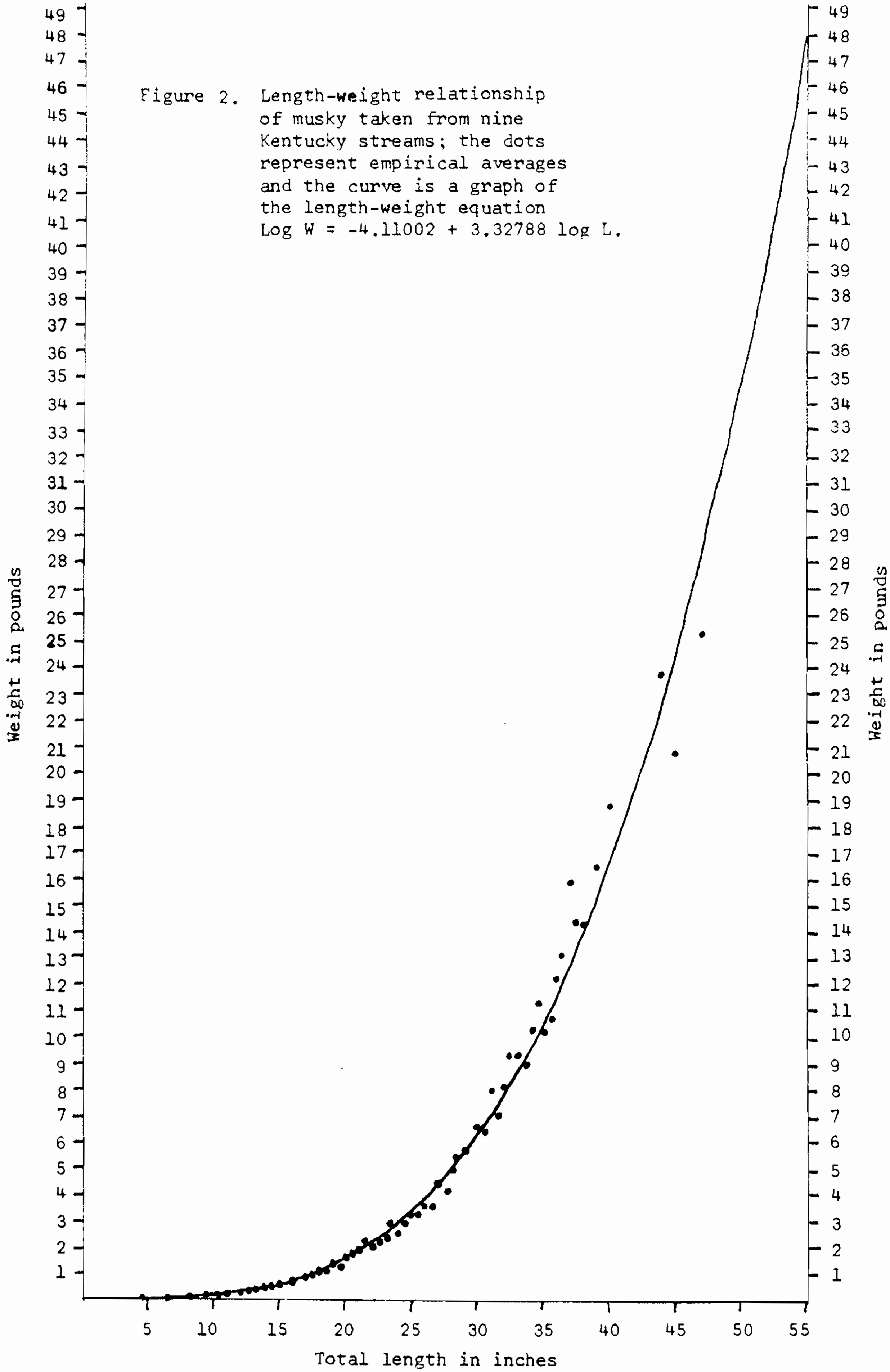


Figure 2. Length-weight relationship of musky taken from nine Kentucky streams; the dots represent empirical averages and the curve is a graph of the length-weight equation Log W = -4.11002 + 3.32788 log L.

Calculated weights for musky at Ages I - VI are presented below:

At age	Average total length (in.)	Calculated weight (lb.)
I	10.4	0.19
II	18.0	1.17
III	24.4	3.21
IV	29.4	5.98
V	32.7	8.51
VI	35.3	10.97

During the first year of life, the weight increment was 0.2 pound; during the second year, the weight increment was 1.0 pound; and, during the 3rd through 6th years of life, the yearly weight increments varied from 2.0 to 2.8 pounds. Lengths and weights were checked for 12 known females and 15 known males; weights for the sexes were generally similar, with a trend towards slightly heavier females (females, 31 to 38 inches long, apparently averaged less than one pound over corresponding males). Males collected during the spawning season showed good condition and sometimes had such girths that they were visually first assumed to be females.

Tagging Results

Table 16, pp. 53-54, presents the data regarding tagged musky which were recollected or creeled. Growth of musky as shown by tag returns corresponded reasonably well with growth as calculated from scale sample readings.

During 1967-1971, 43 muskies (29 inches or longer) were tagged and

Table 16. Returns of tagged musky.

	Date tagged / Date recovered	Time elapsed (months)	Total length (in.)	Total weight (lbs.)	Recovered by fishermen or project crew	Stream when tagged / Stream when recovered
1.	July, 1967 / June, 1969	23	14.0 / 24.5	0.4 / 3.0	Project crew	North Fork Creek / Same
2.	July, 1967 / June, 1969	23	15.0 / 25.0	0.6 / 3.5	Project crew	North Fork Creek / Same
3.	August, 1967 / April, 1968	8	35.0 / 35.0	10.6 / 10.0	Project crew	Kinniconick Creek / Same
4.	May, 1968 / August, 1968	3	17.0 / 22.0	1.0 / 2.3	Project crew	North Fork Creek / Same
5.	April, 1968 / August, 1968	4	19.0 / 23.5	1.7 / 2.6	Project crew	N.F. Triplett Creek / Same
6.	August, 1968 / June, 1969	10	29.0 / 30.5	6.0 / 6.6	Project crew	North Fork Creek / Same
7.	November, 1968 / July, 1969	8	29.0 / 31.0	5.3 / 8.8	Project crew	Kinniconick Creek / Same
8.	June, 1968 / June, 1968	<1	33.0 / Same	10.6 / Same	Fisherman	Kinniconick Creek / Same
9.	August, 1968 / October, 1968	2	33.5 / 34.0	9.5 / ---	Fisherman	North Fork Creek / Same
10.	April, 1968 / February, 1969	10	35.0 / 35.5	10.0 / 10.8	Fisherman	Kinniconick Creek / Same
11.	August, 1968 / March, 1969	19	36.0 / 37.0	11.5 / 14.5	Fisherman	N.F. Triplett Creek / Same
12.	June, 1969 / November, 1969	5	30.5 / 32.0	6.6 / 8.0	Fisherman	North Fork Creek / Same

Table 16. (continued)

	Date tagged Date recovered	Time elapsed (months)	Total length (in.)	Total weight (lbs.)	Recovered by fishermen or project crew	Stream when tagged Stream when recovered
13.	June, 1969 March, 1970	9	33.5 36.0	8.8 12.0	Fisherman	North Fork Creek Unreported
14.	July, 1969 July, 1969	< 1	33.5 Same	9.0 Same	Fisherman	Kinniconick Creek Same
15.	April, 1969 October, 1969	6	39.0 40.0	16.5 16.2	Fisherman	North Fork Creek Licking River
16.	September, 1970 September, 1971	12	16.0 23.0	0.8 2.5	Project crew	North Fork Creek Same
17.	June, 1970 September, 1972	27	22.0 33.0	2.3 8.3	Fisherman	Red River Same
18.	April, 1970 October, 1970	6	29.0 31.0	6.5 ---	Fisherman	North Fork Creek Licking River
19.	April, 1970 April, 1971	12	30.3 32.0	6.4 8.2	Project crew	North Fork Creek Same
20.	April, 1970 May, 1970	1	34.0 34.5	9.6 9.3	Fisherman	Beaver Creek Licking River
21.	April, 1970 July, 1970	3	36.0 Same	12.0 13.0	Fisherman	North Fork Creek Licking River
22.	April, 1970 June, 1970	2	45.0 42.3	18.6 15.3	Fisherman	North Fork Creek Licking River
23.	August, 1971 March, 1972	7	32.5 35.0	9.3 10.4	Fisherman	Tygarts Creek Same
24.	August, 1971 August, 1971	< 1	34.5 Same	12.0 Same	Fisherman	Tygarts Creek Same
25.	April, 1971 November, 1971	7	45.0 47.5	23.0 25.0	Fisherman	N.F. Triplett Creek Licking River

released; of these, 14 or 33% were creeled within a year after tagging. The percentage creeled within one year after tagging showed some consistency as shown below:

Year of tagging	Number of musky (29+ inches) tagged and released	Number (and percentage) of musky creeled within one year after tagging
1967	3	0 - (0%)
1968	6	3 - (50%)
1969	11	4 - (36%)
1970	14	4 - (29%)
1971	9	4 - (33%)

The time of tagging and the time of creel for the aforementioned 14 musky is presented below:

Month	J	F	M	A	M	J	J	A	S	O	N	D
Number tagged	-	-	-	7	-	2	1	4	-	-	-	-
Number creeled	-	1	1	-	3	2	2	1	-	3	1	-

As indicated above, musky were fished for and creeled at the streams during all months of the year. Based on creel reports relayed to the author, it appeared that the peak months for musky fishing and musky creel at the streams were March, April, October, and November.

Nearly all of the tag returns came within the first year after tagging. After the first year, the metal clip-on tags became obscured by the growth of flesh over the tag and it was possible that fishermen then failed to notice the tags. It was also evident, from the project studies, that at least a few of the tags were lost off the musky.

Food Habits

Eleven musky were examined for stomach contents and the results are presented below:

Total length (in.) of musky	Stomach contents
0.9	empty
0.9	empty
1.2	3-4 mayfly nymphs
9.5	one 4" common shiner
9.8	empty
10.0	one 3" spotted bass
18.0	one 5" common shiner; and 10 mixed shiners, minnows and darters (1-3")
19.0	one 4" common shiner
27.0	empty
31.5	empty
36.0	one 10" spotted sucker

Buss (1960) reported that musky eat whatever is most available; if that had been the case at the study streams, then musky diets should have been composed primarily of minnows, panfish (longear, bluegill, etc.), suckers, and gizzard shad.

Physical-Chemical-Biological Studies

The study streams were located in eastern Kentucky where the topography is very hilly, run-off is very rapid, relative inherent fertility ranges from low to very low, and parent rock consists of sandstones, shales, and some limestone. Typically, the narrow bottomlands adjoining the streams are farmed and the surrounding hills are forested. Soils in the area are derived from acid sandstones and shales.

Silt and acid pollution from coal-mining have degraded Big Goose Creek and Sexton Creek. Road construction, sawmill wastes, and sewage periodically caused some degradation at several of the study streams. Adverse land use practices were not severe in the associated watersheds but were common enough in relation to the prevailing run-off pattern to cause some siltation problems.

Physico-Chemical Studies

Physical characteristics of the study streams are presented in Table 17, p. 58. Gradients for the streams are further detailed in the Appendix, Table A-4, pp. 101-103. Typically, musky were found in the low-gradient sections of the streams where fall averaged 10 feet or less per mile.

The results of physico-chemical studies conducted at the study streams during 1967-1969 are presented in Tables 18 and 19, pp. 59-60. The results presented are much as would be expected considering the described watersheds. Little Goose Creek, a tributary to Big Goose Creek, showed relatively low pH readings due to the chronic acid pollution of the stream by coal-mining wastes. During the study years, several fish kills attributed to coal-mining wastes occurred at Sexton Creek and Big Goose Creek; during 1969, the project crew investigated the aftermath of a fish kill at Big Goose Creek and pH values

Table 17. Physical characteristics of the study streams.

Stream	Elevation (feet) at headwaters	Elevation (feet) at mouth	Average stream gradient (feet per mile)
Beaver Cr.	1110	675	22.1
Sexton Cr.	1130	690	19.1
Sturgeon Cr.	1245	620	18.5
N.F. Triplett Cr.	1140	647	15.5
North Fork Cr.	1000	697	14.2
Kinniconick Cr.	1100	475	12.8
Big Goose Cr. + Collins Fork	1100	758	7.9
Red River	1280	570	7.6
Little Sandy River	1050	490	6.8
Tygarts Cr.	1075	483	6.3
Licking River	1110	441	2.2

of 4.2 - 5.1 were recorded over most of that stream's length.

Obviously, severe pollution, such as acid drainage, limited musky at a few streams. At the other streams, factors limiting musky were not so obvious. For example, the Licking River had a musky population in its upper section but not in the lower 131 miles (this river is the only large river in Kentucky not having its lower reaches impounded by either large dams or lock-and-dam structures). The lower 131 miles of this river were located in a different physiographic region than were the upper reaches. The lower region had a less hilly terrain with parent rocks consisting of limestones and calcareous shales; the lower region had medium inherent fertility and as a result farming was relatively more extensive. So, associated physiographic and land use characteristics were different for the lower section of the river. As regards land use practices, North Fork Creek had the least disturbed watershed of any of the study streams and concurrently this stream proved to be the project's best musky reproduction stream (see p. 45). The watershed of North Fork Creek contained no

Table 18. Physico-chemical characteristics of six study streams during 1967-1969 (monthly physico-chemical studies were conducted on the four creeks from March, 1967, through February, 1969, and on the two rivers from January, 1968, through December, 1968). Upper values are the maximum, middle values are the mean, and the lower values are the minimum recorded at each stream.

