GROWTH AND REPRODUCTION OF THE LAKE STURGEON (ACIPENSER FULVESCENS RAFINESQUE) OF THE NELSON RIVER IN MANITOBA

by

LEIF AXEL SUNDE

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Magnified Image of a Cross - Section of the

Marginal "spine" of a Lake Sturgeon.

ABSTRACT

Depletion of Nelson River sturgeon through over-exploitation by the commercial fishery forced two closures of this fishery between 1921 and 1946. These failures prompted a program of biological research to determine rates of growth, reproduction and increments to stocks to provide a basis for the scientific management of this economically important species of fish. From 1953 to 1956 and 1959, 791 sturgeon were sampled from the commercial catch in the Sipiwesk Lake area of the Nelson River.

Preliminary studies were conducted to determine the best method of age determination and back-calculation of growth. It was concluded that the best cross-sections of pectoral "spines", for purposes of age determination and back-calculation of growth, were located at the proximal end of the spine at the base of the swelling which forms the "knuckle" of the spine. The easiest and best measurement on this cross-section for back-calculation of growth was along the radius of the spine from the centre of ossification to the posterior edge of the spine, along the acute angles formed by the annuli in this area.

The relationship between fork length (x) and the average radius of the pectoral spine (y) as determined by the method of least squares was: $x = .14y + 2.2$. In the calculation of size at any previous age, best results were obtained by back-calculating along a line which converged with the intercept.

The best representation of growth in Nelson River sturgeon was obtained by cumulatively totalling the average annual calculated increments of growth for a number of specimens.

It is readily apparent that female lake sturgeon of the Nelson River grows faster and lives much longer than the male. The average annual

increment in size to age 20 years in both sexes is about 0.9 pounds, round weight, and 1.9 inches, fork length. From age 20 to 50 years, males average 0.4 pounds and 0.4 inches per year and females average 0.7 pounds and 0.5 inches per year. Beyond age 50 years, the average annual increment in round weight of females increases to about 1.0 pounds.

A very noticeable change in growth at age 20 to 25 years in both sexes correlates very closely with reproductive maturity of these fish. There is no indication of any asymptotic size in Nelson River sturgeon.

The length-weight relationship of male Nelson River sturgeon is: $\log W = -3.55 + 3.002 \log L$. That for the female is: $\log W = -3.84 + 3.204 \log L$. ($W$ is round weight in pounds and L is fork length in inches). There is a straight-line relationship between dressed weight and round weight. A simple rule of thumb for this relationship is: dressed weight = 2/3 round weight.

Nelson River sturgeon spawn in the spring in late May and early June. The average female matures and spawns the first time at age 25 to 30 years. This corresponds to a round weight of 24 to 29 pounds and a fork length of 42 to 45 inches. All or most males are mature by age 20 years which corresponds to a round weight of about 18 pounds and a fork length of about 38 inches.

Nelson River sturgeon do not spawn every year. The best information available suggests that the female spawns every three to six years. Older fish appear to spawn more frequently than young ones. The frequency of spawning of Nelson River male sturgeon is unknown but it is very unlikely that they spawn every year.

Several lines of evidence indicate that the failure of recent Nelson River sturgeon fisheries is the result of over-exploitation. This species is particularly vulnerable to depletion because of several atypical aspects of its life history, habits and high market value.

Recommendations for the management of future fisheries on the Nelson River and other areas are given. These pertain to production limits, fishing seasons and the minimum legal size of fish and fishing gear.

ACKNOWLEDGEMENTS

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CONTENTS

TABLES

ILLUSTRATIONS

I. INTRODUCTION

Wherever sturgeon have been commercially exploited, marked depletion of stocks has resulted. In many cases this has progressed to the point of commercial extinction of these economically important fishes.

To properly manage and protect any stock of fishes for purposes of insuring a sustained yield, biological research is required to establish rates of increment to such stocks. The pertinent aspects of such research are knowledge of growth, reproduction, natural mortality and qualitative and quantitative ecology.

The research reported herein mainly concerns the study of growth and reproduction of lake sturgeon of the Nelson River, Manitoba. These data are applied to a preliminary assessment of stocks as a tentative basis for provincial legislations.

A. AREA OF RESEARCH

Research on sturgeon has been conducted on several lakes and rivers of Northern Manitoba but sufficient data for adequate appraisal of stocks were obtained only on the Nelson and Churchill Rivers. Data presented here are from fish taken in the vicinity of Sipiwesk Lake (55°00' N, 97°30' W), an enlargement of the Nelson River.

B. MATERIAL COLLECTED

From 1953 to 1956 and in 1959, data were obtained on 791 sturgeon. All specimens were sampled randomly from the commercial catch by biologists of the Provincial Fisheries Branch. Mr. B. Kooyman and Mr. W. B. McTavish obtained all data in 1953 and 1954 respectively and the writer obtained all data in 1955, 1956 and 1959.

The following measurements and observations were made on each fish:

1. LENGTH: Fork length to the nearest quarter inch was recorded in all years. Total length was recorded in 1955 and 1956. Two additional body length measurements were made in 1955 for the purpose of establishing a new minimum legal size limit. These were: (i) the distance from the most posterior limit of the gill cleft to the junction of the posterior edge of the dorsal fin with the body. (ii) the distance from the most posterior limit of the cleithrum to the junction of the posterior edge of the dorsal fin with the body.

2. WEIGHT: Round or live weights to the nearest half pound were recorded in all years. Dressed weights (the carcass minus head and pectoral girdle, viscera, and fins) were recorded in 1953 and 1954.

3. SEX: The sex and the stage of development of the gonad was recorded in all years.

4. STOMACH CONTENT: This was recorded only from a small number of sturgeon.

Other particulars such as the date and the locality of killing of each specimen were also noted.

The marginal "spine" of one of the pectoral fins of each specimen was retained for the purpose of age determination. These were attached to plastic data tags by means of a thin wire which was threaded through a prominent blood vessel in the cartilage at the base of the ray.

C. NATURE AND HISTORY OF THE FISHERY

Available records indicate that the first sturgeon fishery on the Nelson River began in 1907. Since then there have been several periods of fishing alternating with periods of closure, each of several years duration. The last fishery (1953 to 1960) followed a six-year closure. The annual production in pounds is presented graphically in Figure 1.

The Nelson River sturgeon fishery is closely regulated. Only local residents are eligible to hold licenses and the number of licenses is limited. The only legal fishing gear is gill nets and each licensee is allowed not more than 500 yards of net, the minimum legal size of which is 12 inches extension measure. The size of fish to be retained is also restricted by a minimum legal size of ten pounds dressed weight or eighteen pounds round (live) weight. There is also an annual production limit on that part of the river which was opened to fishing. This limit was 25,000 pounds per year from 1953 to 1957 and 50,000 pounds from 1958 to 1960.

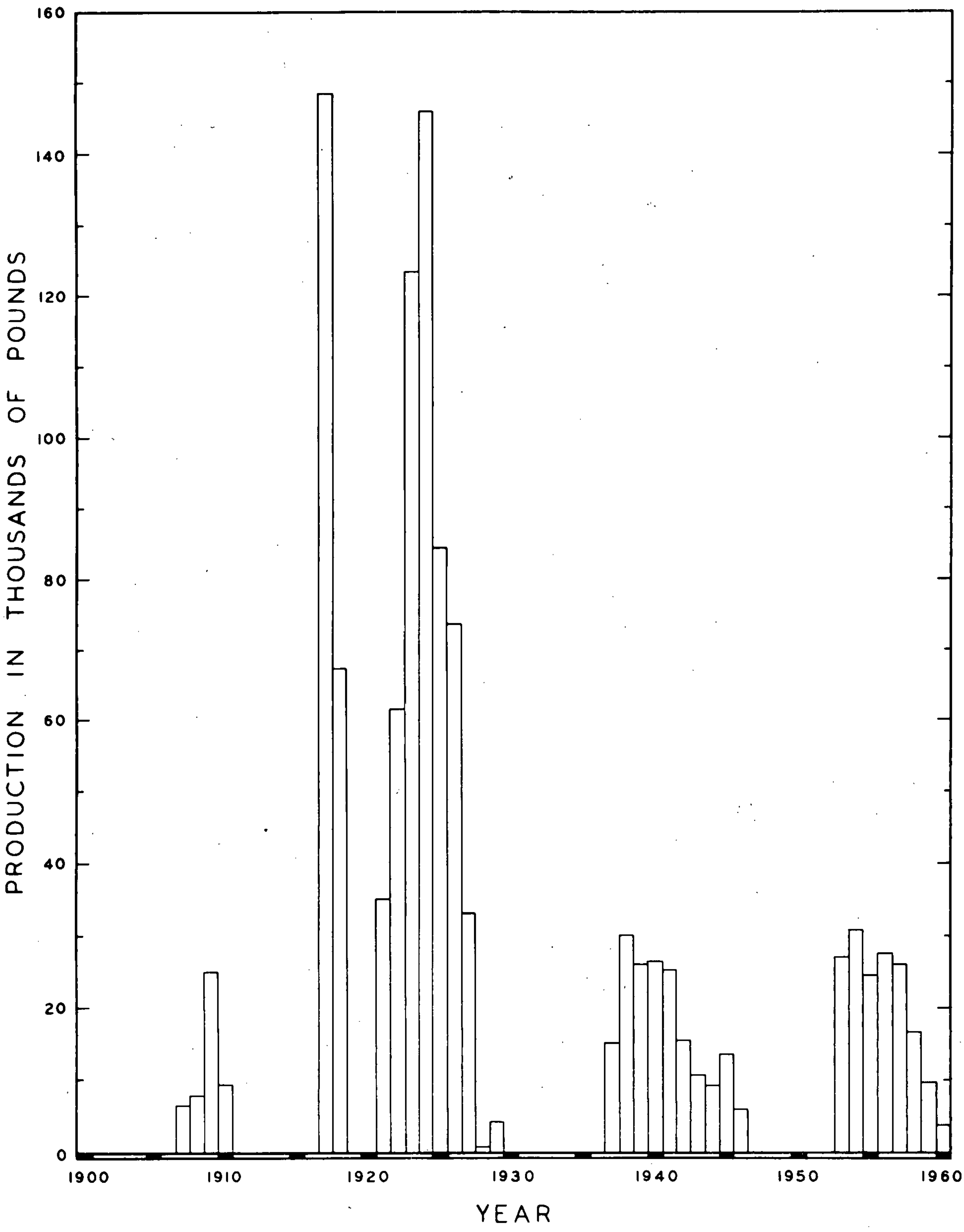

Figure I. Nelson River Sturgeon Production Statistics (dressed weight)

II. LITERATURE REVIEW

Several authors have contributed to our knowledge of the biology of various sturgeon. In Canada, the most extensive studies are by Cuerrier (1949), Roussow (1955), and Harkness (1923). Classen (1944) discusses research done in Spain. Derjavin (1922) and others who are referred to by Roussow (1955), report on research conducted in Russia and Eastern Europe.

The following subjects, which are pertinent to this paper, are discussed and reviewed by a number of authors.

A. THE EFFECT ON STURGEON OF COMMERCIAL FISHERIES

The effect of commercial exploitation on populations of sturgeon in North America is considered by several authors.

Rodd (1926), in a literature review, illustrates the drastic depletion of sturgeon in the St. John River, the Fraser River and in Lake Winnipeg. The over-exploitation of sturgeon and the decline of the fishery on the Great Lakes is described by Van Oosten (1936), and Williams (1951). Depletion of sturgeon in Lake of the Woods is reported by Carlander (1947) and Evermann and Latimer (1910). Wirth and Cline (no date), Pycha (1956) and McCrimmon (1956) report respectively on the depletion in Wisconsin lakes, California rivers and in Lake Simcoe, Ontario.

Various other authors present further reasons for the depletion of sturgeon in different parts of the world. Dams, pollution, shipping and canalization as well as inadequate protection and management of stocks are all blamed. Cuerrier and Roussow (1951), Roussow (1955), Cuerrier (1949) and Harkness (1923, 1936) discuss the situation in Eastern Canada. Roussow (1955) presents the case in Russia and Eastern Europe in a literature review while Ehrenbaum (1926) and Meyr (1950) comment on the situation in Germany and Classen (1947) describes the situation in Spain.

B. ARTIFICIAL PROPOGATION

Literature on the artificial propogation of sturgeon in Russia, Eastern Europe and in North America is reviewed by Roussow (1955). The success of sturgeon culture in North America is summarized by Rodd (1926). Ryder (1890) and Dean (1884) outline many of the problems encountered in the first experiments in sturgeon culture in North America.

C. AGE DETERMINATION OF STURGEON

Literature on age determination of sturgeon is reviewed by Cuerrier (1951), Roussow (1955), Chugunov (1925) and Classen (1944). In these papers the procedure for aging sturgeon by means of thin cross sections of the marginal "spine" of the pectoral fin is described. These authors also present evidence substantiating the validity of this method. Probst and Cooper (1954) provide further evidence to support this method.