	Beaver Creek	North Fork Creek	North Fork of Triplett Creek	Kinniconick Creek	Licking River	Red River
Location of sampling station above mouth	mile 10	mile 4	mile 10	mile 32	mile 187	mile 54
Temperature (in °F.)	80 57 34	73 55 40	73 55 32	76 57 33	72 53 33	73 52 33
Dissolved oxygen (ppm)	13.0 9.6 6.8	11.4 8.9 5.9	13.4 9.5 5.6	12.8 9.5 6.8	11.8 9.4 6.6	12.4 9.7 7.6
Alkalinity (ppm $CaCO_3$)	98 54 8	80 26 4	27 12 2	22 11 2	48 27 9	50 22 4
Turbidity (J.T.U.)*	102 14 2	50 16 5	700 66 5	190 22 3	125 57 10	78 32 5
pH**	7.7 7.0 6.9	6.9 6.7 6.3	6.8 6.5 5.8	6.9 6.4 6.0	6.8 6.8 6.3	7.0 6.7 6.5
Stream discharge (cfs)	115.6 21.2 0.1	252.7 50.5 0.4	900.0 139.4 0.1	149.1 53.3 0.9	- - -	- - -
Conductivity (micromhos) June - Sept. 1967	238	162	76	101	265	115

* Jackson Turbidity Units (using Hach Kit)

** High, mode, and low values

Table 19. Results of quarterly physico-chemical studies conducted at the Little Sandy River, Big Goose Creek, Collins Fork of Big Goose Creek and Little Goose Creek during 1969.

Date	Surface water temperature (°F.)	Dissolved oxygen (ppm)	pH	Turbidity (J.T.U.)*	Total alkalinity (ppm $CaCO_3$)
	Little Sandy River (at mile 43 from mouth)				
2/7/1969	40	11.6	6.8	8	27
5/5/1969	69	7.8	6.6	5	20
8/11/1969	70	6.6	6.6	52	39
10/21/1969	59	8.6	6.7	-	32
	Big Goose Creek (at mile 8 from mouth)				
2/13/1969	32	14.8	6.7	5	11
4/16/1969	-	8.8	6.5	42	6
8/18/1969	-	7.0	6.8	5	30
10/22/1969	57	8.8	6.1	-	31
	Collins Fork of Big Goose Creek (at mile 6 from mouth)				
2/13/1969	-	-	6.7	12	6
4/16/1969	58	8.4	6.5	33	10
8/18/1969	78	6.8	6.7	5	18
10/22/1969	57	9.0	6.3	-	28
	Little Goose Creek (100 feet above mouth)				
2/13/1969	-	-	5.6	8	-
4/16/1969	-	-	5.9	31	-
8/18/1969	76	-	5.6	-	27
10/22/1969	-	-	5.1	-	-

* Jackson Turbidity Units

community of any size and associated farming was very limited. Such limited land use expectedly would have resulted in moderated discharges and reduced silt loads and turbidities for this stream which could well have enhanced musky reproduction success.

The effects of discharge, and also water temperature, on musky reproduction success were investigated by examining water records for the study streams. The U.S. Geological Survey had daily discharge and temperature records for the Licking River for the years 1962-1971; such records were obtained from a gauging station on the river located 170 miles upstream from the mouth, such station being located near the best musky habitat present in the river. The springtime temperature x discharge profiles for the Licking River during the years 1962-1971 are presented in Table 20, pp. 62-67. While the records for the Licking River did not exactly reflect conditions which occurred at the other study streams, the river records did reflect general discharge and temperature trends as determined by general weather conditions. The general trends were evaluated in respect to evident effect on musky reproduction success.

During most years, discharges were relatively high during March and/or April, and relatively low during May. This trend was probably favorable to musky reproduction success since during May musky progressed through the egg and sac fry stages and began initial feeding (see p. 42).

The project's best data regarding musky reproduction success were related to the years 1967, 1968, and 1969; 1967 was a very poor reproduction year, and both 1968 and 1969 were relatively very successful reproduction years (see pp. 43-45). Temperature x discharge profiles for the Licking River show that during 1967 the river experienced extreme discharges during May 7-9 and again during May 15-18; tributaries to the river experienced similar discharges but beginning and ending about a day earlier. The first high discharge in May, 1967, occurred at a time when musky were very probably in the late egg or early sac fry stages. The month of May, 1967, was also unseasonably cool and the prevailing low water temperatures also could have deleteriously affected musky development. On the

Table 20. Daily mean water temperatures (°F.) plotted against daily mean discharges (cfs) for the Licking River, at Farmers, Kentucky, during March, April and May for the years 1962-1971 (temperatures and discharges obtained from the U.S. Geological Survey, Louisville, Kentucky).

——————— stream discharges

- - - - - - - stream temperatures

. . . Average discharge for the Licking River, at Farmers, Kentucky, during the years 1938 - 1967 (29 years) = 1,048 cfs.

- 1962 -

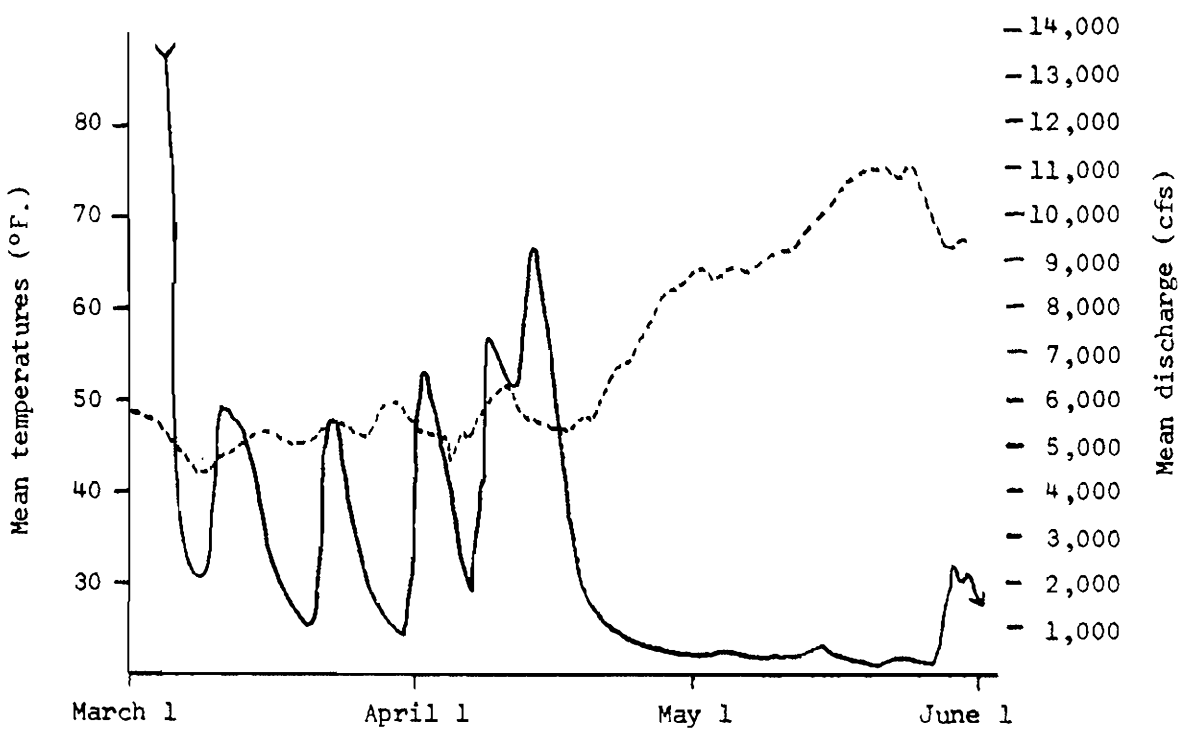
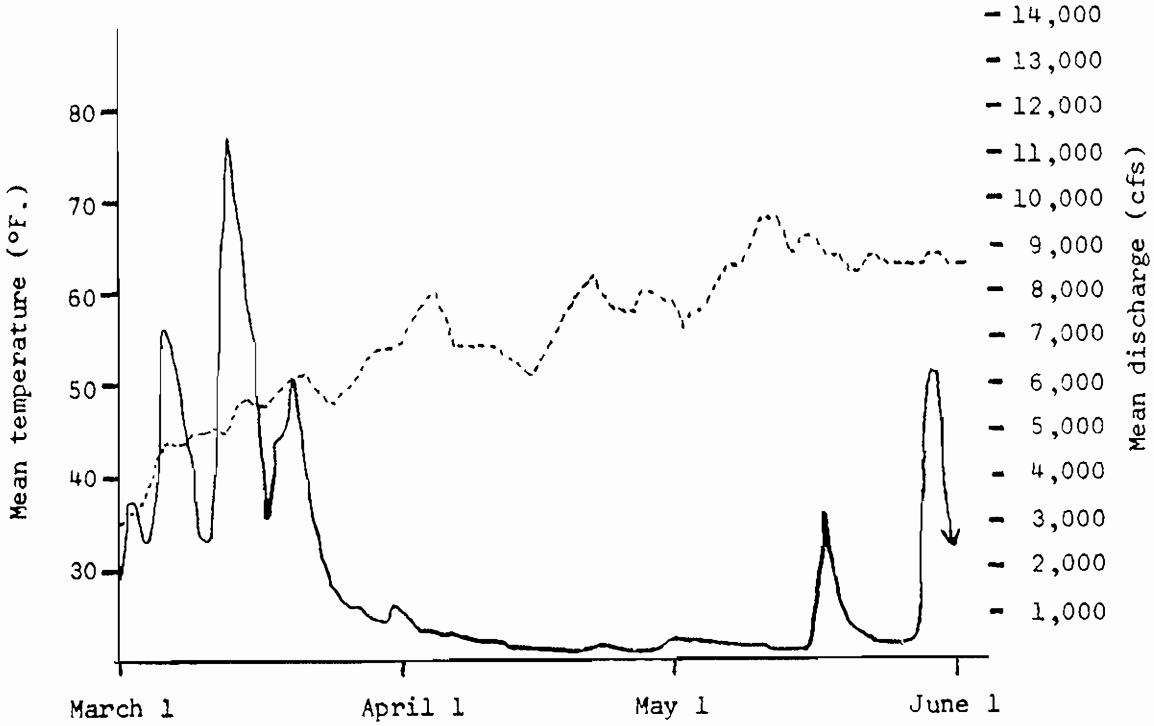


Table 20. (continued)