D. GROWTH

Reviews of literature on the growth of various species of sturgeon are provided by Roussow (1955) and Cuerrier (1949). Roussow refers to studies done on sturgeon in Asia, Europe and North America. Cuerrier refers mainly to North American studies.

Aspects of growth of the lake sturgeon in North America are presented by Roussow(1955 and 1957), Cuerrier (1949), Cuerrier and Roussow (1951), Vladykov (no date), Kooyman (1955), Harkness (1923), Schneberger and Woodbury (1944) and Probst and Cooper (1954).

Roussow (1955) and Classen (1944) discuss methods of back calculation of growth in sturgeon and review the pertinent literature.

E. REPRODUCTION

An extensive literature survey and a thorough discussion of the general aspects of reproduction in sturgeon are presented by Roussow (1955, 1957) and Cuerrier (1949). Roussow refers extensively to research conducted in Europe and North America while Cuerrier refers mainly to North American publications.

Notes on the age of maturity and the periodicity of spawning of sturgeon in Spain and Russia are presented by Classen (1944, 1947) and Derjavin (1922).

The periodicity of spawning and the age of maturity of the lake sturgeon in North America is discussed by Harkness (1923, 1936), Kooyman (1955) and Vladykov (no date). Further data on the time and place of spawning of the lake sturgeon are presented by Bajkov (1930) and Williams (1951).

III. AGE DETERMINATION OF NELSON RIVER STURGEON

The sturgeon is aged by means of its bony parts. Seasonal changes in the metabolism of the fish produce seasonal difference in the amount and kinds of calcium added to the bony parts. These difference are distinguishable as concentric bands which are interpreted as annuli. Bones commonly used in the aging of sturgeon are: otoliths, cleithra, clavicles, scutes and the marginal "spine" of the pectoral fins (Cuerrier, 1951).

Cross sections of the marginal "spine" of the pectoral fin have proved to be most satisfactory, especially for the lake sturgeon (Cuerrier, 1951 and Roussow, 1955). The difficulties encountered and the reservations which must be made in the use of this method are discussed by Classen (1944), Cuerrier (1951) and Roussow (1955).

The validity of this method for aging of sturgeons is still inconclusive. There is, however, considerable evidence to support this method. Chugunov (1925) reports on an experiment by H. Holzmayer in which sterlets (A. ruthenus), kept in captivity for as long as ten years from the period of incubation, exhibited a number of "annuli" in the cross section of the marginal "spine" of the pectoral fin which corresponded exactly to the age of the fish. Chugunov also states that the number of annuli present in different bones of the same fish is constant.

Probst and Cooper (1954) offer further indirect proof for this method. Both age and length-frequency distributions of lake sturgeon from the Lake Winnebago region of Wisconsin were bimodal. These modes in age and length both corresponded closely with points on the growth curve.

A. AGING TECHNIQUE

Cross-sections of the marginal spine of the pectoral fin were obtained by the method outlined by Cuerrier (1951). These sections, 0.3 to 0.5 millimeters in thickness, were cut by means of a jewellers saw using size 2/0 or 3/0 blades. Good sections were obtained either by the use of a single blade or by two closely aligned blades.

The sections were obtained from the proximal end of the spine, roughly at the base of the thickened portion of the spine which articulates with the basal elements. Thus, depending on the size of the fish, the sectioning would be made at a point which is roughly one quarter of an inch to one inch from the proximal end of the spine.

Most sections were read under a low power binocular miscroscope using transmitted light. Some were also aged by means of a micro projector. Each section was placed in a medium of absolute alcohol to increase the differentiation in transparency of the winter and summer rings. As no permanent mounts were made, finished sections were dried and stored in vials.

The microscope image of a fin spine section is illustrated in the frontispiece. The narrow, light-colored rings represent winter growth and the wider, more opaque zones represent summer growth. The closest narrow ring to the centre of ossification is interpreted as the first winter ring. Since all samples were obtained in June and July, the time of year that sturgeon are born, the number of winter rings should correspond to the exact age of the fish.

B. THE CHARACTERISTICS OF CROSS-SECTIONS FROM DIFFERENT POINTS ALONG THE MARGINAL "SPINE" OF THE PECTORAL FIN

(a) Methods

Cuerrier (1951) suggests that the cross-section of the pectoral spine be obtained about one-quarter of an inch from the proximal end of the spine. Classen (1944) suggests that it be obtained one to one and one-half centimeters from the end of the spine. They do not discuss the relative merits of sectioning elsewhere along the spine.

The writer found that better sections were obtained at a point half an inch to one inch from the proximal end of the spine of large sturgeon.

The location on the pectoral spine of the clearest and best cross-sections for purposes of aging and back calculation of growth in Nelson River sturgeon was determined by the following study. A series of sections were cut from pectoral fin spines of sixteen sturgeon of various sizes and ages. These sections were taken at quarter inch intervals along a two and one-half inch portion of the proximal end of the spine. Annuli counts were then made on all cross-sections of each series. In series where aging was difficult, counts were terminated at some well defined reference point which was easily recognizable throughout the series (i.e. a closely packed band of annuli). The results are presented in Table I as "loss" of annuli along the fin spine beginning at the proximal end. Note that counts of annuli were possible on few of the sections obtained a quarter of an inch from the proximal end of the spine. (Annuli here were often too closely packed in the periphery of the spine to be differentiated).

Counts of annuli along each series was terminated when the reference point was lost or when the annuli became obscure.

(b) Results and Discussion

It is evident from Table I that, for age determination, cross-sections of the pectoral spine of Nelson River sturgeon should be obtained within half an inch of the proximal end of the spine. Beyond this point a rapidly increasing number of annuli are lost. At three-quarters of an inch, roughly half of the cross-sections had lost one annulus and by one inch most cross-sections had lost at least one annulus.

TABLE I. Analysis of the Loss of Annuli in Cross-Sections Taken at Regular Intervals Along the Length of the Pectoral Fin "Spine".

Specimen Number	Fork Length of Fish	Age of Fish	Location of Cross-Section* $\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$
N 58	50.8 ins.	34	0	0	0	0	1	1	1	2	.	.
N 70	50.0 ins.	32	.	0	0	2	3	4	4	5	6	6
N 2	48.8 ins.	35	0	1	1	.	.	.	.	.	.	.
N 84	48.5 ins.	45	0	0	1	1	2	2	.	.	.	.
W 30	47.5 ins.	32	.	0	0	0	1	1	2	.	.	.
N 38	46.5 ins.	39	.	0	0	1	1	2	2	3	.	.
N 72	44.5 ins.	45	.	0	0	1	1	2	3	4	.	.
N 99	43.8 ins.	25	.	0	0	0	1	1	2	2	.	.
N 50	42.2 ins.	31	.	0	0	0	0	1	2	.	.	.
H 21	41.0 ins.	31	.	0	1	2	2	3	3	5	6	.
N 4	40.5 ins.	21	.	0	1	1	2	2	3	.	.	.
H 23	40.0 ins.	23	0	0	1	1	1	2	2	3	3	.
H 27	40.0 ins.	21	.	0	1	1	1	1	2	3	3	4
N 93	38.5 ins.	19	.	0	0	1	1	2	2	3	.	.
H 22	34.0 ins.	20	0	0	0	0	1	1	1	2	.	.
SF 1	24.2 ins.	11	0	0	1	1	1	2	2	3	.	.
Average Loss			0.0	0.1	0.4	0.8	1.3	1.8	2.2	3.2	4.5	5.0

* The distance in inches from the proximal end of the spine.

This factor, however, is not the only important consideration. Before accurate aging is possible, the cross-section must exhibit clearly discernible annuli. From the series of spine sections studied, it was found that those obtained between half an inch and one inch from the proximal end of the spine were most easily read. (It should be noted that most of these specimens were large fish).

Sections obtained within half an inch of the proximal end of the pectoral spine of larger fish were wedge shaped, the bony part being quite narrow. Annuli in this section were so closely packed that aging was very difficult, if not impossible.

Sections obtained between half an inch and two inches from the proximal end of the spine generally were quite easily differentiated. The winter rings were narrow and well defined. Those obtained over an inch from the proximal end of the spine lacked one or more annuli, however.

Sections obtained further out along the pectoral spine had not only lost annuli, but were difficult to interpret for several other reasons. Annuli in this area were more closely packed as the cross sectional area of the spine decreased and the spine was often damaged or eroded. The spine also became deformed as more recent annuli of the marginal spine encircled and became fused with the second and even the third fin rays.

It is therefore evident that in aging of sturgeon weighing twenty pounds or more, it is best to obtain the marginal spine cross-section at a point roughly half to three-quarters of an inch from the proximal end of the spine (roughly at the base of the swelling formed at the "knuckle"). In this area the annuli are most distinct, the spine is generally undamaged or worn away and the loss of annuli is not great. If the first annulus of a section obtained in this area is fairly closely aligned with the second annulus (i.e. leaving a large central area devoid of annuli), it is likely that this cross-section is missing the first winter ring.

IV. GROWTH OF NELSON RIVER STURGEON

Growth in length of Nelson River sturgeon was determined by back calculation and by the age-length relationship. Results are presented in the following sections. Growth by sexes, growth in various calendar years, growth in weight, the length-weight relationship, the relationship of dressed weight to round weight and a comparison of growth in widely separated stocks of lake sturgeon is also discussed.

A. BACK-CALCULATION OF GROWTH

(a) Methods Used to Determine the Relationship Between Growth in Length of the Sturgeon and Growth of the Pectoral Spine

Back calculation of growth in fishes is possible only when one has determined the relationship between the rate of growth in length of the fish and that of a body part on which annual growth increments can be measured. The only structure which has been used for back calculation of growth in sturgeon is the cross-section of the marginal spine of the pectoral fin in which the annuli are readily discernible (Roussow, 1955 and Classen, 1944).

Two series of observations were made to determine the relationship between growth in length of Nelson River sturgeon and the growth of the pectoral spine.

Series 1

In the first series, cross-sections of the pectoral spine were prepared from a sample of 74 fish selected in such a way that the greatest possible range in size was represented (stratified random sample). The sections were obtained at a point roughly one-third of the distance from the proximal end of the spine. This position was chosen for the following reasons: the spine in this area is only slightly tapered, cross-sections from various specimens are relatively uniform in shape and the cross-sections are only slightly bifurcated compared to those obtained at the proximal end of the spine.

The prepared sections were mounted on a concave glass slide in a medium of absolute alcohol. All measurements were made on an image of the cross-section (roughly 40x) produced by a microprojector.

Three measurements were made on the image. The area delimited by the outer annulus was measured by means of a polar planimeter. The perimeter of the outer annulus was measured by means of a map measure. A map measure was also used to determine the total length of two radial measurements, the loci of which are illustrated in Figure 2. The common origin of these lines is the centre of ossification of the pectoral spine. They are traced along the acute angles formed by the annuli in the posterior portion of the spine and terminate at the outer annulus at the periphery of the section.

These three measurements were each plotted against fork length on log-log and on arithmetic graph paper. From these graphs it was evident that there was a linear relationship between the length of the fish and the measurements made on the cross-section of the marginal spine of the pectoral fin. This relationship, however, was poor in all cases. Averaging of the pectoral spine measurements by one inch intervals of fork length did not significantly improve the linear relationship.

The relationship between fork length and the radial length of the pectoral spine sections is illustrated graphically in Figure 3.

This series indicated that measurements for back calculation of growth in sturgeon cannot be made on cross-sections obtained from central or distal portions of the marginal spine of the pectoral fin. Despite several

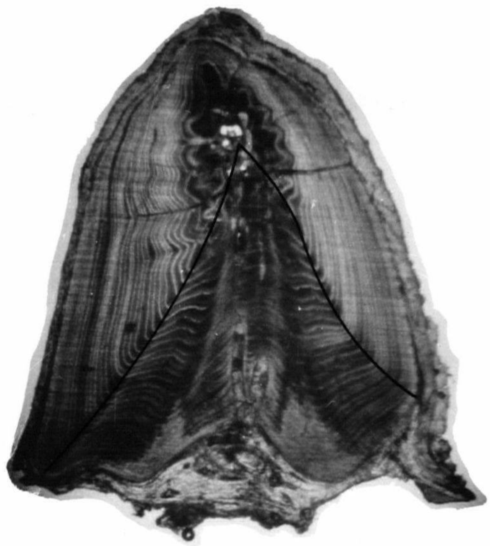

Figure 2. The enlarged image of a cross-section of the marginal "spine" of the pectoral fin illustrating the loci of the radial axes along which measurements for back-calculation of growth were made.

advantages of selecting cross-sections from this area, a few important disadvantages were also apparent. Many of the spines in this area were badly abbraded along the leading edge and more recent annuli often encircled the second or even third fin ray. Cross-sections from this portion of the spine may also lack the first few annuli.