- 1963 -



- 1964 -

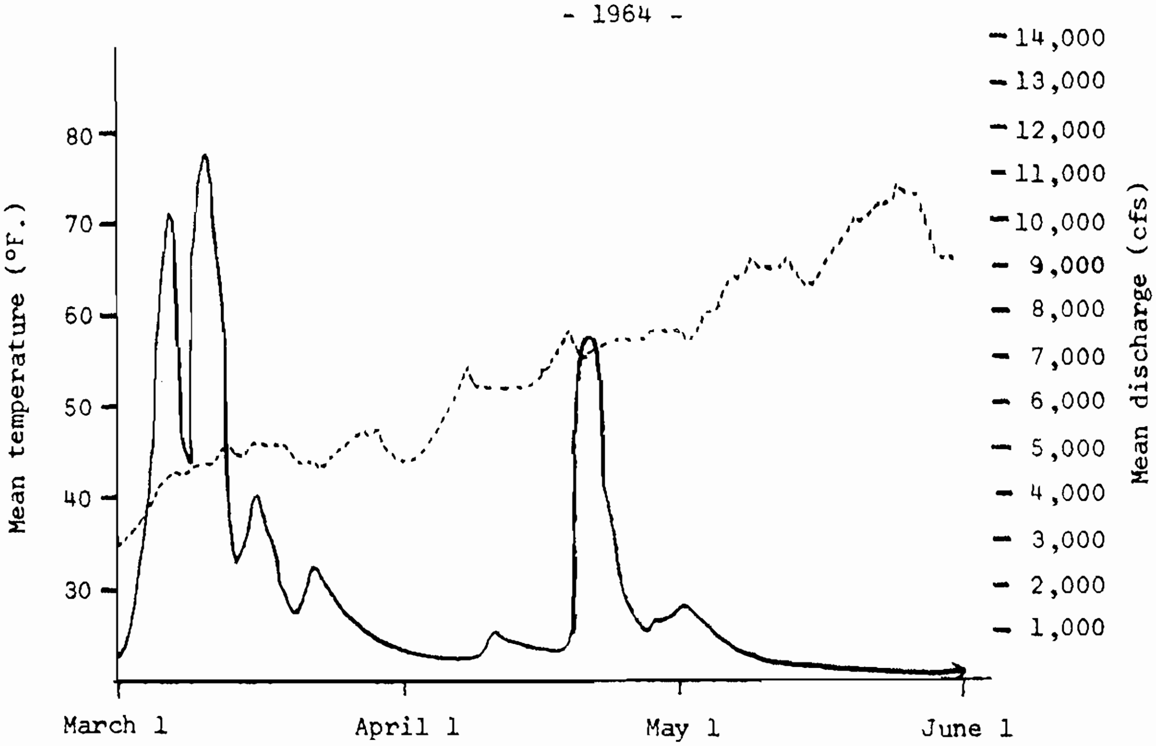
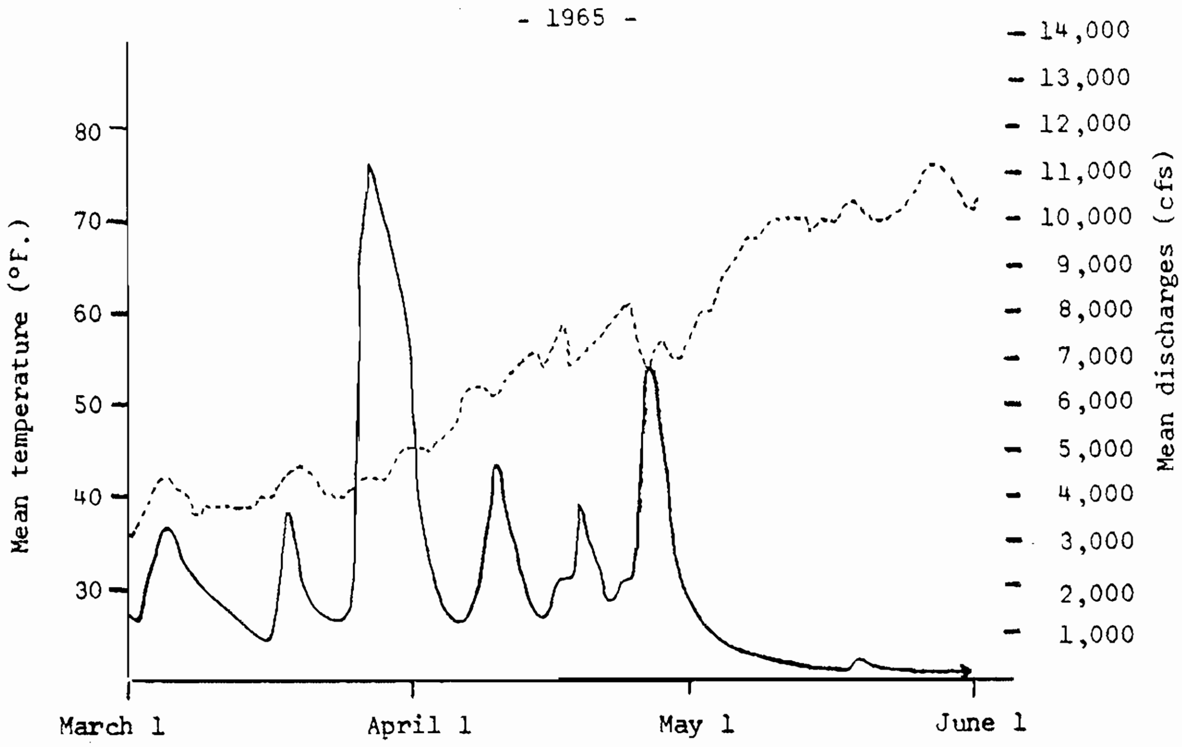


Table 20. (continued)



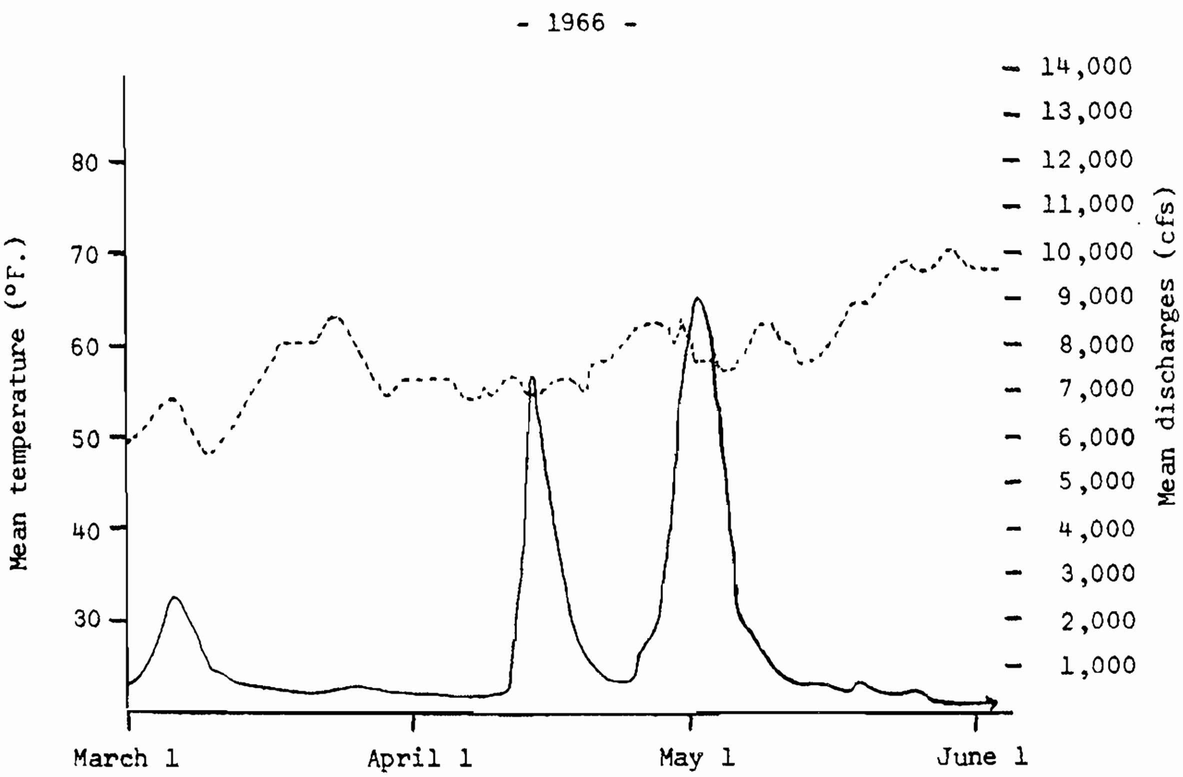
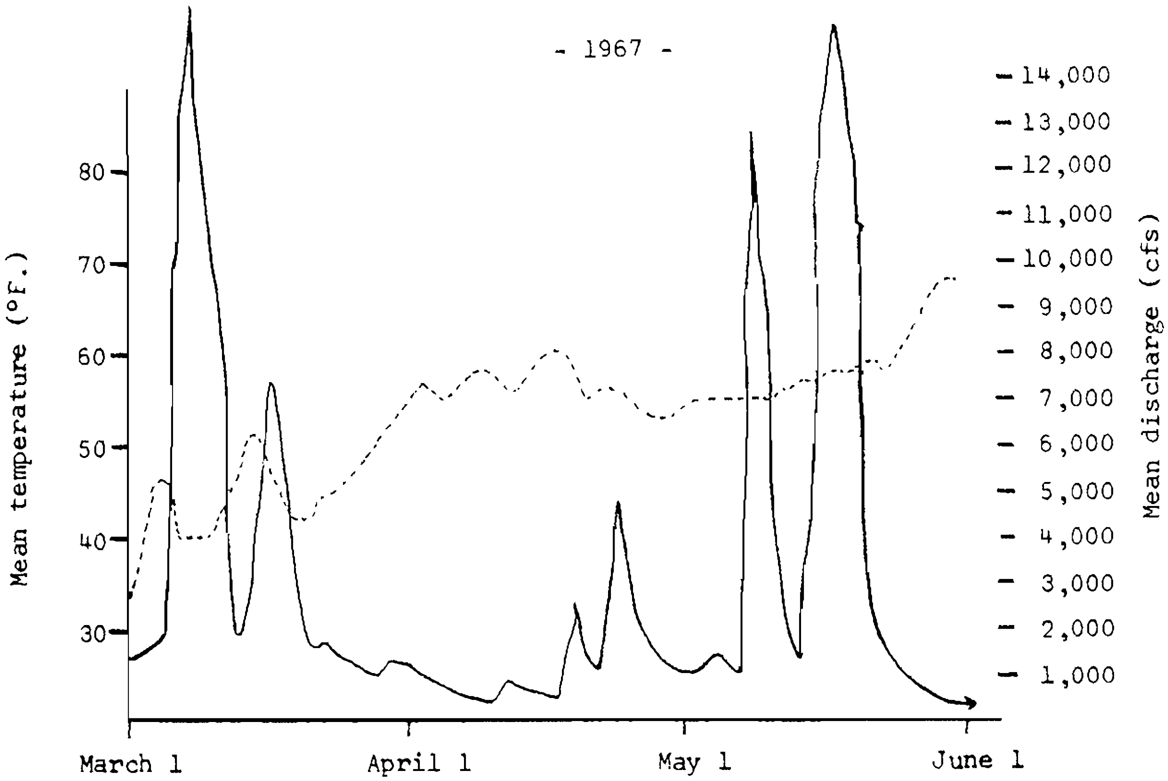


Table 20. (continued)



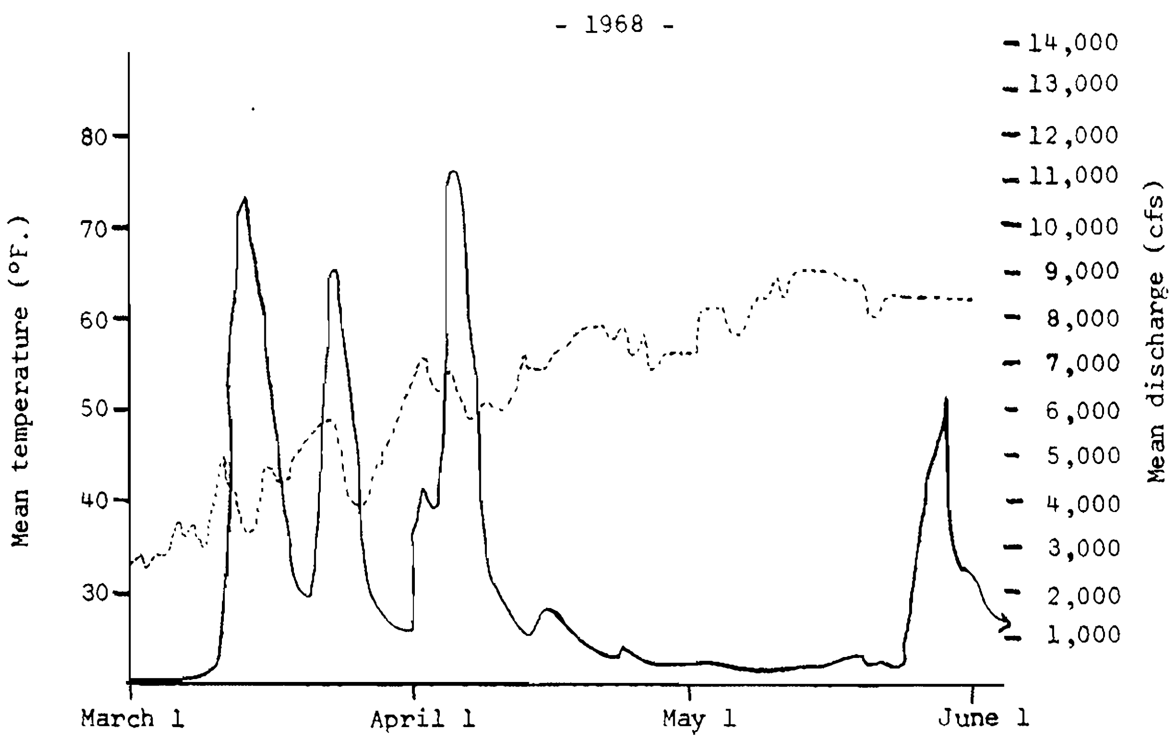
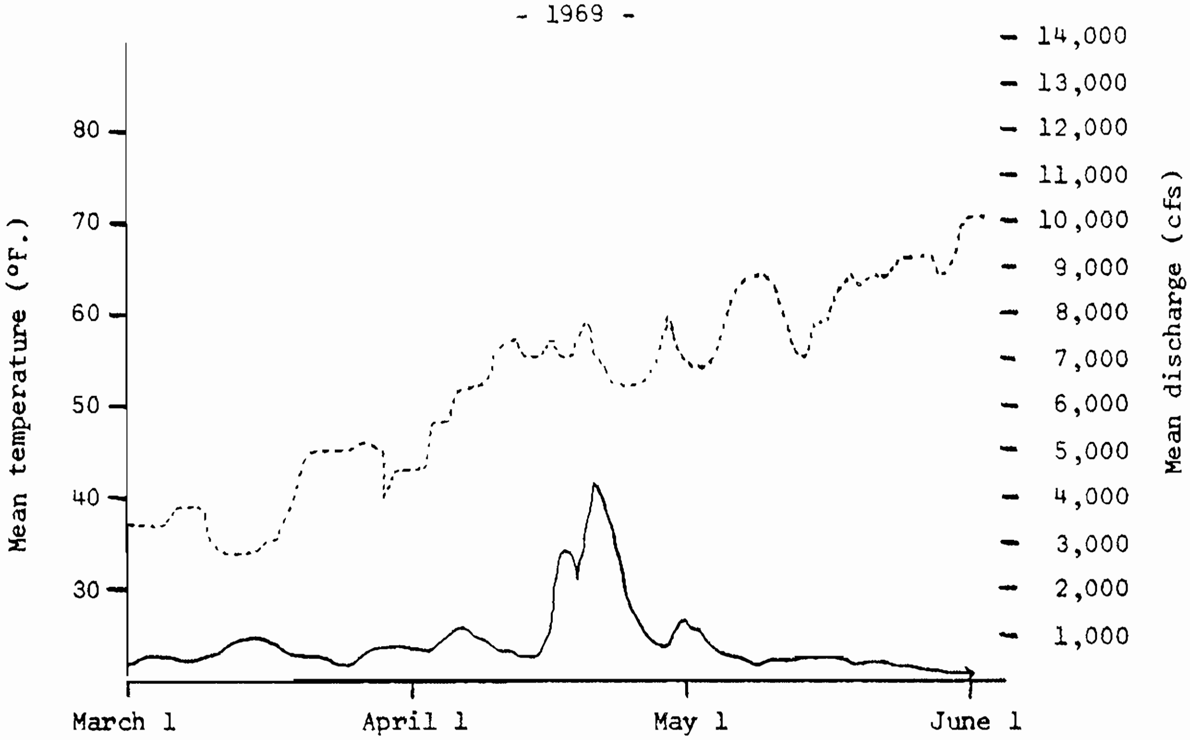


Table 20. (continued)

- 1969 -



- 1970 -

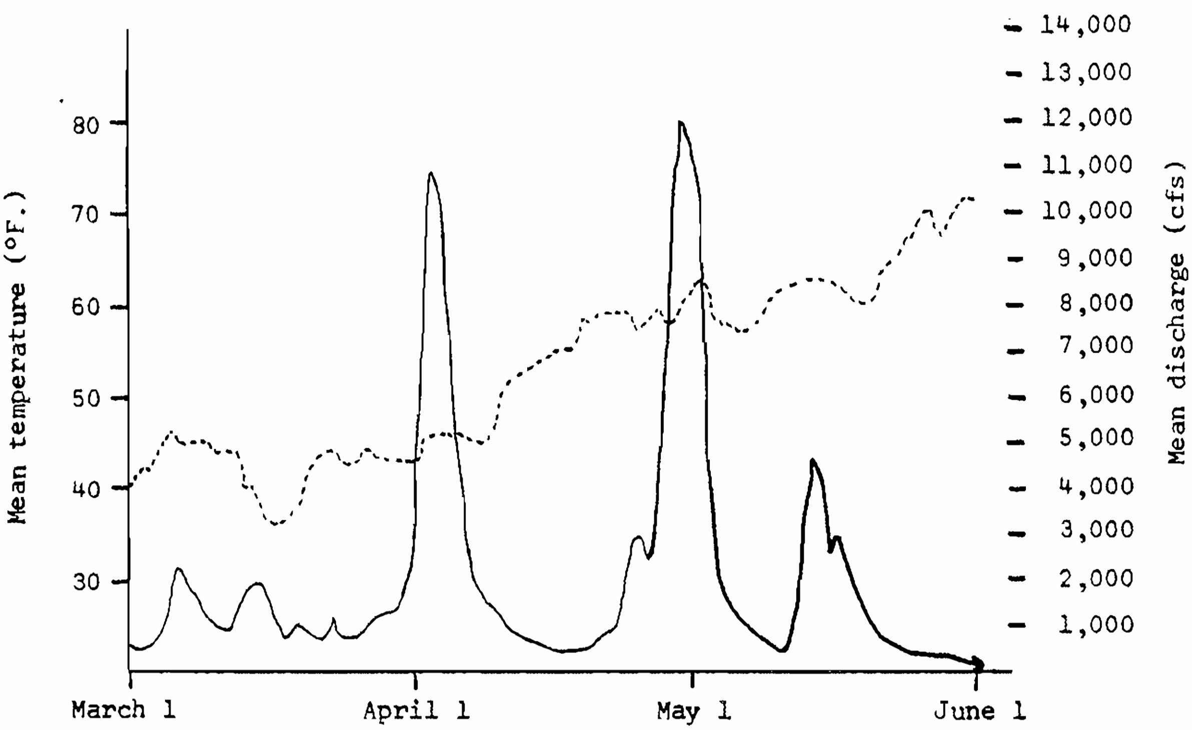
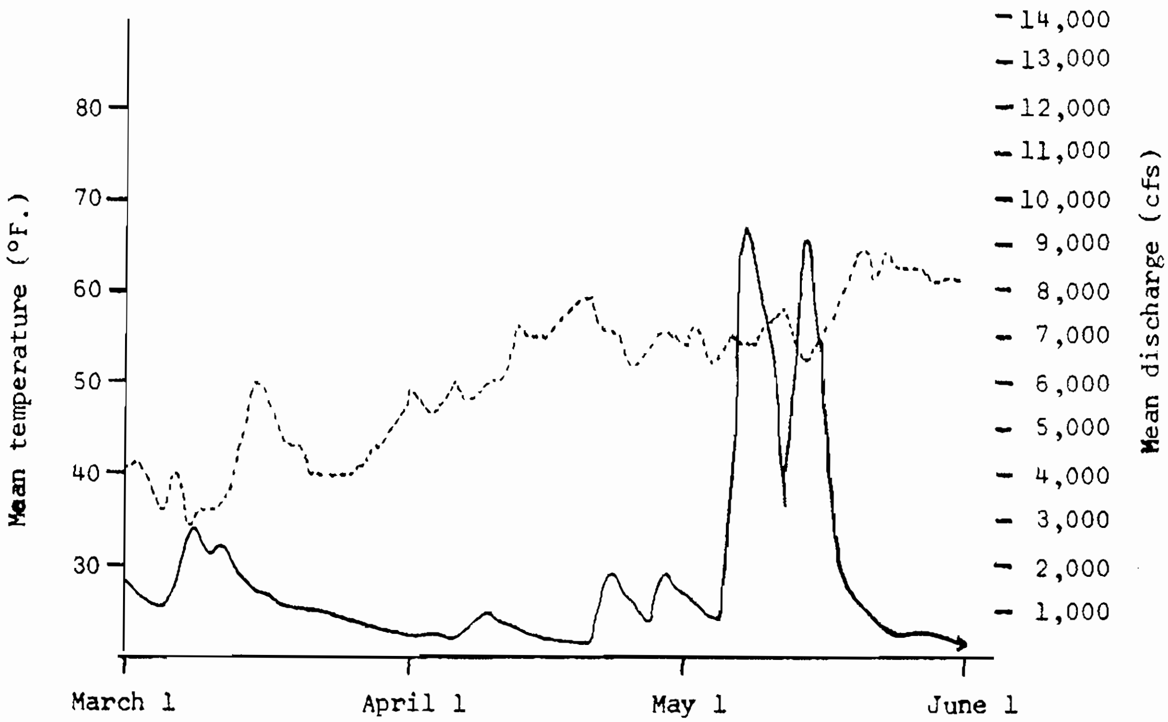


Table 20. (continued)

- 1971 -



other hand, during May of 1968 and 1969, discharges were low and water temperatures were seasonable.

The success of musky reproduction for 1970 and 1971 was less well determined. The data indicated that 1970 was at least a fair musky reproduction year. Discharges at the Licking River were very high during April 29- May 2, 1970; tributaries to the river experienced similar discharges during April 28- May 1. Indications were that some musky at the streams probably spawned during the last week of April; if so, related egg survival may have been affected by the high discharges at the end of April. On the other hand, there were indications that other musky in the streams spawned during the first week of May, 1970, and conditions for egg survival for those musky were more favorable. No data were collected regarding 1971 musky reproduction success, but the 1971 springtime temperature x discharge profile for the Licking River was somewhat similar to that for 1967, i.e., with unseasonably cool temperatures and relatively high discharges during May.

Cold water temperatures and fluctuating water levels at spawning time were considered as factors limiting natural musky reproduction in Wisconsin (Oehmcke, et al., 1958); reportedly, these factors seemed to have their greatest effect on musky eggs and fry. Much the same seemed to be true in Kentucky, with the added effect that higher discharges generally were associated with higher silt loads.

Biological Studies

The results of zooplankton sampling studies during 1969-1971 are presented in Tables 21, 22, and 23, pp. 69-71. Tables A-5 and A-6 in the Appendix, pp. 104-105, list the stream conditions prevalent during zooplankton sampling for the years 1970 and 1971. Previous data, p. 43, indicated that small musky in the streams

Table 21. Relative abundance of zooplankters at eight sampling stations during four sampling periods in May, 1969; zooplankters counted included only cladocerans, copepods, nauplii larvae, annelids, aquatic insect larvae, and the larger rotifers. Total numbers of copepods plus nauplii larvae are listed in parentheses.

Stream	Location of sampling station above the mouth (miles)		Number of zooplankters collected from one 30-foot tow haul with a plankton net: May 8 - 9	May 14 - 15	May 21 - 22	May 28 - 29	Total number
North Fork Creek	2.0		130 (42)	64 (26)	58 (26)	78 (34)	330 (128)
	6.0		52 (30)	16 (4)	6 (4)	28 (14)	102 (52)
		Total	182 (72)	80 (30)	64 (30)	106 (48)	432 (180)
N.F. Triplett Creek	1.0		24 (14)	64 (26)	30 (16)	26 (12)	144 (68)
	10.0		20 (8)	50 (8)	36 (10)	44 (30)	150 (56)
		Total	44 (22)	114 (34)	66 (26)	70 (42)	294 (124)
Beaver Creek	0.4		80 (22)	44 (16)	20 (10)	52 (10)	196 (58)
	6.0		54 (2)	174 (22)	58 (4)	12 (6)	298 (34)
		Total	134 (24)	218 (38)	78 (14)	64 (16)	494 (92)
Kinniconick Creek	30.0		130 (62)	38 (22)	6 (2)	158 (54)	332 (140)
	34.0		22 (10)	54 (20)	8 (2)	28 (12)	112 (44)
		Total	152 (72)	92 (42)	14 (4)	186 (66)	444 (184)
GRAND TOTAL			512 (190)	504 (144)	222 (74)	426 (172)	1664

Table 22. Relative abundance of zooplankters at eight sampling stations during four sampling periods in May and June 1970; zooplankters counted included only cladocerans, copepods, nauplii larvae, annelids, aquatic insect larvae, and the larger rotifers. Total numbers of copepods plus nauplii larvae are listed in parentheses.

Stream	Location of sampling station above the mouth (miles)		Number of zooplankters collected from one 30-foot tow haul with a plankton net: May 12	May 19	May 29	June 2	Total number (May 19-June 2)
North Fork Creek	2.0		*	52 (8)	140 (62)	126 (56)	318 (126)
	6.0		*	42 (6)	32 (14)	98 (24)	172 (44)
		Total	*	94 (14)	172 (76)	224 (80)	490 (170)
N.F. Triplett Creek	1.0		106 (72)	178 (68)	258 (216)	228 (192)	664 (476)
	10.0		24 (10)	46 (8)	260 (208)	140 (122)	446 (338)
		Total	130 (82)	224 (76)	518 (424)	368 (314)	1110 (814)
Beaver Creek	0.4		*	84 (24)	56 (28)	178 (98)	318 (150)
	6.0		*	26 (4)	96 (40)	146 (70)	268 (114)
		Total	*	110 (28)	152 (68)	324 (168)	586 (264)
Kinniconick Creek	30.0		20 (8)	26 (2)	126 (60)	248 (106)	400 (168)
	34.0		26 (10)	10 (8)	142 (88)	104 (46)	256 (142)
		Total	46 (18)	36 (10)	268 (148)	352 (152)	656 (310)
GRAND TOTAL			-	464 (128)	1110 (716)	1268 (714)	2842

* Stream discharge too high for zooplankton sample.

Table 23. Relative abundance of zooplankters at eight sampling stations during four sampling periods in May and June, 1971; zooplankters counted included only cladocerans, copepods, nauplii larvae, annelids, aquatic insects larvae, and the larger rotifers. Total numbers of copepods plus nauplii larvae are listed in parentheses.

Stream	Location of sampling station above the mouth (miles)		Number of zooplankters collected from one 30-foot tow haul with a plankton net: May 4 - 5	May 18 - 19	May 25 - 26	June 1 - 2	Total number
North Fork Creek	2.0		44 (18)	42 (8)	36 (14)	66 (48)	188 (88)
	6.0		34 (8)	54 (16)	16 (6)	32 (16)	136 (46)
		Total	78 (26)	96 (24)	52 (20)	98 (64)	324 (134)
N.F. Triplett Creek	1.0		52 (24)	38 (12)	20 (8)	92 (42)	202 (86)
	10.0		18 (10)	64 (6)	88 (26)	86 (36)	256 (78)
		Total	70 (34)	102 (18)	108 (34)	178 (78)	458 (164)
Beaver Creek	0.4		6 (4)	118 (28)	28 (14)	58 (30)	210 (76)
	6.0		26 (10)	36 (6)	28 (12)	8 (4)	98 (32)
		Total	32 (14)	154 (34)	56 (26)	66 (34)	308 (108)
Kinniconick Creek	30.0		30 (16)	12 (6)	68 (34)	60 (22)	170 (78)
	34.0		70 (28)	46 (6)	78 (38)	60 (12)	254 (84)
		Total	100 (44)	58 (12)	146 (72)	120 (34)	424 (162)
GRAND TOTAL			280 (118)	410 (88)	362 (152)	462 (210)	1514

were usually in the zooplankton-feeding stage during the latter half of May and early June.