This series also indicated that the only possible measurement on the pectoral spine section for purposes of back calculation of growth is the radial measurement. The perimeter of each annulus or the area delimited by

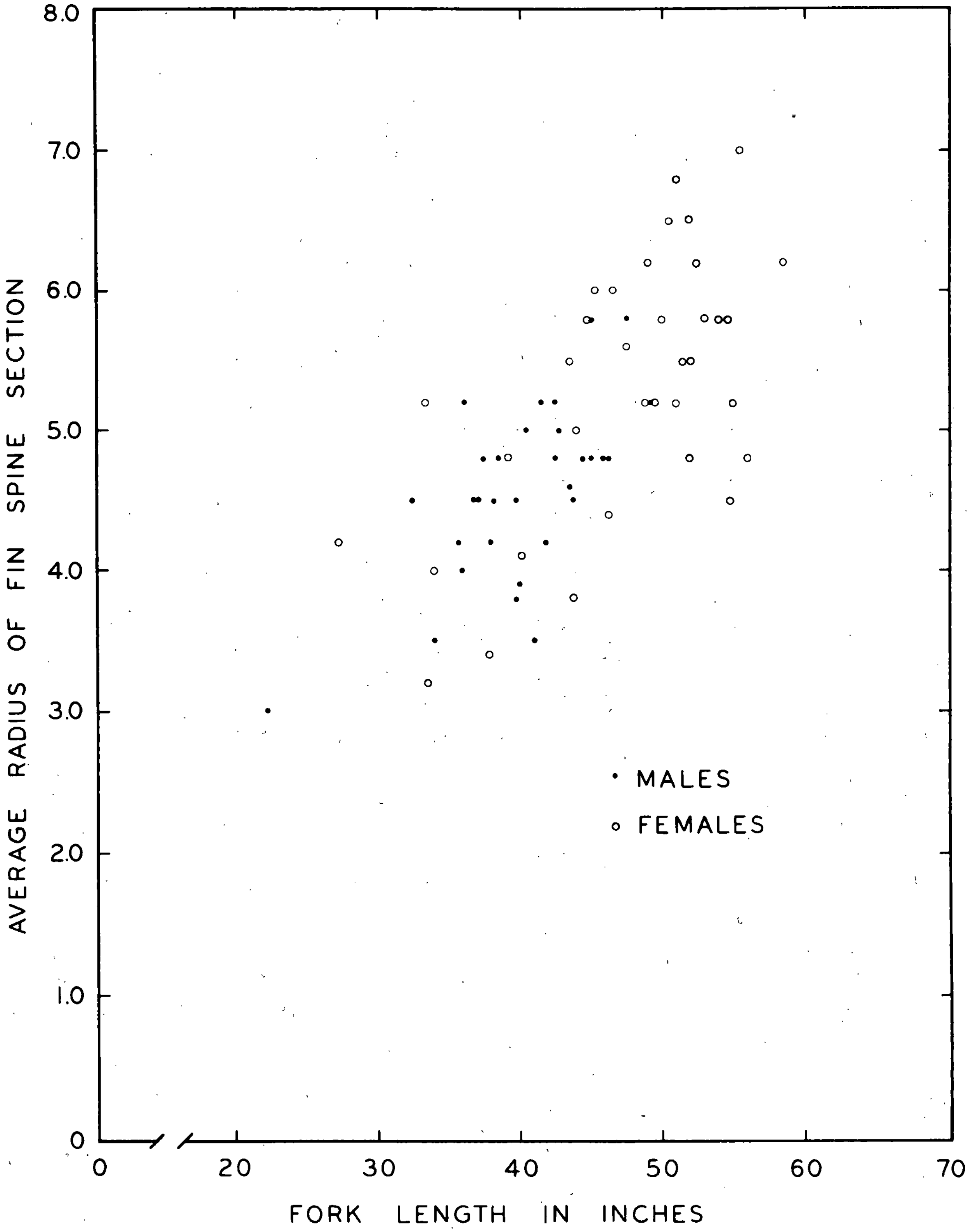

Figure 3. The Relationship Between Fork Length and the Radial Length of the Pectoral Spine Cross - Sections in Nelson River Sturgeon.

each annulus cannot be measured in larger fish because few annuli can be traced throughout the circumference of the pectoral spine due to crowding of annuli or abrasion along the leading edge of the spine.

Series 2

The second series of observations made to determine the relationship between growth in length of the sturgeon and growth of the pectoral spine was made on 97 specimens. These were again selected to insure that the greatest possible range in size of specimens was represented and that each size group (one inch intervals of fork length) was represented by a minimum of three specimens where possible. Cross-sections that were damaged, deformed or difficult to age were discarded.

In this series, pectoral spine sections were obtained at the proximal end of the spine where sections for aging of specimens were obtained. Cross-sections were temporarily mounted on a concave glass slide in a medium of absolute alcohol. An image of each section (roughly 50x) was projected upon a sheet of paper by means of a 35 mm. slide projector equipped with an attachment for microscope slides.

A pencil tracing was then made on the image from the centre of ossification of the spine, posteriorly along the acute angles formed by the annuli, to the outermost annulus at the posterior edge of the spine. (See Figure 2 for illustration) These two radial axes were then measured and the average "radial length" of the cross-section was calculated.

Results are presented in Figure 4, where the average radial length of the pectoral spine of each specimen is plotted against the fork length. The regression line ($x = 0.14y + 2.2$) calculated from these data also appears in this figure. It is evident from the scatter of points that the linear relationship between these two variables is somewhat poor. This may be

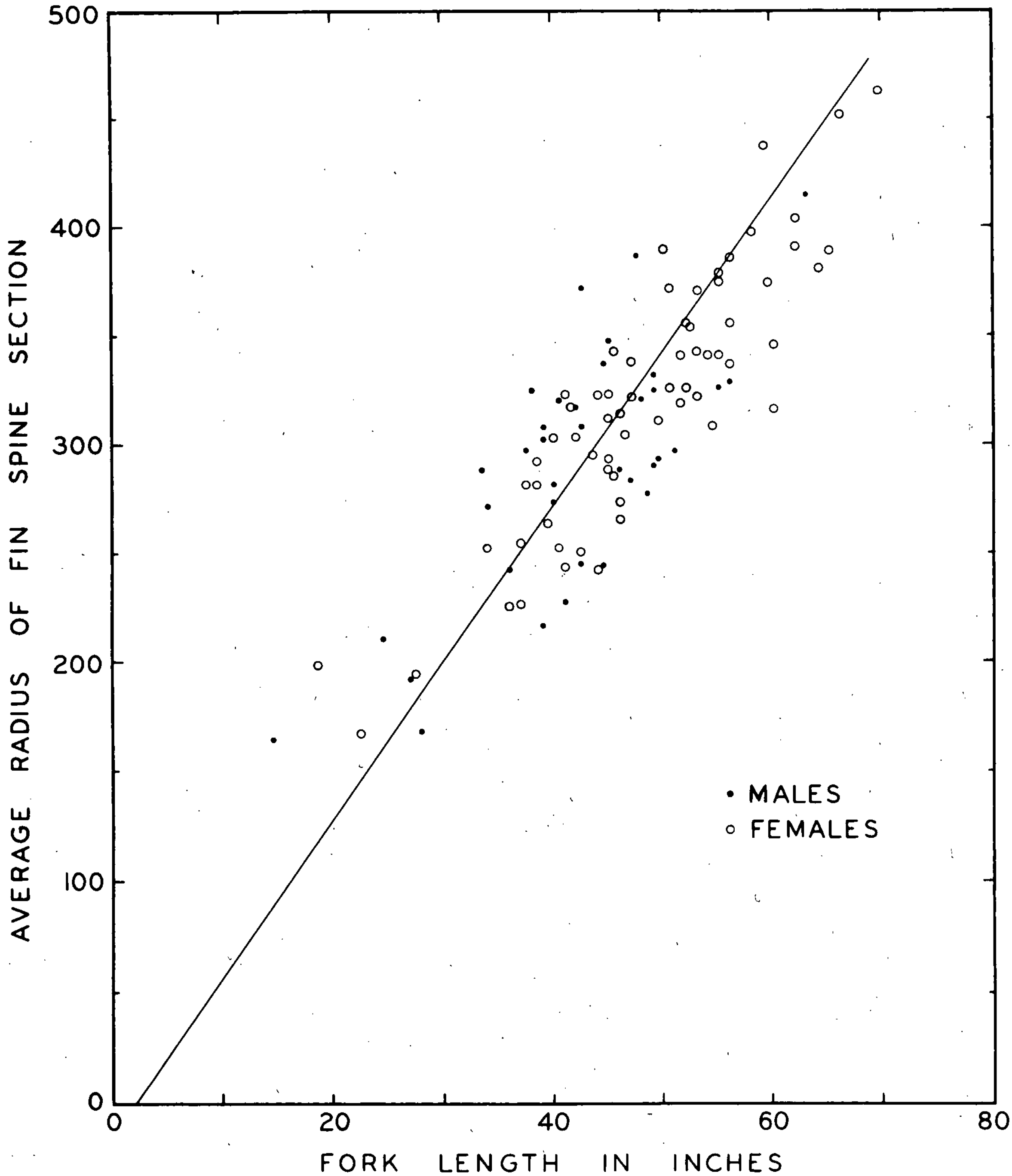

Figure 4. Relationship Between Fork Length and the Average Radius of Pectoral Spine Cross-Sections in Nelson River Sturgeon.

attributed mainly to the difficulty of obtaining a cross-section from the same relative area of the tapered pectoral spine in each specimen. This is akin to neglecting to use a "key scale" in other species of fish.

Since these data are the best available, this regression line was used in back calculation of growth of Nelson River sturgeon. This was considered better than the only other alternative which was to assume a direct relationship between growth in length of sturgeon and growth of the pectoral spine.

It is to be noted that the data presented in this series are not treated separately according to sex. The possibility of a difference between males and females concerning the relationship between growth in length of sturgeon and growth of the pectoral spine was tested by an analysis of covariance in the first series. This test confirmed the supposition that no significant difference in this relationship exists between male and female sturgeon.

(b) Measurements Used in Back-Calculation of Growth

For purposes of back-calculation of growth of Nelson River sturgeon a sample of 23 males and 25 females was again selected so that the greatest possible range in size (or age) of fish was represented. The age distribution and the range in size of specimens chosen is presented in Table II.

All cross-sections of pectoral spines taken for back calculation of growth were obtained at the proximal end of the spine in the same area where sections for age determination were obtained. These sections were temporarily mounted on a glass slide in a medium of absolute alcohol and a magnified image (approximately 50x) was projected upon a sheet of paper by means of a microprojector. The radial axes were then traced on the paper (as in Figure 2) and the intersection of each annulus along these axes was marked off. The distance between each annulus was then measured with a scale graduated in thirtieths of inches. These measurements were added cumulatively to provide the distance between the centre of ossification and each annulus.

TABLE II. Age Composition and Range in Size of Sturgeon Specimens Chosen for Back-Calculation of Length

Age Group	Males Frequency	Males Size Range*	Females Frequency	Females Size Range*
3	1	11.0	.	.
4	.	.	1	14.3
8	1	22.3	.	.
9	1	27.3	.	.
16	1	38.7	.	.
18	1	37.5	1	33.5
19	1	41.0	1	34.0
21	2	39.7 - 42.0	.	.
22	3	36.0 - 39.5	2	40.3 - 45.5
23	4	34.0 - 40.7	3	38.5 - 49.0
24	1	46.3	2	42.7 - 45.0
25	1	44.7	.	.
26	.	.	1	41.0
27	1	44.5	.	.
28	1	43.3	.	.
31	2	42.7 - 47.5	.	.
32	.	.	2	38.7 - 46.7
34	.	.	2	51.0 - 51.5
35	.	.	1	44.5
37	.	.	2	37.7 - 48.7
39	.	.	1	56.0
40	.	.	2	48.7 - 49.5
43	1	47.7	.	.
49	.	.	1	52.0
50	.	.	1	56.0
53	.	.	1	55.0
55	1	42.7	.	.
62	.	.	1	55.5

* Fork length in inches.

B. METHOD OF BACK-CALCULATION

It is evident that few of the data plotted in Figure 4 lie directly on the regression line. Thus, to determine size at a previous age for any individual it is necessary to back calculate along a line parallel to the regression line or along a line that converges to the same intercept as the regression line.

In the parallel method it is assumed that the slope of the regression line of pectoral spine radius measurement against fork length is a constant for all individuals. In this case, back-calculation of length at a previous age involves the implication that at the theoretical fork length of zero, the size of the pectoral spine was not necessarily the same in all individuals.

In the convergent method it is assumed that the slope of the regression line of fin radius measurement against fork length is not the same in all individuals. In this case it is implied that at the theoretical fork length of zero, the pectoral fin was the same size for all fish and that the relation between fin radius measurement and fork length could be different in each individual.

Back-calculations of growth of Nelson River sturgeon were done by both the convergent and parallel methods. Only the results obtained by the convergent method are presented however, since it is unlikely that a large difference in fin size is possible among small sturgeon. It was also evident that the convergent method produced results that were more similar to growth rates determined from actual measurements on sturgeon of different age groups. Furthermore, it was found that the calculated size of many sturgeon of age group one was less than zero when determined by the parallel method.