The total number of zooplankters collected for each year was 1,664 for 1969, 2,842 for 1970, and 1,514 for 1971; during the period of zooplankton sampling, the average water temperature for the Licking River was 63° F. for 1969, 65° F. for 1970, and 59° F. for 1971. So, as would be generally expected, there were indications that increased water temperatures resulted in increased zooplankton abundance. Zooplankton abundance was uniquely high for the sampling periods of May 29 and June 2, 1970; and, these were the only two sampling periods at which prevailing water temperatures had reached into the low 70s. From the above, it was presumed that good warming trends during late May and early June would result in increased zooplankton abundance and therefore more food for young musky.

The study streams were generally similar to each other in regards to zooplankton abundance. Considering all sampling periods during 1969-1971, the mean number of zooplankters collected per sampling period for each stream was as follows:

Stream	Mean number of zooplankters collected per sampling period
North Fork Creek	432
N.F. Triplett Creek	458
Beaver Creek	494
Kinniconick Creek	444

As previously mentioned, p. 45, North Fork Creek was definitely the best study stream in terms of musky population recruitment on a per acre basis; and, zooplankton studies showed nothing to indicate that relative zooplankton abundance was a cause of the good musky recruitment at that stream. The collected data were insufficient to determine whether relative zooplankton abundance was a factor in the yearly variance of musky reproduction success at each stream.

The literature (Buss, 1960) suggests that small crustaceans and certain aquatic insect larvae are important foods for small musky. Of the zooplankters collected during 1969-1971, 45.4% were copepods (65% of those were nauplii larvae), 21.6% were rotifers, 16.5% were aquatic insect larvae, 11.6% were aquatic annelids, and 4.8% were cladocerans. Evidently, copepods were the most important food for young musky fry at the streams, with aquatic insect larvae also becoming important as the fry grew larger.

Regarding the amount of fish forage available for young musky, the author has listed below the abundance of small cyprinids, and the abundance of all small fishes at several streams as shown by 1967-1969 sodium cyanide studies (Brewer, 1970):

Stream	Abundance of small cyprinids (0-3 inches) on a per-acre basis	Abundance of all small fishes (0-4 inches) on a per-acre basis
North Fork Creek	381	628
Beaver Creek	288	474
Kinniconick Creek	93	462
N.F. Triplett Creek	68	142

Since North Fork Creek was the best of the above streams in terms of musky recruitment on a per-acre basis during 1967-1969, and since Beaver Creek was the second best stream in that regard, it seemed that the relative abundance of small forage fishes was important in regards to relative musky reproduction success.

Management Activities

Procurement of Musky Broodstock

A list of musky removed from the study streams during 1970-1971 and placed in temporary holding ponds for later use as hatchery broodstock is presented in Table 24, pp. 75-77. In total, 48 musky, 13.5 to 34 inches long, were removed from the streams.

Personnel of the agencies owning the ponds reported sightings of 1-2 dead musky in the ponds (the author presumed these musky died as a result of the handling involved in transfer). The same personnel reported that at least one musky was illegally creeled from the ponds. Also, each pond had a spillway and, on occasion, high rainwaters caused breakage of installed spillway screens with the possible escapement of a few musky into a lower pond in one case and into a small tailwater stream in the other case.

Initially, holding pond #1 had a fish population overwhelmingly dominated by 3"-4" sunfish and holding pond #2 had a well-balanced bass-bluegill population. During the period October, 1970, to March, 1973, holding pond #1 had musky standing crops ranging from 18 up to 40 ppa and pond #2 had musky standing crops ranging from 8 up to 30 ppa. By March, 1973, pond #1 remained dominated by undersized sunfish and pond #2 continued to have a well-balanced bass-bluegill population.

Growth of musky in the holding ponds is presented in Table 25, p. 78. Growth in length for the smaller musky was similar to that calculated for musky in the study streams; however, the larger musky in the ponds seemed to show less growth in length than did stream musky. All musky exhibited good condition throughout the holding period.

Table 24. List of musky removed from study streams during 1970-1971 and placed in temporary holding ponds for later use as hatchery broodstock.

Stream	Total length (in.)	Weight (lbs.)	Date collected
Holding Pond #1 - Carlisle Water Reservoir (Nicholas County) - 3.8 acres			
North Fork Creek	23.0	2.35	10/11/70
North Fork Creek	23.5	2.92	9/16/70
North Fork Creek	24.0	2.84	10/12/70
North Fork Creek	25.0	2.65	10/11/70
North Fork Creek	25.0	2.94	10/12/70
North Fork Creek	26.5	3.65	9/16/70
North Fork Creek	27.5	3.82	9/16/70
Tygarts Creek	28.0	5.40	7/16/70
North Fork Creek	28.5	5.55	10/11/70
Tygarts Creek	29.0	6.20	7/22/70
Tygarts Creek	29.0	6.45	7/15/70
Tygarts Creek	30.0	6.20	7/15/70
Red River	31.0	7.50	7/1/70
Tygarts Creek	34.0	9.75	7/21/70
	14 fish	68.22 lbs.	
North Fork Creek	25.0	3.27	10/7/71
North Fork Creek	26.0	3.64	10/7/71
	2 fish	6.91 lbs.	
On 10/7/71, removed 4 musky from Holding Pond #3 and placed in Holding Pond #1; the 4 fish weighed approximately 19 pounds.			
	(4 fish)	(19.00 lbs.)	
Total	20 fish	94 pounds	1970-1971
Pond #2 - 4-H Club Lake (Nicholas County) - 2.5 acres			
Tygarts Creek	13.5	0.48	7/15/70
North Fork Creek	14.0	0.49	9/2/70
North Fork Creek	14.5	0.52	9/3/70
North Fork Creek	16.0	0.75	9/2/70
North Fork Creek	16.0	0.80	9/2/70
Beaver Creek	17.0	0.72	9/14/70
Beaver Creek	19.5	1.30	9/14/70

Table 24. (continued)

Stream	Total length (in.)	Weight (lbs.)	Date collected
Holding Pond #2 - 4-H Club Lake (Nicholas County) - 2.5 acres (cont.)			
North Fork Creek	20.0	1.36	9/5/70
North Fork Creek	22.5	2.12	9/3/70
North Fork Creek	22.5	2.22	9/2/70
Tygarts Creek	22.5	2.30	7/15/70
North Fork Creek	22.5	2.32	9/2/70
North Fork Creek	23.0	2.36	9/2/70
North Fork Creek	24.0	2.52	9/2/70
	14 fish	20.26 lbs.	
North Fork Creek	16.0	0.88	9/30/71
Licking River	20.5	1.70	10/13/71
North Fork Creek	21.0	1.96	9/30/71
North Fork Creek	23.0	2.48	9/30/71
Licking River	25.0	3.02	10/13/71
North Fork Creek	25.0	3.40	9/30/71
Red River	27.0	5.50	10/6/71
North Fork Creek	29.0	5.20	9/30/71
	8 fish	24.14 lbs.	

On 10/7/71, removed 3 musky from Holding Pond #3 and placed in Holding Pond #2; the 3 fish weighed approximately 8 pounds.

	(3 fish)	(8.00 lbs.)	
Total	25 fish	52 pounds	1970-1971
Holding Pond #3 - Bath County Farm Pond - 3-4 acres			
Beaver Creek	16.0	0.82	8/24/71
Beaver Creek	17.5	1.10	8/24/71
Beaver Creek	20.0	1.74	8/24/71
Licking River	22.0	2.00	8/31/71
Beaver Creek	23.5	3.24	8/24/71
Licking River	25.5	3.24	9/1/71

Table 24. (continued)

Stream	Total length (in.)	Weight (lbs.)	Date collected
Holding Pond #3 - Bath County Farm Pond - 3-4 acres (cont.)			
Beaver Creek	26.0	3.74	8/24/71
Licking River	27.0	3.60	9/1/71
Licking River	27.0	4.48	9/1/71
N.F. Triplett Creek	30.0	7.35	8/25/71
	10 fish	31.31 lbs.	
On 10/7/71, removed 7 musky from Holding Pond #3 and placed in Holding Ponds #1 and #2.			
	(-7 fish)		
Total	3 fish		

The musky in holding ponds #1 and #2 were transferred to Minor Clark Fish Hatchery in 1973 (Brewer, 1973); neither holding pond could be drained completely, and a total of 15 musky were removed from pond #1 and a total of 11 musky were removed from pond #2. The musky transferred to the hatchery enabled the production of native musky fingerlings in 1973 (Hearn, 1973).

Evaluation of Musky Fry Stockings

Grayson Lake was stocked with 20,000 fry (13 per acre) in 1969 and Lake Linnville was stocked with 20,000 fry (40 per acre) in 1970. Electrofishing efforts at Grayson Lake in 1969 and 1970 and at Lake Linnville in 1970 yielded no musky. Seining efforts at Grayson Lake in 1969 also yielded no musky. As far as known, the above stocked fry have resulted in no creeled musky from either lake.

Table 25. Growth of musky in temporary holding ponds.

	Date tagged / Date recaptured	Time elapsed (months)	Total length (inches)	Total weight (pounds)
1.	September, 1971 / May, 1972	8	21.0 / 21.5	1.96 / 2.04
2.	September, 1970 / September, 1971	12	22.5 / 30.5	2.22 / 5.40
3.	September, 1970 / September, 1971	12	22.5 / 29.0	2.12 / 6.30
4.	October, 1971 / March, 1973	17	26.0 / 32.0	3.64 / -
5.	September, 1970 / May, 1972	20	26.5 / 32.5	3.65 / -
*6.	July, 1970 / April, 1971	9	28.0 / 31.5	5.40 / 9.35
*7.	April, 1971 / September, 1971	5	31.5 / 33.5	9.35 / -
*8.	September, 1971 / March, 1973	18	33.5 / 36.0	- / -
9.	September, 1971 / May, 1972	8	29.0 / 29.5	5.20 / 7.30
10.	July, 1970 / March, 1973	32	29.0 / 34.0	6.45 / -
11.	July, 1970 / March, 1973	32	30.0 / 33.5	6.20 / -
12.	July, 1970 / March, 1973	32	31.0 / 34.0	7.50 / -
**13.	July, 1970 / September, 1971	14	34.0 / 34.5	9.75 / 11.50
**14.	September, 1971 / March, 1973	18	34.5 / 36.0	11.50 / -

* Regards the same fish
** Regards the same fish

On May 21, 1970, a total of 1,000 musky fry were stocked into three pools on Big Benson Creek near Frankfort, Kentucky. Observations after stocking showed that many of the stocked fry were immediately preyed upon by sunfishes and possibly by large shiners. On May 24, 1970, the stocking sites were waded and one musky fry was observed; on May 27, 1970, the stocking sites were again waded and no fry were seen. Jones (1973) chemically sampled two of the stocking sites during August and September, 1970, and no musky were collected from a total sample of 419 feet, or 0.43 acre.

Estimation of the Miles and Acres of Musky Pool Habitat Present in Native Musky Streams

A list of streams in Kentucky which have reportedly yielded creeled musky during the last 25-30 years is presented in Table 26, pp. 80-81. Presently, musky have an extinct or remnant population status at North Fork of Kentucky River, Big Sandy River, Middle Fork of Kentucky River (below Buckhorn Dam), Kentucky River, and Big South Fork of Cumberland River. The North Fork of Kentucky River and Big Sandy River have been significantly degraded by silt pollution from coal-mining operations (Jones, 1973; Evenhuis, 1973). The Middle Fork of Kentucky River (below Buckhorn Dam) and the upper section of the Kentucky River are apparently suitable for musky populations but an impoundment on Middle Fork of Kentucky River and lock-and-dam structures on Kentucky River have apparently restricted musky spawning at the two rivers by either eliminating spawning habitat or by restricting access to such habitat. Musky are present in the Big South Fork of Cumberland River in Tennessee (Parsons, 1959), but are apparently very uncommon in the Kentucky section of that river.

Table 26. Acreage of musky pool habitat in those streams reportedly yielding musky during recent history (approximately 1945 to 1972). Yields reported by local conservation officers.