A nomograph (Figure 5) was designed for the purpose of speeding up the back-calculation of lengths which involved roughly 1300 calculations on the 48 specimens. The two scales represent the x and y axes. The short scale, which represents fork length, has been rotated to a vertical position so that the moveable thread may intersect both scales.

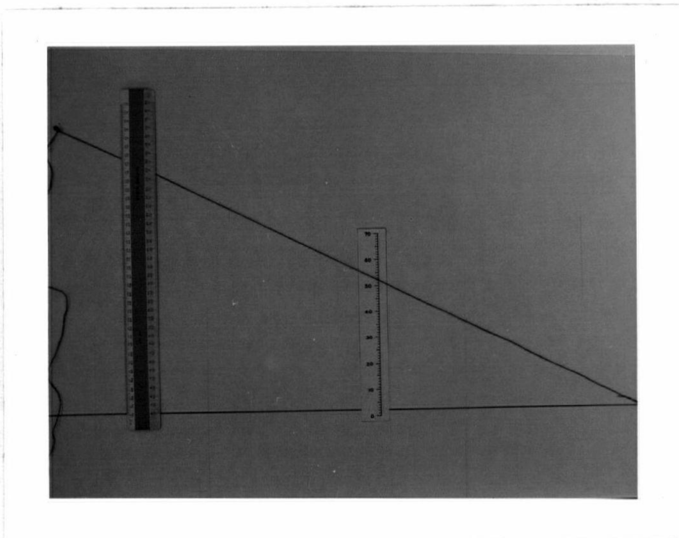

FIGURE 5. Nomograph Used in Back-Calculation of Length of Nelson River Sturgeon

In the operation of the machine by the convergent method of back-calculation the pectoral spine radius scale was fixed and the fork length scale was set at the average intercept determined from the regression line. The latter was then moved laterally to left or right to provide the different theoretical slope for each fish. This is comparable to joining the point for a particular fish to the intercept for the average regression line and back-calculating along this line.

C. RESULTS AND DISCUSSION

(a) Growth in Length of Nelson River Sturgeon

Growth in length of Nelson River sturgeon was determined by three methods: (1) by averaging empirical lengths of age groups, (2) by averaging calculated lengths by age groups, (3) by cumulatively totaling average calculated increments of length between successive age groups. Determinations by method (1) are presented in Table III and in Figure 6. Those for methods (2) and (3) are presented in Table IV and in Figures 7 and 8. A comparison of growth curves determined by all three methods for female sturgeon is presented in Figure 9.

TABLE III. The Average Size (Empirical Fork Lengths) by Age Groups of Nelson River Sturgeon. 1953 to 1956 Data.

	Males		Females			Males		Females	
Age Group	Freq.	Ave.* Length	Freq.	Ave.* Length	Age Group	Freq.	Ave.* Length	Freq.	Ave.* Length
1-3	1	11.0	.	.	49-51	6	49.5	22	50.5
4-6	.	.	1	14.3	52-54	7	47.7	8	52.0
7-9	2	24.9	.	.	55-57	1	48.0	7	49.9
10-12	.	.	.	.	58-60	.	.	.	.
13-15	.	.	1	27.2	61-63	.	.	5	55.6
16-18	6	40.0	3	35.5	64-66	1	52.5	7	56.7
19-21	28	39.2	7	37.8	67-69	.	.	3	52.7
22-24	43	41.1	24	42.5	70-72	.	.	2	56.0
25-27	34	43.3	25	43.7	73-75	.	.	2	55.5
28-30	34	42.2	22	43.8	84 only	.	.	4	63.0
31-33	34	43.5	35	45.9	86 only	.	.	1	60.5
34-36	46	44.8	38	47.1	88 only	.	.	1	65.0
37-39	34	44.9	38	46.8	98 only	.	.	1	59.0
40-42	27	45.1	34	48.6	102 only	.	.	1	69.0
43-45	42	46.0	42	48.4	105 only	.	.	1	67.0
46-48	16	46.3	37	50.3	110 only	.	.	1	63.0
					Totals	362		372	

* Average fork length in inches.

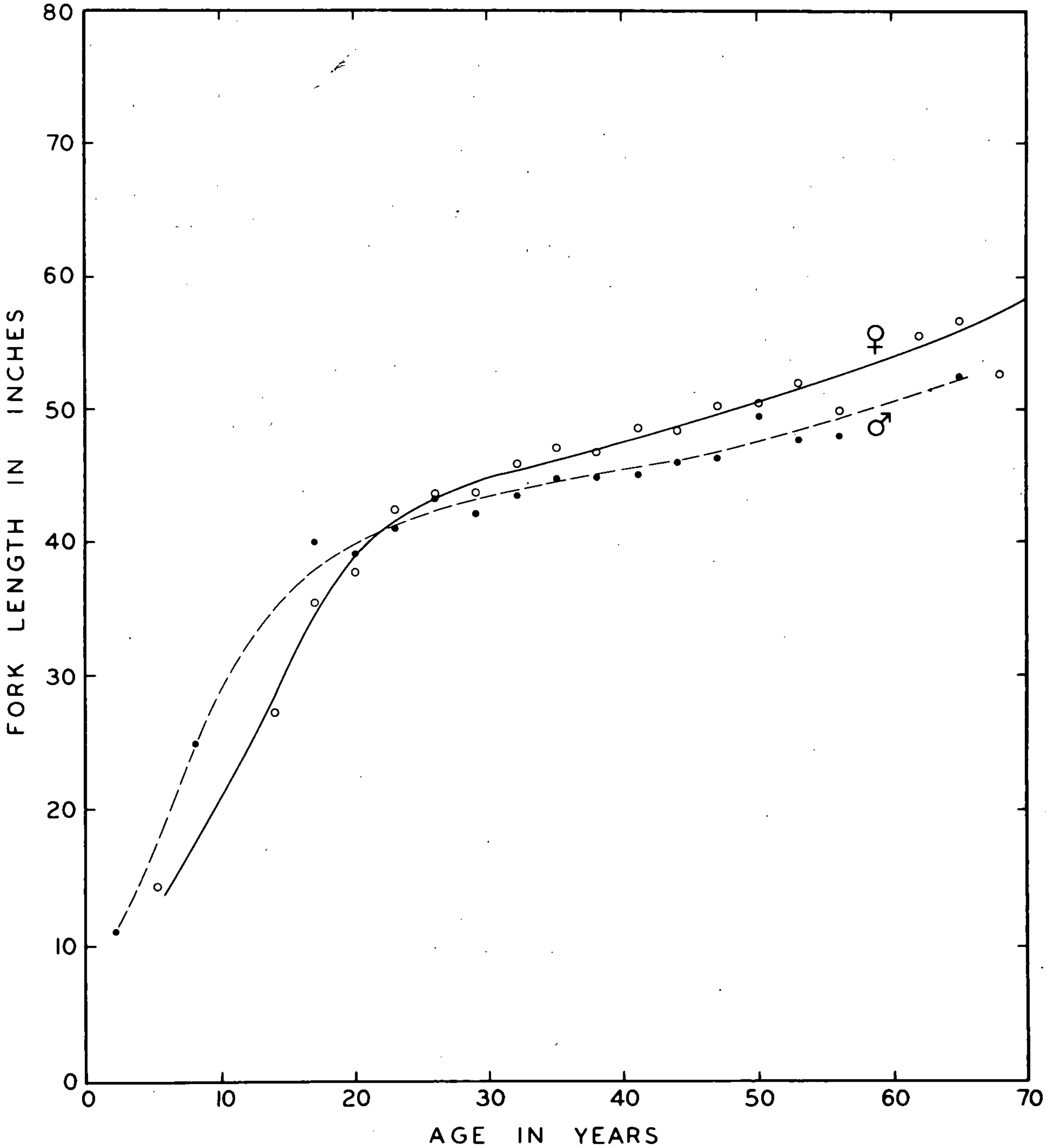

Figure 6. Growth in Length of Nelson River Sturgeon (Average Empirical Fork Lengths by Age Groups.)

TABLE IV. The Average Size (Calculated Fork Lengths)by Age Groups of Nelson River Sturgeon

	Males				Females			
Age Group	Freq.	Ave.* Calc. Size	* Ave. Incr.	* Cumul. Incr.	Freq.	Ave.* Calc. Size	* Ave. Incr.	* Cumul. Incr.
1	23	6.6	6.6	6.6	25	7.1	7.1	7.1
2	23	11.5	4.9	11.5	25	12.3	5.2	12.3
3	23	15.5	4.1	15.6	25	16.4	4.1	16.4
4	22	19.0	3.2	18.8	25	19.6	3.2	19.6
5	22	21.7	2.7	21.5	24	22.3	2.5	22.1
6	22	23.8	2.2	23.7	24	24.3	2.0	24.1
7	22	25.6	1.8	25.5	24	26.2	1.8	25.9
8	22	27.1	1.5	27.0	24	27.6	1.5	27.4
9	21	28.9	1.6	28.6	24	29.0	1.3	28.7
10	20	30.5	1.5	30.1	24	30.1	1.2	29.9
11	20	31.8	1.3	31.4	24	31.2	1.1	31.0
12	20	33.0	1.2	32.6	24	32.2	1.0	32.0
13	20	33.9	.9	33.5	24	33.1	.9	32.9
14	20	34.8	.9	34.4	24	33.8	.9	33.8
15	20	35.2	.7	35.1	24	34.9	.9	34.7
16	20	36.4	.7	35.8	24	35.2	.8	35.5
17	19	36.9	.7	36.5	24	36.5	.8	36.3
18	19	37.6	.7	37.2	24	37.2	.7	37.0
19	18	38.2	.5	37.7	23	38.1	.7	37.7
20	17	38.5	.5	38.2	22	38.9	.6	38.3
21	17	39.0	.5	38.7	22	39.6	.7	39.0
22	15	39.1	.4	39.1	22	40.3	.7	39.7
23	12	39.7	.4	39.5	20	40.7	.6	40.3
24	8	41.6	.4	39.9	17	41.1	.7	41.0
25	7	41.4	.5	40.4	15	41.4	.7	41.7
26	6	41.1	.3	40.7	15	42.1	.7	42.4
27	6	41.6	.5	41.2	14	42.8	.7	43.1
28	5	41.5	.5	41.7	14	43.6	.7	43.8
29	4	41.4	.3	42.0	14	44.2	.7	44.5
30	4	41.8	.3	42.3	14	44.7	.5	45.0
31	4	42.1	.4	42.7	14	45.2	.5	45.5
32	2	39.7	.6	43.3	14	45.8	.6	46.1
33	2	40.2	.6	43.9	12	46.8	.4	46.5
34	2	40.5	.2	44.1	12	47.1	.4	46.9
35	2	40.9	.4	44.5	10	46.8	.5	47.4
36	2	41.3	.4	44.9	9	47.5	.5	47.9
37	2	41.6	.4	45.3	9	48.1	.6	48.5
38	2	42.2	.5	45.8	7	50.1	.5	49.0
39	2	42.4	.2	46.0	7	50.6	.5	49.5
40	2	42.6	.2	46.2	6	50.2	.4	49.9
41	2	43.0	.4	46.6	4	51.0	.2	50.1
42	2	43.2	.2	46.8	4	51.3	.2	50.3
43	2	43.4	.2	47.0	4	51.6	.4	50.7
44	1	39.5	.3	47.3	4	51.8	.2	50.9
45	1	40.0	.5	47.8	4	52.4	.5	51.4
46	1	40.2	.2	48.0	4	52.6	.3	51.7
47	1	40.5	.3	48.3	4	53.0	.3	52.0

TABLE IV continued

	Males				Females			
Age Group	Freq.	Ave.* Calc. Size	* Ave. Incr.	* Cumul. Incr.	Freq.	Ave.* Calc. Size	* Ave. Incr.	* Cumul. Incr.
48	1	40.7	.2	48.5	4	53.2	.3	52.3
49	1	41.2	.5	49.0	4	53.6	.3	52.6
50	1	41.5	.3	49.3	3	54.4	.3	52.9
51	1	41.7	.2	49.5	2	53.8	.2	53.1
52	1	42.0	.3	49.8	2	54.0	.3	53.4
53	1	42.2	.2	50.0	2	54.4	.3	53.7
54	1	42.5	.3	50.3	1	54.0	.3	54.0
55	1	42.7	.2	50.5	1	54.2	.2	54.2
56	.	.	.	.	1	54.5	.3	54.5
57	.	.	.	.	1	54.7	.2	54.7
58	.	.	.	.	1	55.0	.3	55.0
59	.	.	.	.	1	55.1	.1	55.1
60	.	.	.	.	1	55.2	.1	55.2
61	.	.	.	.	1	55.3	.1	55.3
62	.	.	.	.	1	55.5	.2	55.5

* Fork length in inches.
Ave. Calc. Size = Average Calculated Size.
Ave. Incr. = Average Increment.
Cumul. Incr. = Cumulative Increment.