Stream	Range of musky distribution in each stream (mile 0 is at the mouth)	Number of miles of musky pool habitat in each stream	Average width of musky pool habitat in each stream	Total acreage of musky pool habitat in each stream
Ohio River Drainage				
Salt Lick Creek	mile 0 to mile 7	(a very small musky population)		---
Kinniconick Creek	mile 0 to mile 38	19	85	195
Laurel Creek	mile 0 to mile 12	(used by musky as a spawning site)		---
Tygarts Creek	mile 0 to mile 75	43	80	413
Little Sandy River	mile 0 to mile 50	30	110	400
Big Sandy River	mile 0 to mile 28	(extinct or remnant population)		(400)
Licking River	mile 131 to mile 240	68	90	783
North Fork Triplett Creek	mile 0 to mile 15	7	70	76
North Fork Creek	mile 0 to mile 10	3	-	22
Beaver Creek	mile 0 to mile 7	2	-	13
Kentucky River	mile 195 to mile 259	(remnant population)		(1,784)
Red River	mile 0 to mile 66	33	67	268
Station Camp Creek	mile 0 to mile 19	7	53	49
Sturgeon Creek	mile 0 to mile 12	5	70	41
North Fork Kentucky River	mile 0 to mile 63	(extinct population)		(648)
Middle Fork Kentucky River				
Below Buckhorn Dam	mile 0 to mile 43	(extinct or remnant population)		(256)
Above Buckhorn Dam	mile 67 to mile 81	7	79	68
Greasy Creek	mile 0 to mile 10	(used by musky as a spawning site)		---
South Fork Kentucky River	mile 0 to mile 40	32	130	509
Sexton Creek	mile 0 to mile 12	4	60	28
Big Goose Creek plus Collins Fork of Big Goose Creek	mile 0 to mile 33	12	80	112

Table 26. (continued)

Stream	Range of musky distribution in each stream (mile 0 is at the mouth)	Number of miles of musky pool habitat in each stream	Average width of musky pool habitat in each stream	Total acreage of musky pool habitat in each stream
Ohio River Drainage				
Green River	Lock 4 to Green River Lake	130	156-195	2412
Nolin River	mile 0 to mile 8	8	90	88
Barren River	mile 0 to mile 78	70	173	1451
Drakes Creek	mile 0 to mile 16	9	100	110
Little Barren River	mile 0 to mile 16	(used by musky as a spawning site)		---
Big South Fork of Cumberland River	Yamacraw to state line	(extinct or remnant population)		(127)
TOTALS (Excluding streams with extinct or remnant populations and streams used only for spawning)	758 miles	489 miles	50-200	7038 acres*

* During the year 1974, Cave Run Dam impounded 62 miles of musky range or 28 miles of musky pool habitat or 315 acres of musky pool habitat.
During the years 1969-1974, pollution from coal mining degraded musky in Big Goose Creek and Sexton Creek to the level of a remnant population thereby affecting 45 miles of musky range or 16 miles of musky pool habitat or 140 acres of musky pool habitat.

Some of the streams listed in Table 26 have only very minimal musky populations and are used by musky primarily only for spawning. These include Salt Lick Creek (Lewis County), Laurel Creek (Lewis County), Greasy Creek (Leslie County), and Little Barren River.

As of 1973, there were 18 Kentucky streams having appreciable musky populations. These streams provided 758 miles of musky range and 489 miles or 7,038 acres of musky pool habitat (see Table 26). By 1974, Cave Run Dam had impounded portions of Licking River, North Fork Creek and Beaver Creek; and Cave Run Lake impounded 62 miles of musky range and 28 miles or 315 acres of musky pool habitat in the above three streams. Also, by 1974, silt and acid pollution at Big Goose Creek and Sexton Creek had been sufficiently chronic to degradate musky in those two streams to a remnant status. So by 1974, Kentucky had 14 streams with appreciable musky populations and these streams provided 651 miles of musky range and 445 miles or 6,583 acres of musky pool habitat. These streams included the following:

Kinniconick Creek	Sturgeon Creek
Tygarts Creek	Green River
Licking River (below Cave Run Dam)	Middle Fork Kentucky River (above Buckhorn Dam)
Little Sandy River	South Fork Kentucky River
North Fork Triplett Creek	Barren River
Red River	Drakes Creek
Station Camp Creek	Nolin River*

*(the author is not very familiar with Nolin River and that stream may not presently have an appreciable musky population).

North Fork of Triplett Creek, Station Camp Creek and Sturgeon Creek are all comparatively small streams. During the project years, Drakes Creek was polluted at least twice by industrial wastes and at least some musky kill occurred. There are presently flood-control impoundments on Little Sandy River, Licking River, Middle Fork of Kentucky River, Green River, Barren River, and Nolin River; and, at various times, flood-control dams have been proposed for Kinniconick Creek, Tygarts Creek, Red River, and South Fork of Kentucky River. To date, impounded waters on musky streams have yielded extremely few musky to the creel, and it appears that musky reproduction in the impounded waters has been very minimal at best. Fishermen reports indicate that musky populations in the tailwaters of such impoundments have shown some decline possibly due to the restriction of musky access to former spawning sites and also possibly due to unfavorable discharge regimes in regards to musky spawning.

DISCUSSION

Sufficient data were gathered to provide relevant findings for all project objectives. In general, methodology improved over the project years and an earlier employment of the developed techniques would have resulted in somewhat better overall findings.

A general problem throughout the study was the inherently small size of the studied musky populations. This problem was most noticeable in regards to determinations of the size and structure of the musky populations. In retrospect, more chemical fish population studies would have been beneficial. Evaluations of musky population status were especially difficult for the larger streams; and it probably would have been beneficial if there had been an earlier and more extensive employment of such techniques as "intensive" electrofishing (see p. 9) and the use of more than one electrofishing unit at the larger study pools.

For the most part, musky population status was determined on the basis of sodium cyanide studies. Such studies were generally regarded as satisfactory but the chemical seemed to be relatively ineffective in regards to such fishes as carp, buffalo, and catfish, i.e., at the prevalent rates of application. It would also seem possible that large musky could have been frightened from the study areas during the initial setting of nets (this possibility was never substantiated but its possibility would have been important in regards to sampling a fish so generally uncommon as is the musky).

The study probably did not satisfactorily determine the extent to which small musky utilized small pools and riffle areas. Small pools and riffles were spot-sampled with sodium cyanide during 1967 and no musky were collected from such areas, but as it turned out, the 1967 musky year class was almost non-existent at the study streams. Of course, the near absence of the 1967 year-class influenced musky population data throughout the project since that year-class should have been important structure-wise during the project years 1967-1971.

Spawning studies were generally satisfactory, with the principal drawback being in the inadequate number of three-year-old musky collected during the spawning season. Such inadequacy somewhat obscured the determination of the first age of sexual maturity for musky.

In the determination of musky growth, it was necessary to use a mixed sample, i.e., musky scale samples were collected for different streams, different year-classes and different sexes; and, the overall sample was unbalanced and therefore biased towards certain streams, year-classes, and sexes. Generally speaking, calculated growth for musky in the streams was equal to or greater than growth reported for natural musky populations in other states (see Buss, 1960; Karvelis, 1964).

Certain environmental factors were evaluated in regard to their effect on musky reproduction success, and some of these factors did apparently affect musky reproduction. In regard to the effect of stream temperature and discharge, the evaluation placed a relatively high reliance on profiles of springtime temperature and discharge patterns for the Licking River. Such profiles were of good use especially when correlated with empirical findings such as the determined time of musky spawning, egg-hatching, etc, On the other hand, these simplified profiles were inadequate to account for musky reproduction success in an atypical year, e.g., 1966 (the spring of 1966 was unseasonably warm and expectedly musky would have spawned early, and any early spawning in 1966 would have been followed by high discharges indicating poor reproduction success but the data showed 1966 was a reasonably good musky reproduction year - 1966 was not a study year, so empirical data were lacking regarding reproduction events).

The studied streams were evidently much alike regarding springtime zooplankton abundance and zooplankton abundance did not appear to be a factor in the differences between streams in regards to musky reproduction success. Zooplankton studies were not conducted during 1967 and 1968 and as a result there was insufficient evidence to determine whether yearly changes in zooplankton abundance influenced yearly musky reproduction success at the individual streams.

Musky fry stockings at two reservoirs were apparently completely unsuccessful in terms of establishing any musky populations. Both reservoirs were at least partially filled during the summer prior to musky stocking and consequently each could have had sufficient fish populations to affect considerable predation on stocked fry. Pennsylvania has stocked musky fry into new impoundments at rates of about 100 fry per acre (Sanderson, pers. comm.), so the rates of 13 and 40 fry per acre at the two reservoirs were perhaps too small.

The findings provided some justification for maintenance stockings of large musky fingerlings into native musky streams. Evidently, the studied streams were capable of providing musky recruitment at rates of 1.0 - 1.6 large fingerlings per acre of pool habitat during a good year, yet overall annual recruitment averaged only 0.5 large fingerling per acre of pool habitat. Important factors limiting recruitment appeared to be unfavorable temperatures, discharges, and silt loads during the reproduction season. Supposedly, maintenance stockings would compensate for any musky reproduction lost due to the above physical factors. Also, sodium cyanide studies showed sizeable populations of harvestable-sized suckers and shad at the study streams and supposedly some of this "forage" weight would be converted to gamefish weight if musky populations were increased by fingerling stockings.

Those streams exhibiting good musky recruitment had relatively undisturbed watersheds and/or relatively abundant populations of small forage fishes; it could not be determined whether watershed characteristics or small forage abundance was the more important factor affecting recruitment. Supposedly, if watershed characteristics were more important, then there would probably be even more justification for maintenance stockings; but, if the abundance of small forage was more important, then maintenance stockings would not be so effective since the success of such stockings would require a certain level of small forage abundance. It would seem obvious that both factors are at least somewhat important and, while maintenance stockings seem to have evident justification, it follows that such stockings should be evaluated to determine whether stockings are showing results comparable to the involved costs.

At present, retention of the 30-inch size limit seems justified according to the findings. A greater size limit of 32 or 33 inches would be somewhat more inclusively protective of musky through their first spawning season, but such increased size limits would in effect change the average legal creel age from Age IV to Age V and musky suffering natural mortality between Ages IV and V would be lost to the creel.

S U M M A R Y

Native populations of muskellunge (Esox masquinongy ohioensis) in Kentucky streams were investigated in respect to the following: the size and structure of such populations; the minimum size of the musky at maturity; the time, places, and duration of musky spawning; the success of reproduction and the survival of young musky; the growth rate; and an evaluation of factors limiting musky populations. Initially, investigations were limited to six streams but later studies were expanded to include a total of eleven streams, all of which were located in eastern Kentucky (musky also occur in some south-central Kentucky streams). Musky were collected by use of electrofishing gear, sodium cyanide, and hoop nets.

Initial studies indicated that musky in the streams primarily inhabited low-gradient pools; therefore, the amount of such pool habitat was determined for each stream and the quantitative status of musky populations was determined solely in terms of such habitat. For example, musky were usually found to occur at rates of 1.5 to 2.0 pounds per acre of pool habitat. And, population sampling showed that musky comprised 5.4% of the existing fish weight at such pools. The structure of musky populations at the smaller streams was as follows: young-of-the-year musky generally occurred at a rate of about one per every 2.0 acres of pool habitat; sub-legal musky (10.5 to 29.9 inches) occurred at rates of about one per every 2.0 to 2.5 acres of pool habitat; and, legal musky occurred at rates of about one per every 12 to 14 acres of pool habitat. At the larger streams, there were indications that legal musky often occurred at rates of one per every 7 to 10 acres of pool habitat and concurrently, rates for the smaller musky seemed to be less than that at smaller streams.

Musky in the streams generally first spawned at Age 4, but there was some evidence that relatively fast-growing musky may have spawned at Age III. The average length of musky at Age IV was 29.4 inches and the prevailing 30-inch size limit protected most musky through their first spawning season. As far as could be determined, spawning took place at those shallow waters located at either the upper or lower ends of low-gradient pools. The chronology of reproduction events was typically as follows: musky began their initial pre-spawning movements near the end of March, with such movements directed towards spawning habitat located either in the trunk stream or in a tributary stream; by the second or third week in April most musky had reached their spawning habitat; musky generally spawned during the last half of April or early May when water temperatures were averaging 55°-60° F.; the time of egg-hatching was determined to have been about the second week of May, with swim-up occurring about the third week of May; by the last week of May, young musky were 0.8 to 1.2 inches long. Adult musky made post-spawning movements and by June they were found as far as 12 miles from their spawning habitat.

Success of reproduction varied considerably from year to year, with almost no recruitment during a very poor year, and with recruitment averaging about one large fingerling (9 - 10 inches) per acre of pool habitat during a very good year. Overall, large fingerlings were recruited at an average rate of about one per every two acres of pool habitat.

Growth in length as calculated by the Lee Method was 10.4 inches at Age I, 18.0 inches at Age II, 24.4 inches at Age III, 29.4 inches at Age IV, 32.7 inches at Age V, and 35.3 inches at Age VI. The equation expressing length-weight relationship was determined to be Log W = -4.11002 + 3.32788 Log L; and, calculated weights were determined for all lengths of musky expected to be found at the streams. Growth as shown by tagging studies agreed well with calculated growths. Tagging studies also showed that about 33% of all tagged musky were creeled within a year after tagging.

Prevailing springtime water temperatures and discharges evidently had a decided impact on musky reproduction success, with low discharges and seasonable temperatures during late April and early May being favorable, and high discharges and low temperatures during the same period being unfavorable. The relative effect seemed most important in regards to the musky egg and early sac fry stages. Those streams exhibiting good musky reproduction had relatively undisturbed watersheds and relatively abundant populations of small forage fishes; relative springtime zooplankton abundance was similar for both good and poor reproduction streams.