Significant differences are evident in some of these growth curves. This is particularly so of the curves for male sturgeon that were determined by both methods of back-calculation. These curves are very similar to age 30 but thereafter the curve determined by method (2) is erratic and falls off rapidly. This can hardly be considered significant, however, as calculations beyond age 30 are unreliable because of scanty data. This erratic curve serves only to illustrate the principle that slower growing fish appear to live longer.

The curves determined by empirical measurements also differ significantly from those determined by the two methods of back-calculation. The lower portion of the curve representing empirical lengths, however, is also unreliable because of scanty data.

The discrepancies in the curves representing empirical and calculated sizes beyond age 20 may be due to several factors. This fishery

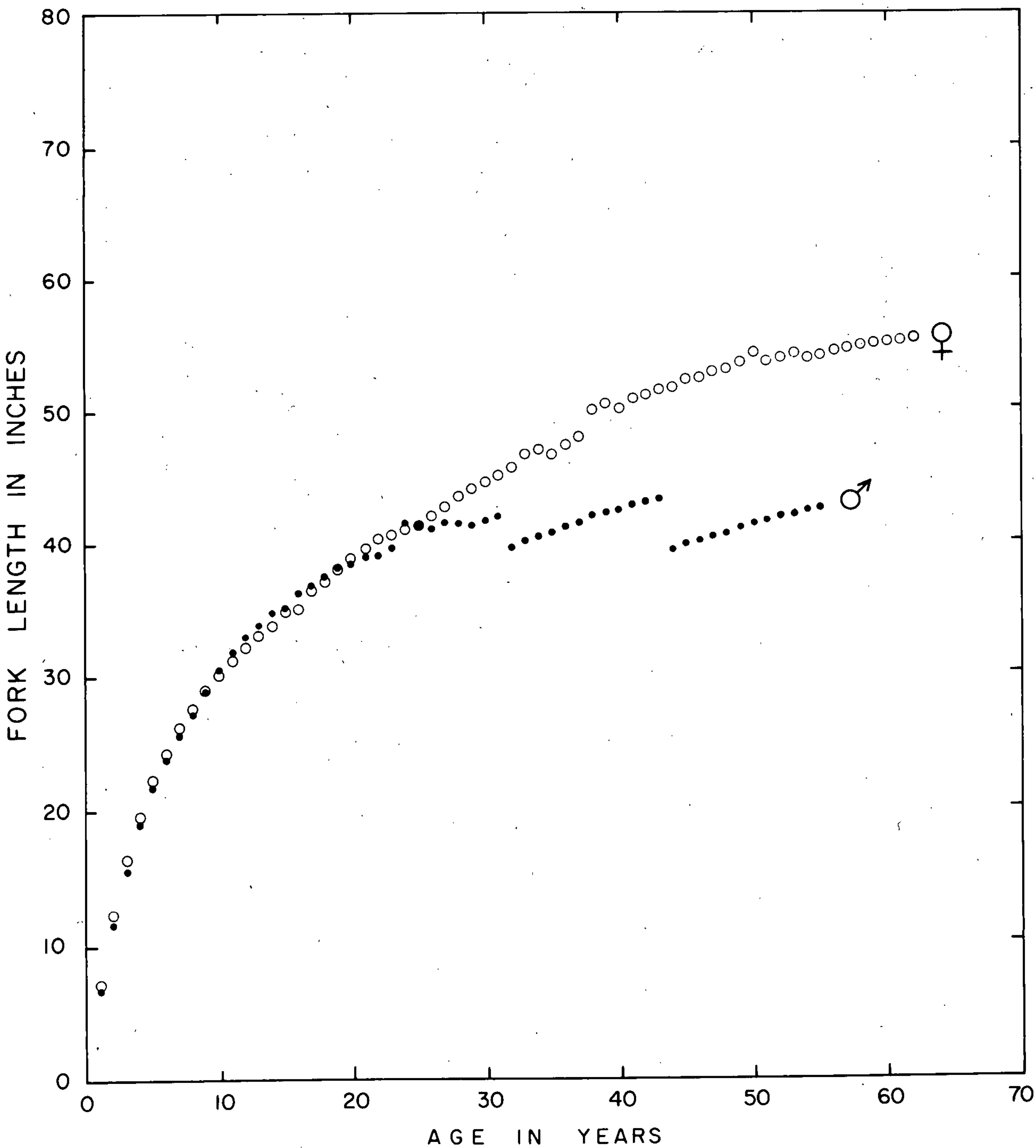

Figure 7. Growth in Length of Nelson River Sturgeon (Average Back – Calculated Fork Lengths by Age Groups)

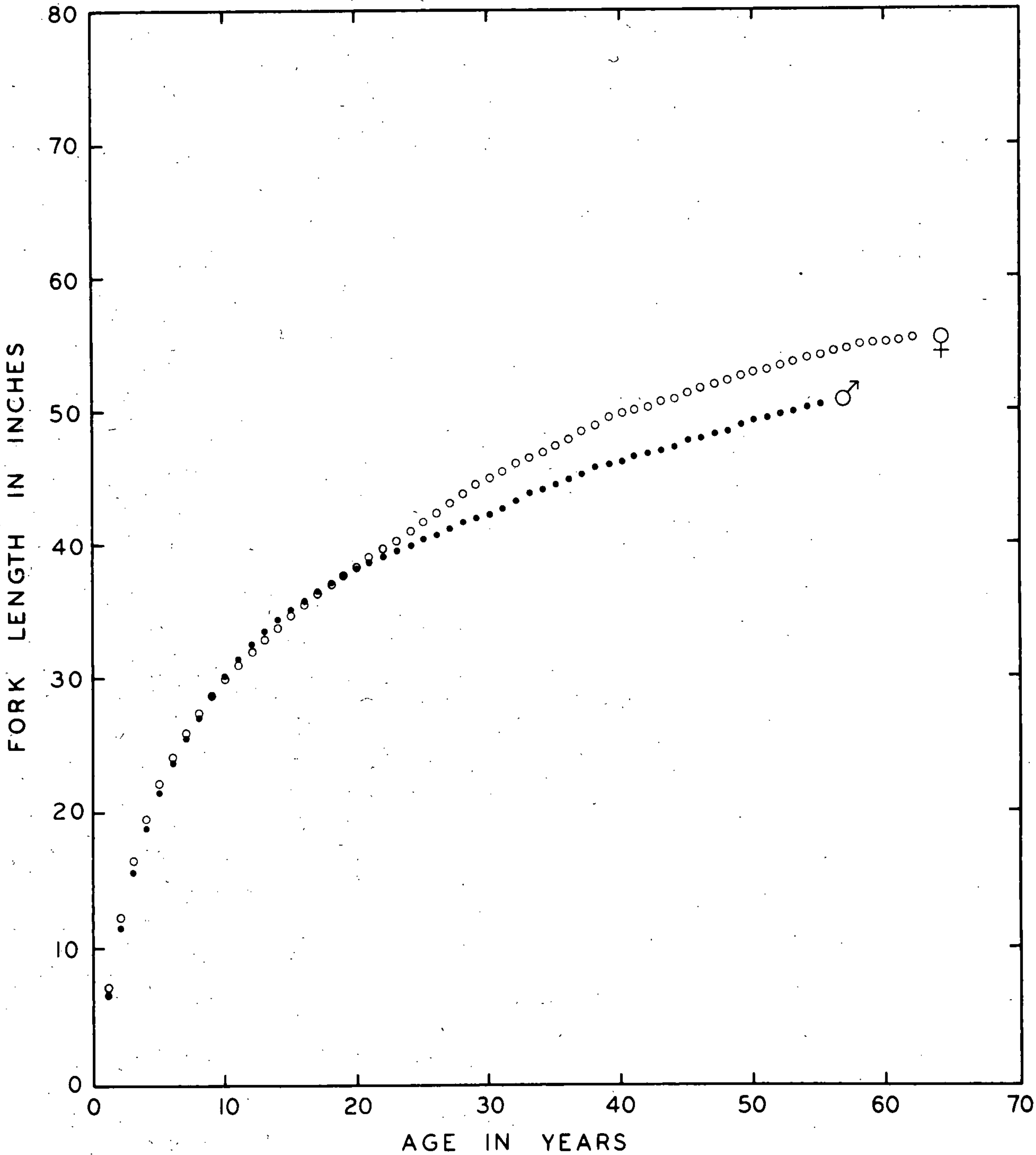

Figure 8. Growth in Length of Nelson River Sturgeon (Cumulative Average Back - Calculated Increments of Fork Length by Age Groups.)

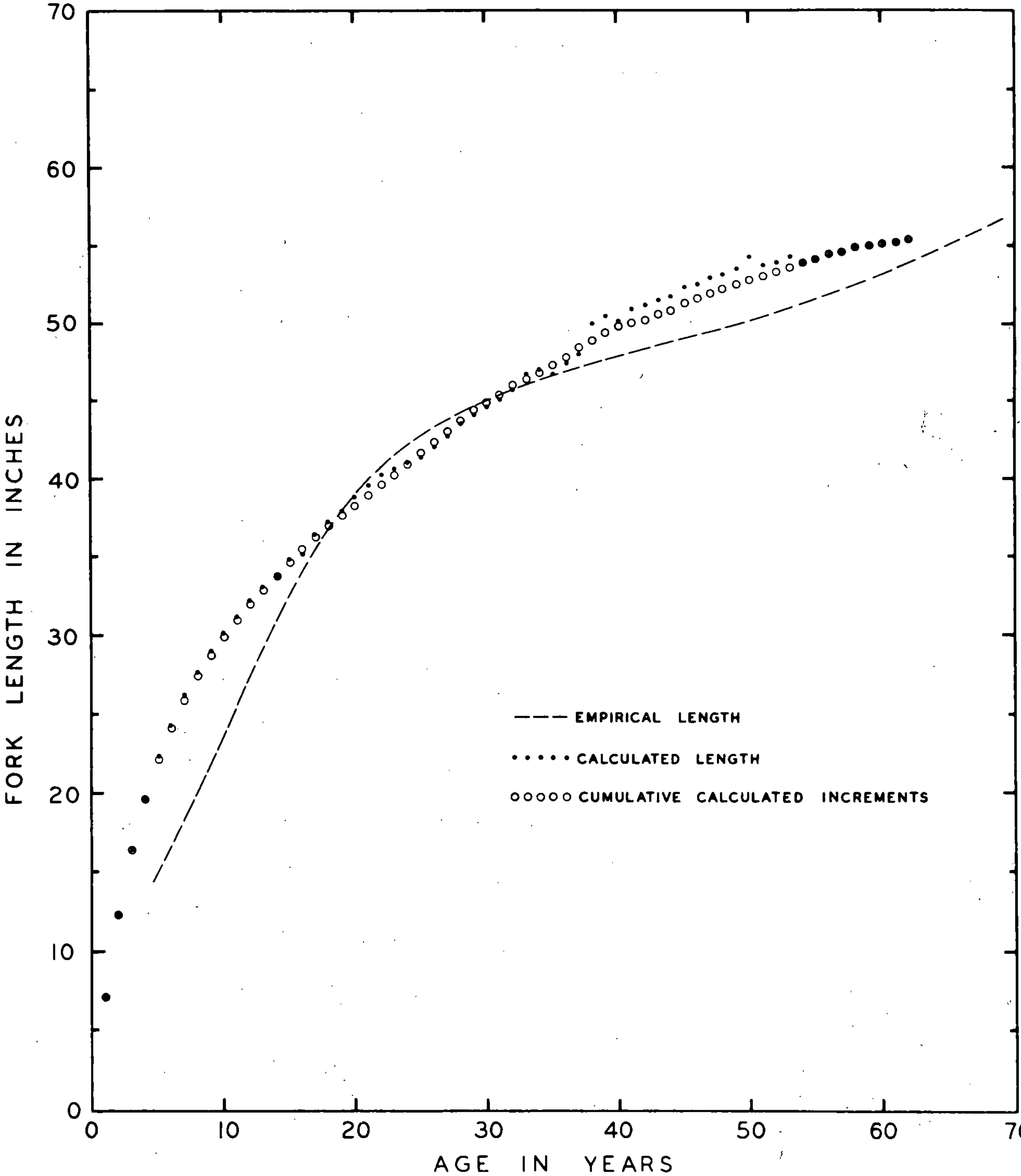

Figure 9. Comparison of Growth Curves Representing Three Methods by Which Growth in Fork Length of Nelson River Female Sturgeon was Determined.

would tend to select for fish of a particular size range. Fish of age 20 to 25 which grow fast would be disproportionately taken in the commercial catch. The average actual size would therefore be greater than the average calculated size for fish age 20 to 25 years. Fish of age 30 and over which grow slowly would also be disproportionately taken in the commercial catch. The average actual size beyond age 30 would therefore be less then the average calculated size.

Growth rates for older sturgeon that were determined by the two methods of back-calculation may have been overestimated too. Of the large, old specimens, only those with easily differentiated annuli were chosen for back-calculation to insure accuracy. It is very possible that these were the healthiest and fastest growing individuals.

Each of the methods presented has its limitations. Method (1) is the fastest and simplest procedure for determining growth but its accuracy is greatly reduced by selective sampling and insufficient representation of all age groups.

The main disadvantage inherent in back-calculation is the frequent occurence of Lee's phenomenon where successively older year classes appear to have been smaller at early ages than the younger year classes. There is also the tendency to select easily aged, faster growing specimens for back-calculation.

There are several important advantages in growth determinations by back-calculation. It is possible to determine the size of a fish of any age even though specimens of each age group are not represented, it is possible to explore the peculiarities of growth of single year classes or individuals, and it is possible to determine the growth of all age groups in any year. This method may also limit some of the effects of selective sampling and insure that the growth potential is not underestimated (Ricker 1958).

The following discussion of growth in length of Nelson River sturgeon will be based mainly on calculations made by method (3) where the average back-calculated increments of growth are cumulatively totalled. This method appears to provide the best representation of growth over the greatest range of age groups in Nelson River sturgeon.

The growth curves for Nelson River sturgeon determined by method (3) are more or less typical of long living fishes of cool-temperate or subarctic waters. Note in Figure 8 that although the rate of growth decreases with age, neither asymptotic length nor an inflection in growth at early ages is apparent.

From these data it is impossible to determine the age at which the first inflection in growth may occur because accurate back-calculation of growth in the first few years of life is difficult. The annuli visible in a cross-section of the pectoral spine are actually cross-sectional views of concentric cones of growth, much like those in trees. In obtaining the cross-section it is difficult to section the cone representing annulus "one" at the same point on each fish. This results in a variation in the relative diameters of the first few annuli which cannot be corrected.

The Walford transformation for female sturgeon (Figure 10) produces two relatively straight lines which suggests that these fish have two growth stanzas. The lower segment appears to intersect the 45^{o} diagonal at an L_t of about 34 inches. This corresponds approximately to age 15. The upper segment lies close to the 45^{o} diagonal but does not intersect it. The Walford plot for male sturgeon is almost identical to that of the female sturgeon except that the lower segment of the curve appears to intersect the 45^{o} diagonal at an L_t of about 32 inches.

Further evidence that no maximum size is attained by sturgeon is indicated in Figure 6 where the empirical length of specimens is plotted

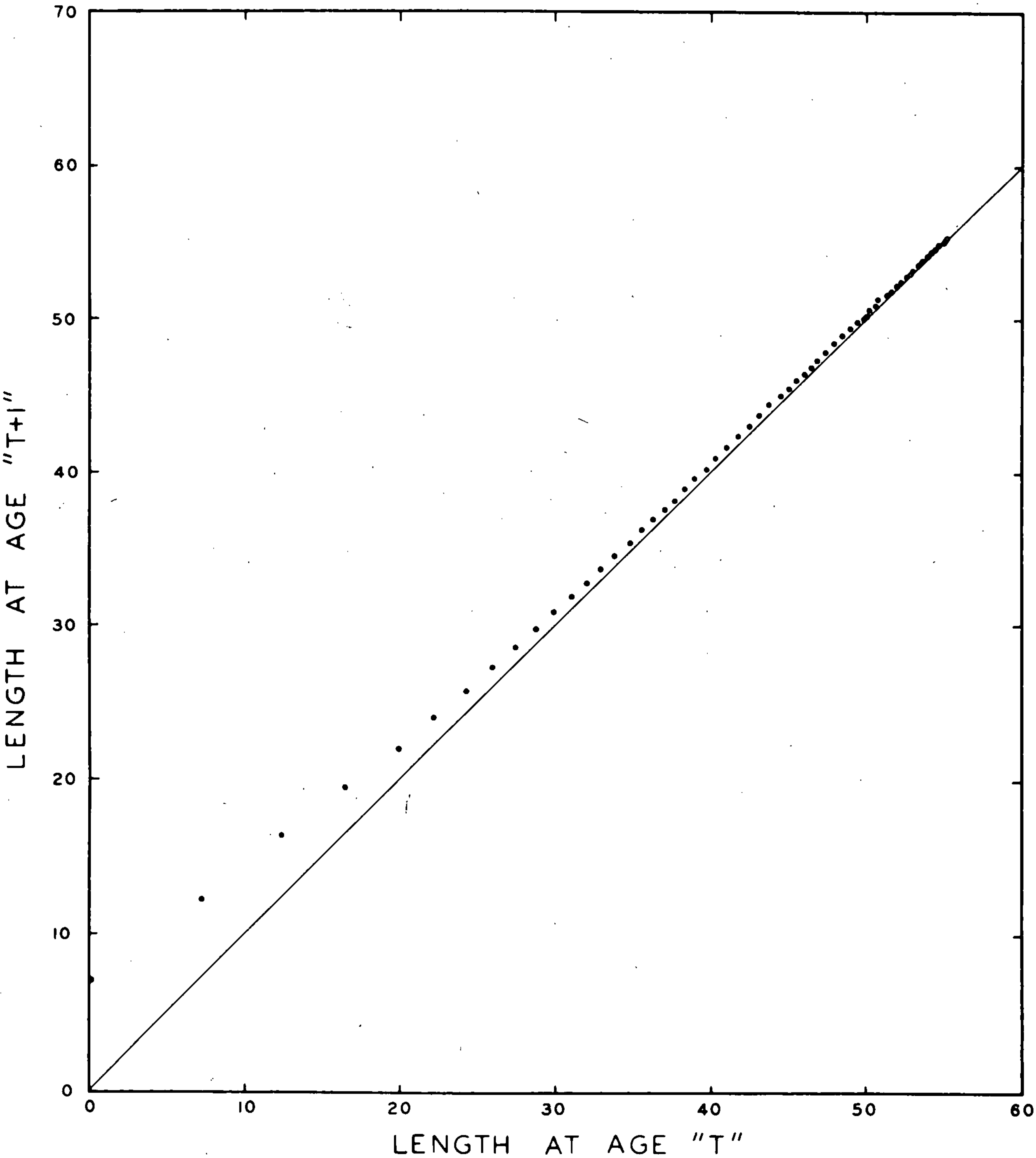

Figure 10. Walford Transformation of Calculated Lengths of Nelson River Female Sturgeon.

against age. It is seen here that after age 60, growth of female sturgeon appears to accelerate again rather than level off towards an asymptotic length.

Various other studies on lake sturgeon have yielded similar results. Cuerrier (1949) and Roussow (1955) present growth curves for lake sturgeon of Quebec that show no tendency to level out towards an asymtotic length. The maximum age of specimens in each case was 50 and 55 years respectively. On the other hand, the curve for Wisconsin sturgeon presented by Probst and Cooper (1954) illustrates a marked leveling towards an asymptotic length at age 80 or more. The shape of the curve at ages beyond 50 years, however, was determined by only one specimen.

A plot of the length at any age against the following year's increment in length (L_t x $L_{t+1} - L_t$) should produce a straight line if Nelson River sturgeon grow according to Von Bertalanffy's equation: $L_t = L_\infty \left[1-e^{-K(t-t_o)}\right]$. Such a plot of back-calculated data for female sturgeon appears in Figure 11. Again two stanzas of growth are indicated by the two straight lines which were fitted by eye. The asymptotic length of the first stanza again is about 34 inches. The second stanza also indicates an asymptotic length that appears to be between 60 and 65 inches.

(b) Growth in Length by Sexes

It is apparent from Tables III to V and Figures 6 to 8 and 13 that female sturgeon grow faster and larger and live longer than male sturgeon. From back-calculated data, the growth rate of males and females to age 20 is about the same, averaging 1.91 inches per year. Beyong age 20, however, the growth rate of the female is greater. Between age 20 and 50, the average growth in length of the female is 0.49 inches per year while that of the male is 0.37 inches per year. The growth rate of the female again accelerates beyond age 60.

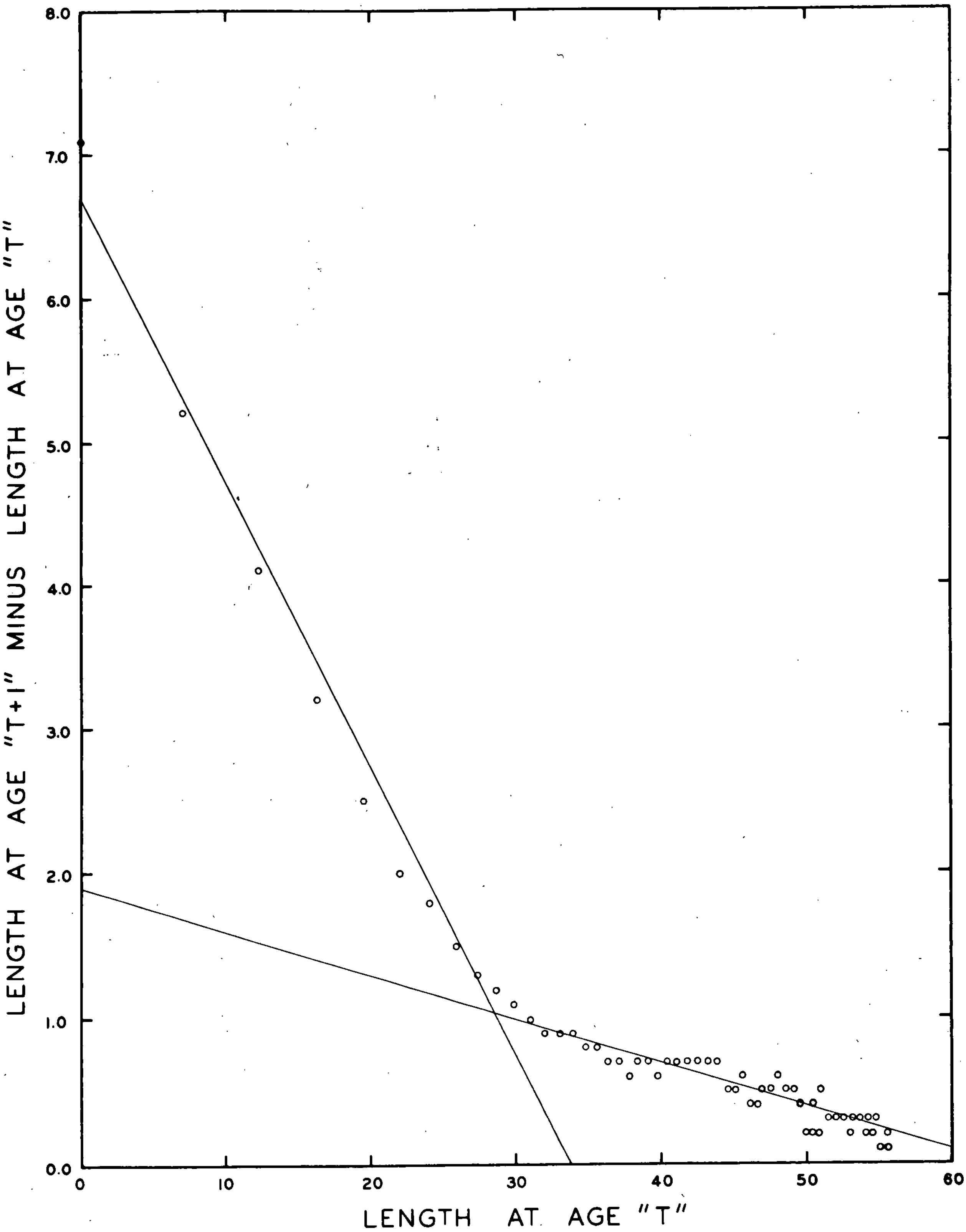

Figure II. The Relationship Between Fork Length at any age and the Following Year's Increment in Fork Length. Nelson River Female Sturgeon.

Similar results for lake sturgeon were obtained by Cuerrier (1949) and Schneberger and Woodbury (1944). Both found that the female sturgeon of Quebec and Wisconsin grew faster than the male. Probst and Cooper (1954) however found no significant difference in growth of the male and female sturgeon in four lakes in Wisconsin. Studies of other species of sturgeon have also produced varying results concerning the growth of sexes. Classen (1944), Derjavin (1922) and Roussow (1955) all report that the female sturgeon grows faster than the male. Classen was referring to *Acipenser sturio* of Spain while Derjavin and Roussow were referring to *Acipenser stellatus* of Europe. Probst and Cooper (1954) stated that certain Russian authors found no difference in the growth rates in males and females of the Russian sturgeon, *Acipenser stellatus* and *Acipenser guldenstadti*.

It is noticeable that the growth rate in both sexes of Nelson River sturgeon decelerates at approximately age 20. It is at this point that the growth curves of the two sexes diverge. This corresponds very closely to the age of maturity of these sturgeon.

(c) Growth of Nelson River Sturgeon in Various Calendar Years

It is very interesting and informative to examine the back-calculated growth of fish in various calendar years. Sturgeon are admirably suited to such a study because of their extraordinarily long life span.

It is well known that both extrinsic and intrinsic factors have a very strong influence on the annual growth of an organism. The effect on growth of extrinsic factors alone can be determined by averaging growth in each calendar year for a number of specimens, preferably of different ages.

This was done for the ten largest specimens of Nelson River female sturgeon on which back-calculated data were available. These specimens were representatives of year classes: 1893, 1903, 1905, 1906, 1915, 1916, 1919 and 1921. Year classes 1916 and 1919 are represented by two specimens.