Studies involving musky populations were eventually appended to include several management-oriented activities. A number of collected musky were removed from the study streams for use as broodstock at a state hatchery; such broodstock later enabled the production of native musky fingerlings. Also, two reservoirs were stocked with non-native musky fry and follow-up evaluations indicated no success resulting from the stockings. The final activity involved a determination of the amount of musky stream habitat present in the state. As of 1974, Kentucky had 14 streams with appreciable musky populations and such streams provived about 6,600 acres of musky pool habitat. Several other streams had either small, remnant, or extinct musky populations. The available evidence indicated that considerable musky stream habitat in the state had been destroyed or degraded by the impoundment and/or pollution of musky streams.

It was recommended that data from this investigation be used for the purpose of abating or litigating further encroachments on musky stream habitat. It was also recommended that most musky streams in the state receive maintenance stockings of large musky fingerlings. The recommended stocking rate for most musky streams was one fingerling per every two acres of pool habitat, but stocking rates for a few streams could be as high as one fingerling per acre of pool habitat. A list of musky streams having possible potential for maintenance stockings was presented along with the associated amount of pool habitat for each stream. Maintenance stockings were recommended on the basis that certain environmental factors limit inherent musky recruitment at the streams.

R E C O M M E N D A T I O N S

1. The findings of this study should be used for the abatement or litigation of further encroachment on musky habitat in Kentucky streams.

2. Most musky streams in the state should receive maintenance stockings of large fingerling musky with such stockings being in compensation of natural musky reproduction which is lost due to adverse environmental factors. A list of streams having possible potential for maintenance stockings is presented in Table 27, p. 91. The recommended annual stocking rate for most streams is one large musky fingerling per every two acres of musky pool habitat. Stocking rates of one fingerling per acre could be implemented at such streams as Kentucky River which apparently have limited musky spawning areas or at such streams as Green River or Barren River which have relatively high fish standing crops (see Charles, 1964; Turner, 1963, 1964). Pennsylvania has stocked large musky fingerlings at rates of 50-75 per mile for streams about 300 feet wide, such streams having either inadequate musky reproduction or recovery from fish kills (Sanderson, pers. comm.); these rates apparently would average out to about 1.5 - 2.0 fingerlings per acre which would seem somewhat high for Kentucky streams although one studied stream, i.e., North Fork Creek, produced large musky fingerlings at a rate of 1.6 per acre of pool habitat during the period 1967-1969.

3. Future maintenance stockings should be evaluated to determine whether such stockings are showing results comparable to the involved costs.

Table 27. Native musky streams having potential for maintenance stockings with fingerling musky. Stockings should be recommended only after considering prevalent pollution and other stocking programs (such as tailwater trout stocking programs).

Stream	Total miles of musky range in stream	Total miles of musky pool habitat in stream	Total acreage of musky pool habitat in stream
Kinniconick Creek	38	19	195
Tygarts Creek	75	43	413
Little Sandy River Below Grayson Dam	50	30	400
Licking River Below Cave Run Dam	45	34	433
North Fork of Triplett Creek	15	7	76
Kentucky River	64	64	1784
Red River	66	33	268
Station Camp Creek	19	7	49
Sturgeon Creek	12	5	41
Middle Fork Kentucky River Below Buckhorn Dam	43	28	256
South Fork Kentucky River	40	32	509
Sexton Creek	12	4	28
Big Goose Creek	33	12	112
Green River From Green River Dam down to Lock 4	156	130	2412
Nolin River Below Nolin Dam	8	8	88
Barren River Below Barren Dam	78	70	1451
Drakes Creek	16	9	110
Totals	770	535	8625

A C K N O W L E D G M E N T S

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A P P E N D I X

Table A - 1. Fish population composition of study streams during 1967-1969 (13.82 acres); all streams combined (North Fork Creek, North Fork of Triplett Creek, Beaver Creek, Kinniconick Creek, Red River, and Big Goose Creek). Populations sampled by sodium cyanide.

Species	Fingerling size: Size range (inches)	Fingerling size: Number per acre	Fingerling size: Pounds per acre	Intermediate size: Size range (inches)	Intermediate size: Number per acre	Intermediate size: Pounds per acre	Harvestable size: Minimum size (inches)	Harvestable size: Number per acre	Harvestable size: Pounds per acre	Percent of total number	Percent of total weight
Game Fishes											
Ohio Muskellunge				5-29	0.9	1.43	30	0.1	0.43	0.2	5.40
Grass Pickerel	0-4	0.4	0.01	5-9	2.1	0.14	10	0.3	0.08	0.4	0.64
Largemouth Bass	0-4	1.4	0.03	5-9	1.3	0.39	10	0.4	0.60	0.5	2.95
Smallmouth Bass				5-9	0.8	0.24	10	0.3	0.24	0.2	1.39
Spotted Bass	0-4	4.8	0.08	5-9	3.5	0.73	10	0.7	0.50	1.4	3.78
White Crappie	0-4	71.8	0.34	5-7	0.4	0.03	8	1.0	0.57	11.5	2.73
TOTALS		78.3	0.44		9.1	2.95		2.7	2.43	14.2	16.90
Food Fishes											
Channel Catfish	0-4	0.2	tr.	5-9	0.1	0.01	10	0.1	0.27	0.1	0.81
Flathead Catfish	0-4	0.2	tr.	5-9	0.3	0.04	10	0.4	0.21	0.1	0.73
TOTALS		0.4	tr.		0.4	0.05		0.5	0.47	0.2	1.54
Predatory Fishes											
Longnose Gar				5-23	1.1	0.21	24	0.1	0.40	0.2	1.75
TOTALS					1.1	0.21		0.1	0.40	0.2	1.75
Panfishes											
Rock Bass	0-2	4.2	0.03	3-5	10.4	0.56	6	8.7	2.19	3.7	8.07
Bluegill	0-2	20.8	0.08	3-5	11.1	0.67	6	5.7	1.21	5.9	5.70
Green Sunfish	0-2	2.5	0.02	3-5	9.3	0.43	6	1.7	0.29	2.1	2.14
Hybrid Sunfish				3-5	0.4	0.04	6	0.1	0.04	0.1	0.21
Longear Sunfish	0-2	61.3	0.34	3-5	70.8	2.75	6	4.7	0.64	21.6	10.84
Warmouth	0-2	0.5	tr.	3-5	0.9	0.03	6	0.2	0.05	0.3	0.26
TOTALS		89.3	0.47		103.0	4.48		21.1	4.42	33.6	27.23

Table A - 1. (continued)

Species	Fingerling size: Size range (inches)	Fingerling size: Number per acre	Fingerling size: Pounds per acre	Intermediate size: Size range (inches)	Intermediate size: Number per acre	Intermediate size: Pounds per acre	Harvestable size: Minimum size (inches)	Harvestable size: Number per acre	Harvestable size: Pounds per acre	Percent of total number	Percent of total weight
Commercial Fishes											
Buffalofishes							12	0.1	0.74	tr.	2.16
Hogsucker	0-4	0.4	0.01	5-11	0.9	0.24	12	0.1	0.07	0.2	0.91
Redhorses	0-4	13.7	0.23	5-11	12.8	3.21	12	4.8	4.70	4.9	23.68
White Sucker				5-11	0.4	0.03				0.1	tr.
Spotted Sucker	0-4	1.4	0.02	5-11	2.9	0.68	12	0.3	0.21	0.7	2.64
Bullheads	0-4	0.4	tr.	5-8	0.1	0.02	9	0.1	0.06	0.1	0.23
Drum							10	0.2	0.70	tr.	2.04
TOTALS		15.8	0.26		17.1	4.19		5.5	6.48	6.1	31.76
Forage Fishes											
Gizzard Shad				4-7	1.0	0.11	8	20.3	5.60	3.4	16.58
Notropis spp.	0-3	33.6	0.18	4-7	4.9	0.19	8	0.1	0.01	6.1	1.14
Other Cyprinids	0-3	157.9	0.54	4-7	3.9	0.08				25.5	1.82
Madtoms	0-3	12.5	0.09	4-7	1.6	0.02				2.2	0.33
Stonecat				4-7	0.2	0.01				tr.	0.03
Darters	0-3	47.7	0.25	4-7	2.7	0.06				7.9	0.88
Brook Silversides	0-3	3.4	0.01							0.5	0.04
Sculpins	0-3	0.1	tr.							tr.	tr.
TOTALS		255.1	1.08		14.3	0.48		20.4	5.61	45.7	20.81
GRAND TOTALS		439.0	2.25		144.9	12.34		50.4	19.81	100.0	100.00

Table A-2 List of fishes collected from six study streams during 1967 - 1971.

		Beaver Creek	N.F. Triplett Cr.	North Fork Creek	Licking River	Red River	Kinniconick Creek
PETROMYZONTIDAE - Lampreys							
Lampetra aepyptera (Abbot)	Least brook lamprey	x	x	x	x	x	
LEPISOSTEIDAE - gars							
Lepisosteus osseus (Linnaeus)	Longnose gar	x	x	x	x	x	x
ANGUILLIDAE - freshwater eels							
Anguilla rostrata (LeSueur)	American eel		x		x	x	x
CLUPEIDAE - herrings							
Alosa chrysochloris (Rafinesque)	Skipjack herring				x		
Dorosoma cepedianum (LeSueur)	Gizzard shad	x	x	x	x	x	x
HIODONTIDAE - mooneyes							
Hiodon tergisus LeSueur	Mooneye				x	x	
SALMONIDAE - trouts							
Salmo gairdneri Richardson	Rainbow trout		x	x			x
ESOCIDAE - pikes							
Esox americanus vermiculatus LeSueur	Grass pickerel	x	x	x	x		x
Esox masquinongy Mitchill	Muskellunge	x	x	x	x	x	x
CYPRINIDAE - minnows and carps							
Campostoma anomalum (Rafinesque)	Stoneroller	x	x	x	x	x	x
Cyprinus carpio Linnaeus	Carp	x	x	x	x	x	x
Ericymba buccata Cope	Silverjaw minnow		x				x
Hybopsis amblops (Rafinesque)	Bigeye chub				x		x
Hybopsis storeriana (Kirtland)	Silver chub				x		
Nocomis micropogon (Cope)	River chub		x	x	x	x	x
Notropis ardens (Cope)	Rosefin shiner	x	x				x
Notropis ariommus (Cope)	Popeye shiner						x
**Notropis atherinoides* Rafinesque	Emerald shiner				x		
Notropis blennius (Girard)	River shiner		x				
Notropis boops Gilbert	Bigeye shiner		x				x
Notropis cornutus (Mitchill)	Common shiner	x	x	x	x	x	x
Notropis photogenis (Cope)	Silver shiner	x	x	x	x	x	x

		Beaver Creek	N.F. Triplett Cr.	North Fork Creek	Licking River	Red River	Kinniconick Creek
CYPRINIDAE - (continued)							
Notropis rubellus (Agassiz)	Rosyface shiner	x	x	x	x	x	x
Notropis spilopterus (Cope)	Spotfin shiner		x				
Notropis stramineus (Cope)	Sand shiner	x					
Notropis umbratilis (Girard)	Redfin shiner	x		x	x		
Notropis volucellus (Cope)	Mimic shiner	x		x	x	x	
Notropis whipplei (Girard)	Steelcolor shiner				x		
Pimephales notatus (Rafinesque)	Bluntnose minnow	x	x	x	x	x	x
Pimephales promelas Rafinesque	Fathead minnow	x	x				
Pimephales vigilax (Baird and Girard)	Bullhead minnow		x		x		
Phoxinus erythrogaster (Rafinesque)	Southern redbelly dace	x					
Semotilus atromaculatus (Mitchill)	Creek chub	x	x	x	x		x
CATOSTOMIDAE - suckers							
Carpiodes carpio (Rafinesque)	River carpsucker				x		
Carpiodes cyprinus (LeSueur)	Quillback				x		
Carpiodes velifer (Rafinesque)	Highfin carpsucker				x	x	
Catostomus commersoni (Lacépède)	White sucker	x	x	x	x		
Hypentelium nigricans (LeSueur)	Northern hogsucker	x	x	x	x	x	x
Ictiobus bubalus (Rafinesque)	Smallmouth buffalo		x		x		x
Ictiobus cyprinellus (Valenciennes)	Bigmouth buffalo		x		x		
Minytrema melanops (Rafinesque)	Spotted sucker	x	x	x	x	x	x
Moxostoma anisurum (Rafinesque)	Silver redhorse	x		x	x	x	
Moxostoma macrolepidotum (LeSueur)	Shorthead redhorse	x		x	x	x	
Moxostoma carinatum (Cope)	River redhorse	x	x	x	x	x	x
Moxostoma duquesnei (LeSueur)	Black redhorse					x	
Moxostoma erythrurum (Rafinesque)	Golden redhorse	x	x	x	x	x	x
ICTALURIDAE - freshwater catfishes							
Ictalurus melas (Rafinesque)	Black bullhead	x	x				
Ictalurus natalis (LeSueur)	Yellow bullhead	x	x		x		x
Ictalurus punctatus (Rafinesque)	Channel catfish	x	x	x	x	x	x
Noturus flavus Rafinesque	Stonecat	x	x	x	x		x
Noturus miurus Jordan	Brindled madtom	x	x	x	x	x	x
Pylodictis olivaris (Rafinesque)	Flathead catfish	x		x	x	x	x
PERCOPSIDAE - trout perch							
Percopsis omiscomaycus (Walbaum)	Trout-perch						x
ATHERINIDAE - silversides							
Labidesthes sicculus (Cope)	Brook silverside	x	x	x	x		x