The relative growth in each calendar year was calculated for each specimen. The first ten years of life were excluded from calculations on each specimen, however, because little annual variation was evident in the first few years of back-calculated growth in all large sturgeon.

The average relative growth in length per calendar year was then determined for the representatives of year classes 1893 to 1906 and 1915 to 1921. The sample was divided to provide some test of the consistency of the data. These data are presented graphically in Figure 12. The upper curve represents year classes 1915 to 1921 and the lower curve represents year classes 1893 to 1906.

It is evident that these curves are relatively consistent. The factors that produce a noticeable peak in the annual growth of one group produces a similar peak in the curve representing the other.

The general "straight line" trend of these curves indicates a diminishing rate of relative growth between 1915 and 1950. This may be th e actual case but it is more likely that this trend is due to bias in the nature of the data. In calculations of the relative growth of the specimens since 1935 or 1940, all specimens were relatively old, large fish. On the other hand, most of the calculations prior to 1935 were based on young, small fish. These curves therefore serve to illustrate that relative growth decreases with size and/or age rather than with calendar years.

These curves suggest that growth was abnormally high during the period 1929 to 1931. Relative growth also appears to have been high in the years 1919, 1937, 1942 and 1947.

These fluctuations in the relative growth of Nelson River sturgeon may be due to one or more of a number of extrinsic factors such as abundance

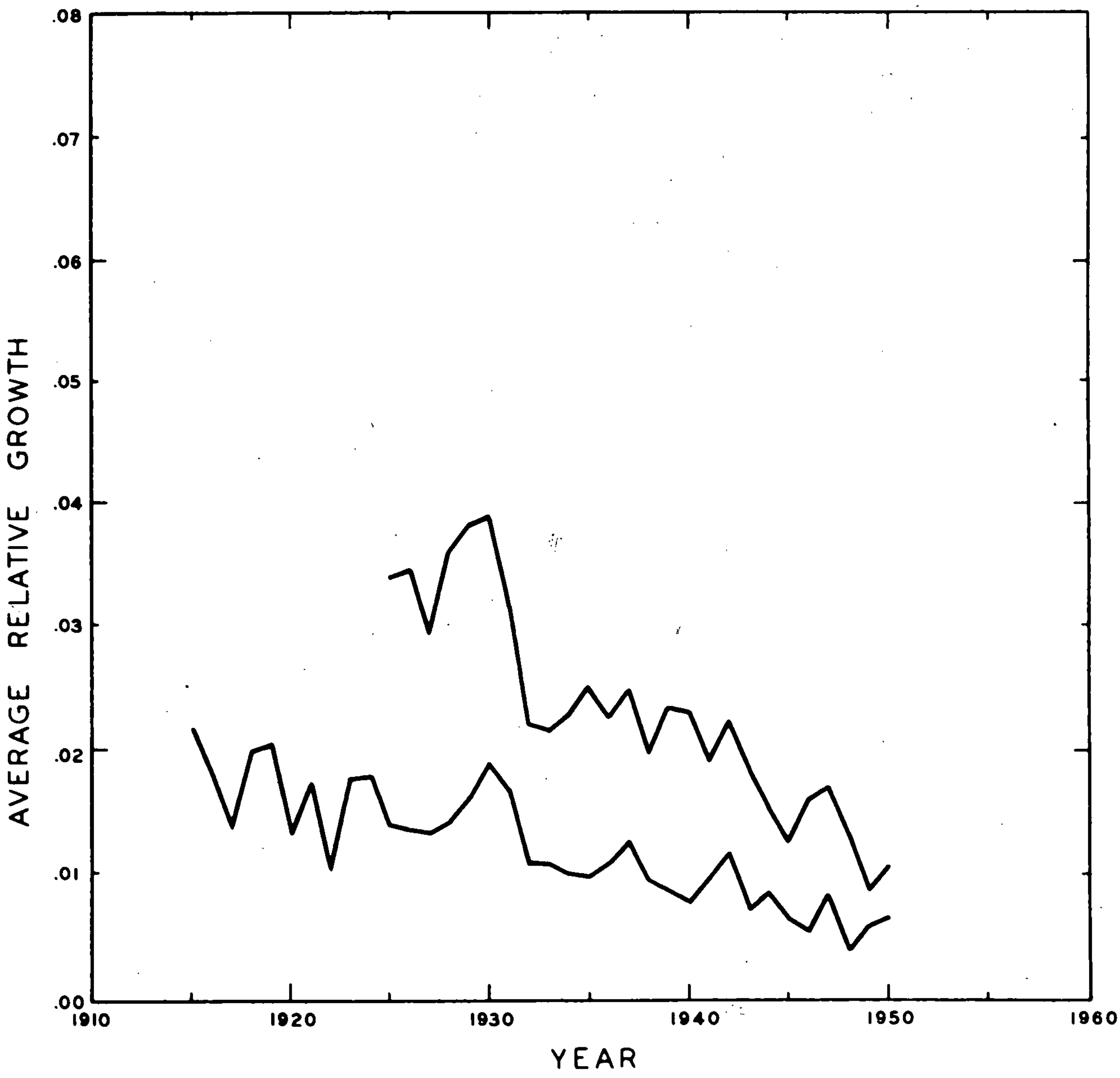

Figure 12. Average Relative Growth in Fork Length by Calendar Years of Two Samples of Nelson River Female Sturgeon.

or availability of food, annual difference in water temperature or levels, etc.

These data on relative growth were correlated with mean water discharges (in cubic feet per second) at a station located on the Nelson River about twenty-five miles from Sipiwesk Lake. They were also correlated with Nelson River sturgeon production statistics. Although it appears that growth may have been slightly greater in years of low water and/or years when population density would have been low; the correlation of these data is not sufficiently consistent to be significant.

(d) Growth in Weight of Nelson River Sturgeon

The growth in weight of Nelson River sturgeon is presented in Table V where the average size has been calculated for age groups of three-year intervals. These data are also presented graphically in Figure 13.

Data are based on 733 specimens sampled from 1953 to 1956.

TABLE V. The Average Size (Round Weight in Pounds) by Age Groups of Nelson River Sturgeon. 1953 to 1956 Data.

	Males		Females			Males		Females	
Age Group	Freq.	Ave. Weight	Freq.	Ave. Weight	Age Group	Freq.	Ave. Weight	Freq.	Ave. Weight
7-9	2	4.2	.	.	52-54	7	32.4	8	44.7
10-12	.	.	.	.	55-57	1	33.0	7	41.3
13-15	.	.	1	5.5	58-60	.	.	.	.
16-18	6	17.1	3	10.8	61-63	.	.	5	56.6
19-21	28	17.5	7	16.9	64-66	1	44.0	7	64.4
22-24	43	19.8	24	22.6	67-69	.	.	3	45.3
25-27	34	20.8	25	24.9	70-72	.	.	2	56.0
28-30	34	20.6	22	26.5	73-75	.	.	2	57.8
31-33	34	23.0	35	31.4	84 only	.	.	4	79.2
34-36	46	25.2	38	32.0	86 only	.	.	1	77.0
37-39	34	24.7	38	31.4	88 only	.	.	1	100.0
40-42	27	24.8	34	35.4	98 only	.	.	1	52.0
43-45	42	27.0	42	34.2	102 only	.	.	1	110.0
46-48	16	28.1	37	38.2	105 only	.	.	1	122.0
49-51	6	34.3	22	38.7	110 only	.	.	1	101.0
					Totals	361		372	

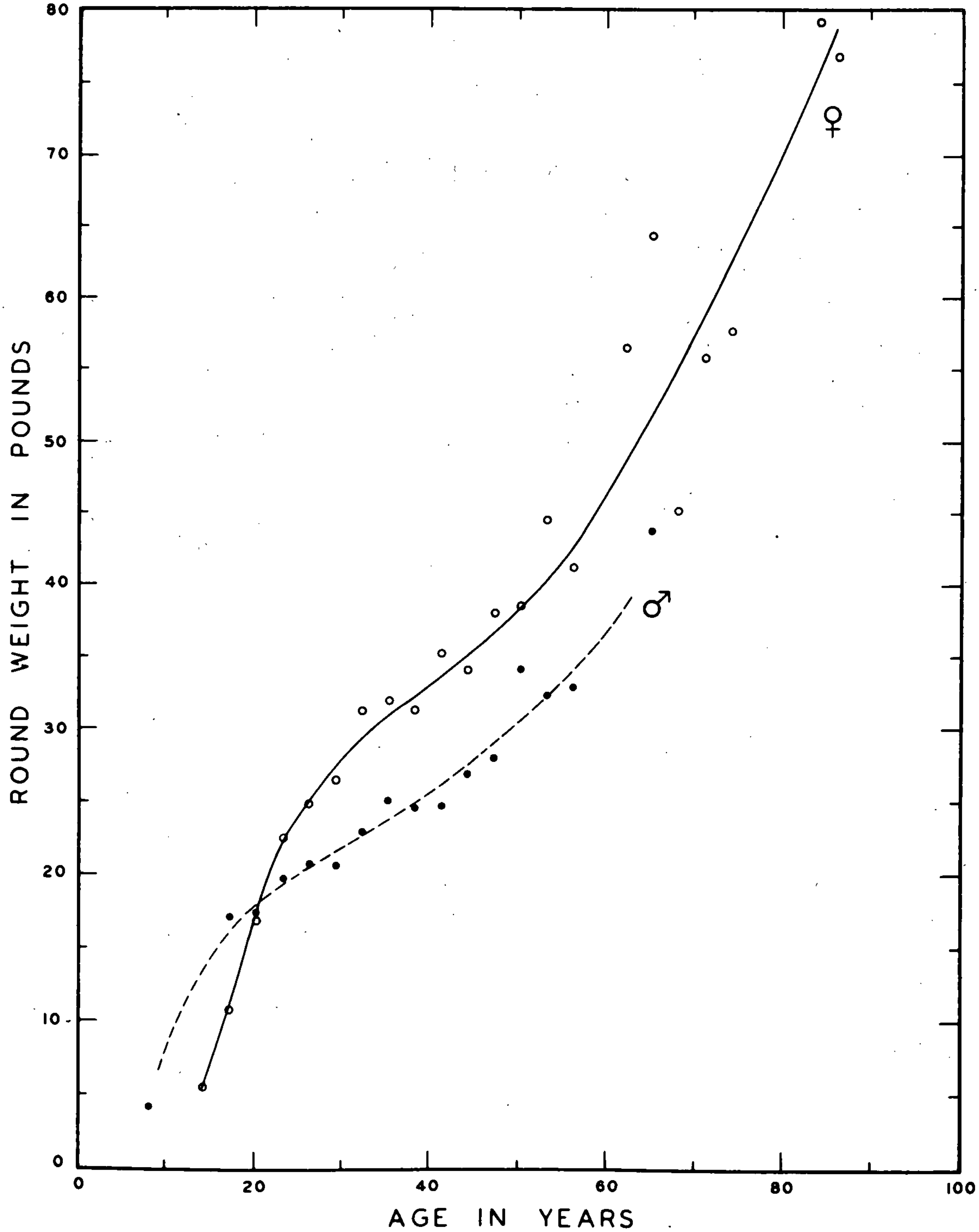

Figure 13. Growth in Weight of Nelson River Sturgeon.

The scatter of points in Figure 13 is quite wide despite the fact that most age groups are well represented by specimens. This illustrates the variability of growth in weight of the individual.

It is evident from these curves that female sturgeon grow much faster than the male sturgeon and attain a much larger size. Of 361 males and 372 females sampled from 1953 to 1956, only 5 male sturgeon exceeded 40 pounds and none exceeded 50 pounds while 97 female sturgeon exceeded 40 pounds, 40 females exceeded 50 pounds and 11 females exceeded 70 pounds.

The growth curves in Figure 13 suggest that the female sturgeon grows slower than the male to age 20. This portion of the growth curve, however, is not likely representative of the average growth of Nelson River sturgeon since only eight males and four females under 19 years of age are represented. It is more reasonable to assume that the rate of growth in weight of males and females is similar at these ages as in the case of growth in length determined by back-calculation.

From the growth curves (fitted by eye) in Figure 13, it is evident that the average annual increment in weight to age 20 is 0.90 pounds in both sexes. Beyond age 20 the female grows much faster than the male. From age 20 to 50, the average annual increment in weight of the male is 0.44 pounds while that of the female is 0.68 pounds. Beyond age 50, the average increase in weight per year of the female sturgeon is about 1.0 pounds. Note that there is no indication whatsoever of an asymptotic weight in either sex.

(e) The Length-Weight Relationship

The length-weight relationship of male and female Nelson River sturgeon is presented in Table VI.

TABLE VI. Length-Weight Relationship of Nelson River Sturgeon. 1953 to 1956 and 1959 Data.