		Beaver Creek	N.F. Triplett Cr.	North Fork Creek	Licking River	Red River	Kinniconick Creek
CENTRARCHIDAE - sunfishes							
Ambloplites rupestris (Rafinesque)	Rock bass	x	x	x	x	x	x
Lepomis cyanellus Rafinesque	Green sunfish	x	x	x	x		x
Lepomis gulosus (Cuvier)	Warmouth		x	x	x		x
Lepomis macrochirus Rafinesque	Bluegill	x	x	x	x	x	x
Lepomis megalotis (Rafinesque)	Longear sunfish	x	x	x	x	x	x
Lepomis microlophus (Günther)	Redear sunfish	x				x	
Lepomis sp.	Hybrid sunfish	x	x	x		x	x
Micropterus dolomieui Lacépède	Smallmouth bass	x	x	x	x	x	x
Micropterus punctulatus (Rafinesque)	Spotted bass	x	x	x	x	x	x
Micropterus salmoides (Lacépède)	Largemouth bass	x	x	x	x	x	x
Pomoxis annularis Rafinesque	White crappie	x	x	x	x	x	x
Pomoxis nigromaculatus (LeSueur)	Black crappie	x	x	x	x		
PERCIDAE - perches							
Ammocrypta pellucida (Putnam)	Eastern sand darter			x	x		
Etheostoma blennioides Rafinesque	Greenside darter	x	x	x	x	x	x
Etheostoma caeruleum Storer	Rainbow darter	x	x	x	x	x	x
Etheostoma flabellare Rafinesque	Fantail darter	x	x	x	x	x	x
Etheostoma nigrum Rafinesque	Johnny darter	x	x	x	x	x	x
Etheostoma stigmaeum (Jordan)	Speckled darter				x		
Etheostoma variatum Kirtland	Variegate darter	x	x	x	x	x	x
Etheostoma zonale (Cope)	Banded darter			x	x		
Percina caprodes (Rafinesque)	Logperch	x	x	x	x	x	x
Percina copelandi (Jordan)	Channel darter			x	x		
Percina cymatotaenia (Gilbert and Meek)	Bluestripe darter					x	
**Percina evides* (Jordan and Copeland)	Gilt darter				x		
Percina macrocephala (Cope)	Longhead darter				x		x
Percina maculata (Girard)	Blackside darter	x	x	x	x	x	x
**Percina phoxocephala* (Nelson)	Slenderhead darter				x		
Percina sciera (Swain)	Dusky darter					x	x
**Percina shumardi* (Girard)	River darter				x		
**Stizostedion canadense* (Smith)	Sauger		x		x		
SCIAENIDAE - drums							
Aplodinotus grunniens Rafinesque	Freshwater drum	x		x	x	x	x
COTTIDAE - sculpins							
Cottus bairdi Girard	Mottled sculpin		x	x			

*Species collected by William R. Turner during 1963 from the Licking River and not subsequently collected during this project.

Table A - 3. Lengths of musky collected from the study streams with corresponding empirical and calculated weights.

Total length (in.)	Average empirical weight (lb.)	Calculated weight (lb.)	Total length (in.)	Average empirical weight (lb.)	Calculated weight (lb.)
1.0		0.00	22.5	2.25	2.45
1.5		0.00	23.0	2.37	2.64
2.0		0.00	23.5	2.97	2.84
2.5		0.00	24.0	2.68	3.04
3.0		0.00	24.5	2.98	3.26
3.5		0.01	25.0	3.27	3.49
4.0		0.01	25.5	3.40	3.72
4.5	0.01	0.01	26.0	3.70	3.97
5.0		0.02	26.5	3.65	4.23
5.5		0.02	27.0	4.47	4.50
6.0		0.03	27.5	4.10	4.79
6.5	0.04	0.04	28.0	5.09	5.08
7.0		0.05	28.5	5.55	5.39
7.5		0.06	29.0	5.68	5.71
8.0	0.10	0.08	29.5		6.04
8.5		0.10	30.0	6.65	6.39
9.0		0.12	30.5	6.58	6.75
9.5	0.15	0.14	31.0	8.08	7.13
10.0	0.15	0.17	31.5	7.19	7.52
10.5	0.20	0.19	32.0	8.20	7.92
11.0	0.23	0.23	32.5	9.30	8.34
11.5		0.26	33.0	9.38	8.78
12.0	0.29	0.30	33.5	9.06	9.23
12.5	0.43	0.35	34.0	10.30	9.70
13.0	0.46	0.40	34.5	11.34	10.18
13.5		0.45	35.0	10.22	10.68
14.0	0.49	0.51	35.5	10.75	11.19
14.5	0.62	0.57	36.0	12.25	11.73
15.0	0.61	0.64	36.5	13.20	12.28
15.5		0.71	37.0	15.95	12.85
16.0	0.81	0.79	37.5	14.35	13.43
16.5		0.87	38.0	14.27	14.04
17.0	0.87	0.97	38.5		14.66
17.5	1.01	1.06	39.0	16.45	15.31
18.0	1.12	1.17	39.5		15.97
18.5	1.23	1.28	40.0	18.83	16.65
19.0	1.38	1.40	40.5		17.35
19.5	1.42	1.52	41.0		18.08
20.0	1.62	1.66	41.5		18.82
20.5	1.79	1.80	42.0		19.59
21.0	1.89	1.95	42.5		20.37
21.5	2.26	2.11	43.0		21.18
22.0	2.19	2.28	43.5		22.01

Table A - 3 . (Continued)

Total length (in.)	Average empirical weight (lb.)	Calculated weight (lb.)	Total length (in.)	Average empirical weight (lb.)	Calculated weight (lb.)
44.0	23.85	22.87	50.0		34.99
44.5		23.47	50.5		36.17
45.0	20.80	24.64	51.0		37.37
45.5	-	25.56	51.5		38.61
46.0		26.51	52.0		39.87
46.5		27.48	52.5		41.16
47.0	25.30	28.48	53.0		42.48
47.5		29.50	53.5		43.82
48.0		30.54	54.0		45.20
48.5		31.62	54.5		46.61
49.0		32.72	55.0		48.05
49.5		33.84			

Table A - 4. Individual stream gradients.

Stream	Distance from headwaters (miles)	Gradient (feet per mile)	Extent of musky population*
Beaver Creek	0.0 - 5.0	56.0	0
	5.0 - 10.0	13.0	0
	10.0 - 15.0	10.0	+
	15.0 - 19.3	7.1	+
North Fork Creek	0.0 - 5.0	40.0	0
	5.0 - 10.0	12.6	0
	10.0 - 15.0	4.4	+
	15.0 - 21.4	2.8	+
Sexton Creek	0.0 - 8.0	31.3	0
	8.0 - 13.0	19.0	0
	13.0 - 18.0	11.0	+
	18.0 - 23.0	4.0	+
North Fork Triplett Creek	0.0 - 5.0	53.4	0
	5.0 - 10.0	18.6	0
	10.0 - 15.0	13.0	0
	15.0 - 20.0	6.0	+
	20.0 - 25.0	5.0	+
	25.0 - 31.8	1.9	+
Sturgeon Creek	0.0 - 8.8	35.2	0
	8.8 - 13.8	20.0	0
	13.8 - 18.8	15.0	0
	18.8 - 23.8	10.0	x
	23.8 - 28.8	11.0	+
	28.8 - 33.8	9.0	+
Big Goose Creek and Collins Fork of Big Goose Creek	0.0 - 5.0	40.6	0
	5.0 - 10.0	2.8	0
	10.0 - 15.0	7.0	+
	15.0 - 20.0	2.6	+
	20.0 - 25.0	2.4	+
	25.0 - 30.0	3.2	+
	30.0 - 35.0	1.6	+
	35.0 - 40.0	1.6	+
	40.0 - 43.1	7.3	+

Table A - 4. (continued)

Stream	Distance from headwaters (miles)	Gradient (feet per mile)	Extent of musky population*
Kinniconick Creek	0.0 - 5.0	61.0	0
	5.0 - 10.0	15.0	0
	10.0 - 15.0	8.0	+
	15.0 - 20.0	9.0	+
	20.0 - 25.0	9.0	+
	25.0 - 30.0	4.0	+
	30.0 - 35.0	3.0	+
	35.0 - 40.0	4.4	+
	40.0 - 45.0	5.6	+
	45.0 - 49.0	7.5	+
Little Sandy River	0.0 - 10.0	38.0	0
	10.0 - 20.0	5.3	0
	20.0 - 30.0	2.1	+
	30.0 - 40.0	2.4	+
	40.0 - 50.0	1.5	+
	50.0 - 60.0	2.2	+
	60.0 - 70.0	1.7	+
	70.0 - 80.0	2.3	+
	80.0 - 82.5	4.8	+
Tygarts Creek	0.0 - 10.0	32.5	0
	10.0 - 20.0	5.9	x
	20.0 - 30.0	4.8	+
	30.0 - 40.0	3.8	+
	40.0 - 50.0	3.5	+
	50.0 - 60.0	2.4	+
	60.0 - 70.0	2.3	+
	70.0 - 80.0	2.5	+
	80.0 - 87.5	2.0	+
Red River	0.0 - 10.0	24.4	0
	10.0 - 20.0	16.6	0
	20.0 - 30.0	8.0	+
	30.0 - 40.0	10.2	+
	40.0 - 50.0	3.8	+
	50.0 - 60.0	2.0	+
	60.0 - 70.0	2.3	+
	70.0 - 80.0	2.0	x
	80.0 - 93.5	1.3	x

Table A - 4. (continued)

Stream	Distance from headwaters (miles)	Gradient (feet per mile)	Extent of musky population*
Licking River	0.0 - 15.0	11.3	0
	15.0 - 30.0	7.0	0
	30.0 - 45.0	2.3	0
	45.0 - 60.0	2.3	0
	60.0 - 75.0	1.8	x
	75.0 - 90.0	1.5	+
	90.0 - 105.0	1.8	+
	105.0 - 120.0	1.3	+
	120.0 - 135.0	2.0	+
	135.0 - 150.0	0.9	+
	150.0 - 165.0	1.3	+
	165.0 - 180.0	0.9	x
	180.0 - 195.0	1.0	0
	195.0 - 210.0	0.9	0
	210.0 - 225.0	1.1	0
	225.0 - 240.0	1.2	0
	240.0 - 255.0	1.6	0
	255.0 - 270.0	2.0	0
	270.0 - 299.5	1.1	0

* Extent of musky population; 0 = no musky population; x = marginal musky population; + = musky population present. Extent of musky populations was derived from local conservation officer reports.

Table A - 5. Stream conditions prevalent at four study streams during 1970 zooplankton studies.

Date	Surface water temperature (°F.)	Turbidity (J.T.U.)*	Stream discharge (cfs)
		Kinniconick Creek	
5/1/70	64	11	High Discharge
5/6/70	56	10	54.24
5/12/70	65	10	Not taken
5/14/70	54	160	High discharge
5/19/70	62	15	Not taken
5/26/70	68	8	52.21
		Beaver Creek	
5/1/70	62	12	High discharge
5/8/70	54	3	7.78
5/12/70	60	60	Not taken
5/13/70	65	5	Not taken
5/19/70	58	10	Not taken
5/25/70	72	4	5.79
		North Fork Creek	
5/1/70	61	-	High discharge
5/8/70	56	5	38.39
5/12/70	60	250	Not taken
5/13/70	66	170	High discharge
5/19/70	56	17	Not taken
5/25/70	72	5	29.18
		North Fork of Triplett Creek	
5/1/70	64	8	- - -
5/8/70	61	7	28.29
5/12/70	67	10	Not taken
5/14/70	60	90	High discharge
5/19/70	62	10	Not taken
5/26/70	71	3	16.34

* Jackson Turbidity Units

Table A - 6. Stream conditions prevalent at four study streams during 1971 plankton studies.

Date	Surface water temperature (°F.)	Turbidity (J.T.J.)*	Stream discharge (cfs)
		Kinniconick Creek	
4/28/71	52	4	Somewhat high
5/5/71	51	10	Somewhat high
5/13/71	58	315	High
5/18/71	62	22	Nearly normal
5/25/71	64	13	Somewhat high
6/2/71	68	5	Normal
		Beaver Creek	
4/28/71	54	4	Low
5/12/71	57	240	High
5/19/71	65	12	Nearly Normal
5/25/71	64	18	Normal
6/1/71	66	4	Normal
		North Fork Creek	
4/27/71	52	5	Normal
5/12/71	58	115	High
5/18/71	64	10	Normal
5/26/71	62	7	Somewhat high
6/1/71	67	5	Normal
		North Fork of Triplett Creek	
4/26/71	56	7	Normal
5/5/71	53	6	Normal
5/13/71	59	280	High
5/18/71	63	8	Nearly normal
5/25/71	66	25	Somewhat high
6/2/71	67	8	Normal

* Jackson Turbidity Units