Fork Length*	Males		Females	
	Frequency	Ave. Weight*	Frequency	Ave. Weight*
20.1-22.0	1	3.3	.	.
22.1-24.0	1	3.0	1	3.5
24.1-26.0	.	.	.	.
26.1-28.0	1	5.0	1	5.5
28.1-30.0	.	.	.	.
30.1-32.0	1	8.5	.	.
32.1-34.0	2	9.1	3	14.6
34.1-36.0	4	13.8	2	11.3
36.1-38.0	17	15.0	6	19.8
38.1-40.0	28	18.4	13	19.2
40.1-42.0	54	19.7	30	20.8
42.1-44.0	76	21.8	41	26.0
44.1-46.0	60	24.7	53	28.6
46.1-48.0	55	28.4	44	32.7
48.1-50.0	24	31.2	56	36.1
50.1-52.0	4	35.0	45	39.9
52.1-54.0	2	41.5	18	47.5
54.1-56.0	1	54.5	15	50.7
56.1-58.0	.	.	3	59.7
58.1-60.0	.	.	7	56.6
60.1-62.0	.	.	7	70.3
62.1-64.0	.	.	3	86.7
64.1-66.0	.	.	3	96.3
66.1-68.0	.	.	2	106.0
68.1-70.0	.	.	1	111.0
Total	331		354	

* Fork Length in inches and round weight in pounds.

A logarithmic plot of these data appears in Figure 14. The regression lines were determined by the least-squares method. For males and females respectively, these regression lines are:

$$\text{Log } W = -3.55 + 3.002 \log L$$
$$\text{Log } W = -3.84 + 3.204 \log L$$

These regression lines indicate that growth of Nelson River sturgeon is very nearly "isometric" since the slope of these lines is close to 3. This would more aptly apply to larger sturgeon as few specimens under 35 inches in length are represented.

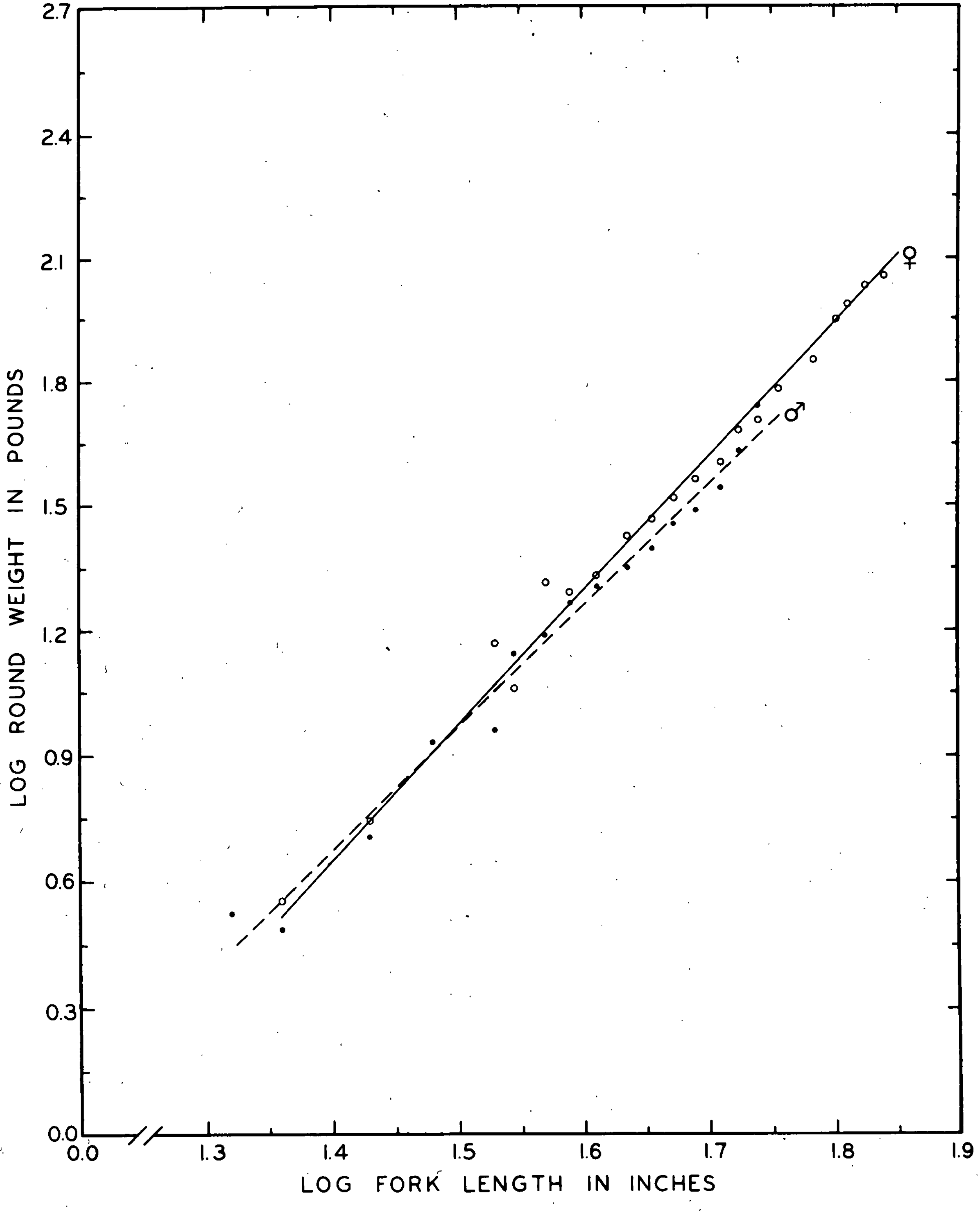

Figure 14. Length - Weight Relationship of Nelson River Sturgeon.

These data indicate that female sturgeon are more rotund than males. This may be accounted for by the large volume of eggs carried by mature females, or the large body of fat that is associated with the developing ovary in immature females. No data are available on the ratio of gonad weight to body weight for Nelson River sturgeon but Cuerrier (1949) found that the weight of the gonad of Quebec Lake sturgeon accounted for as much as 12.7% and 28.8% of the body weight of males and females respectively.

Probst and Cooper (1954) found no appreciable difference in the length-weight relationship of male and female sturgeon from Lakes Poygan, Winneconne and Butte des Morts in Wisconsin.

(f) The Relationship of Dressed Weight to Round Weight

The relationship of dressed weight to round weight of Nelson River male and female sturgeon sampled in 1953 and 1954 from the commercial fishery is presented in Table VII.

TABLE VII. The Relationship of Dressed Weight to Round Weight of Nelson River Sturgeon

Round	Dressed Weight			Round	Dressed Weight		
Weight	Freq.	Average	Range	Weight	Freq.	Average	Range
9.2-10.8	1	6.0	.	41.2-42.8	11	28.0	24-32
11.2-12.8	1	8.0	.	43.2-44.8	3	29.7	28-32
13.2-14.8	1	10.0	.	45.2-46.8	5	31.0	24-35
15.2-16.8	9	10.3	10-11	47.2-48.8	5	33.0	30-36
17.2-18.8	14	10.9	10-12	49.2-50.8	3	33.7	32-37
19.2-20.8	37	12.5	11-16	51.2-52.8	3	36.0	34-39
21.2-22.8	31	13.4	11-16	53.2-54.8	2	34.5	34-35
23.2-24.8	31	15.2	12-19	55.2-56.8	3	35.7	31-43
25.2-26.8	28	16.7	13-18	60 only	1	48.0	.
27.2-28.8	24	18.4	15-21	65 only	1	51.0	.
29.2-30.8	22	19.4	15-23	72 only	1	47.0	.
31.2-32.8	22	21.2	17-25	77 only	1	63.0	.
33.2-34.8	23	21.8	19-27	90 only	1	67.0	.
35.2-36.8	19	24.2	22-30	97 only	1	52.0	.
37.2-38.8	8	23.1	16-27	100 only	1	62.0	.
39.2-40.8	7	26.6	25-30	122 only	1	76.0	.
Total					321		

Note: All weights are in pounds.

These data are presented graphically in Figure 15. The dots represent average dressed weights and the vertical bars represent the range in dressed weights for each two inch interval of round weight.

The range in dressed weight that is recorded for each interval of round weight below 15 pounds and above 42 pounds cannot be considered too reliable because of the scanty data.

The data presented here indicates that the relationship between round and dressed weights of Nelson River sturgeon is very variable. Much of this variability can be attributed to the fact that these data represent both males and females. The variability within each sex, however, would also be fairly great due to differences in the general "condition" or the stage of reproductive maturity of the individual. Differences in the method of dressing by various fishermen may also introduce some variability in the round to dressed weight relationship.

The curve in Figure 15, which was fitted by eye, indicates a fairly straight line relationship between round and dressed weights. This line suggests a simple "rule of thumb" for determining dressed weights from round weights of average sturgeon:

Dressed weight = 2/3 round weight

(g) Comparison of the Growth of Nelson River Sturgeon with that of Sturgeon from Other Areas

Curves representing growth in length of lake sturgeon of several regions are presented in Figure 16. These data were obtained from the following sources:

Lake Nipigon, Ontario; Harkness, 1923

Lake St. Francis, Quebec; Cuerrier and Roussow, 1951

Lake St. Peter, Quebec; Cuerrier, 1949

Lake Winnebago Region, Wisconsin; Probst and Cooper, 1954

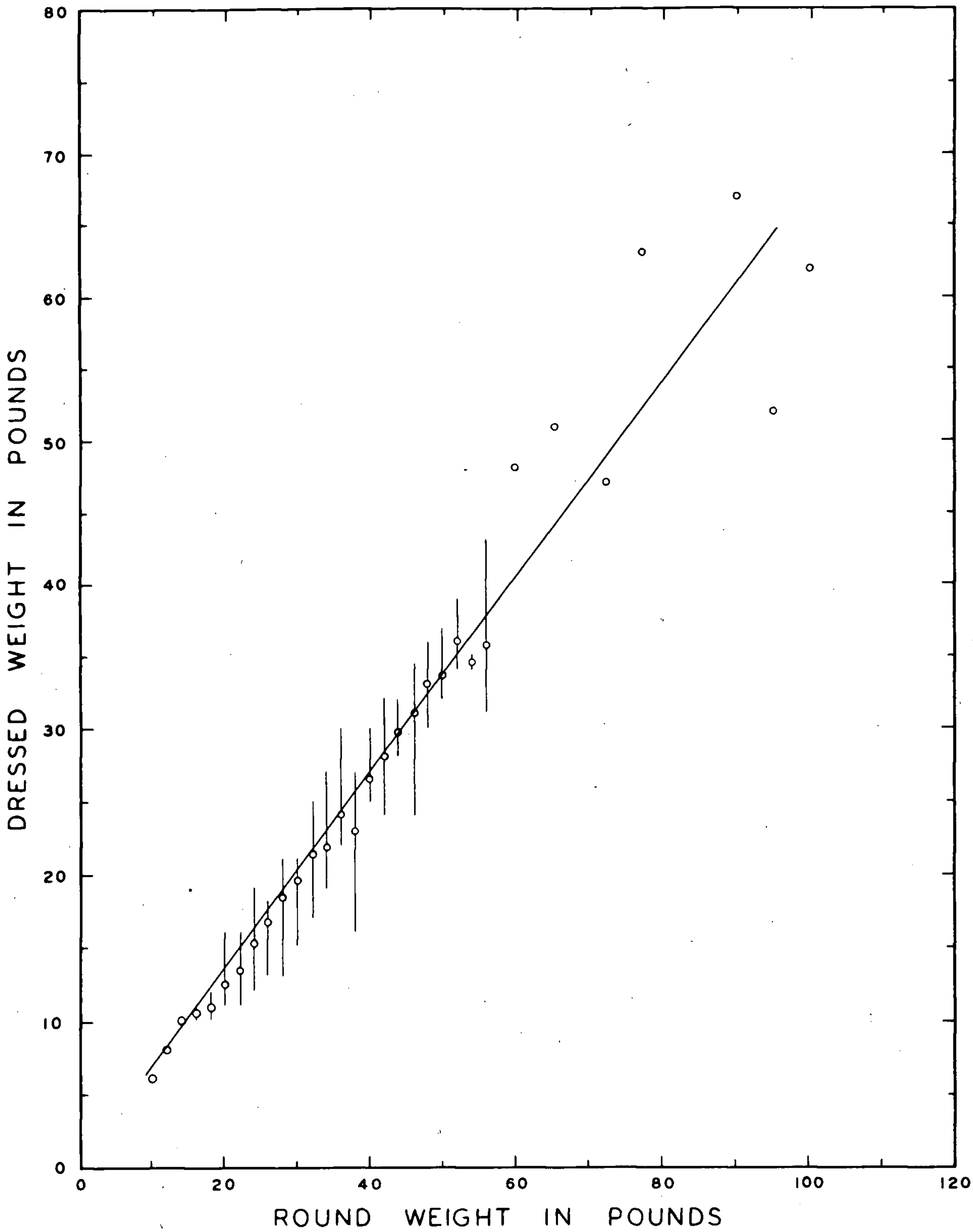

Figure 15. The Relationship of Dressed Weight to Round Weight in Nelson River Sturgeon.

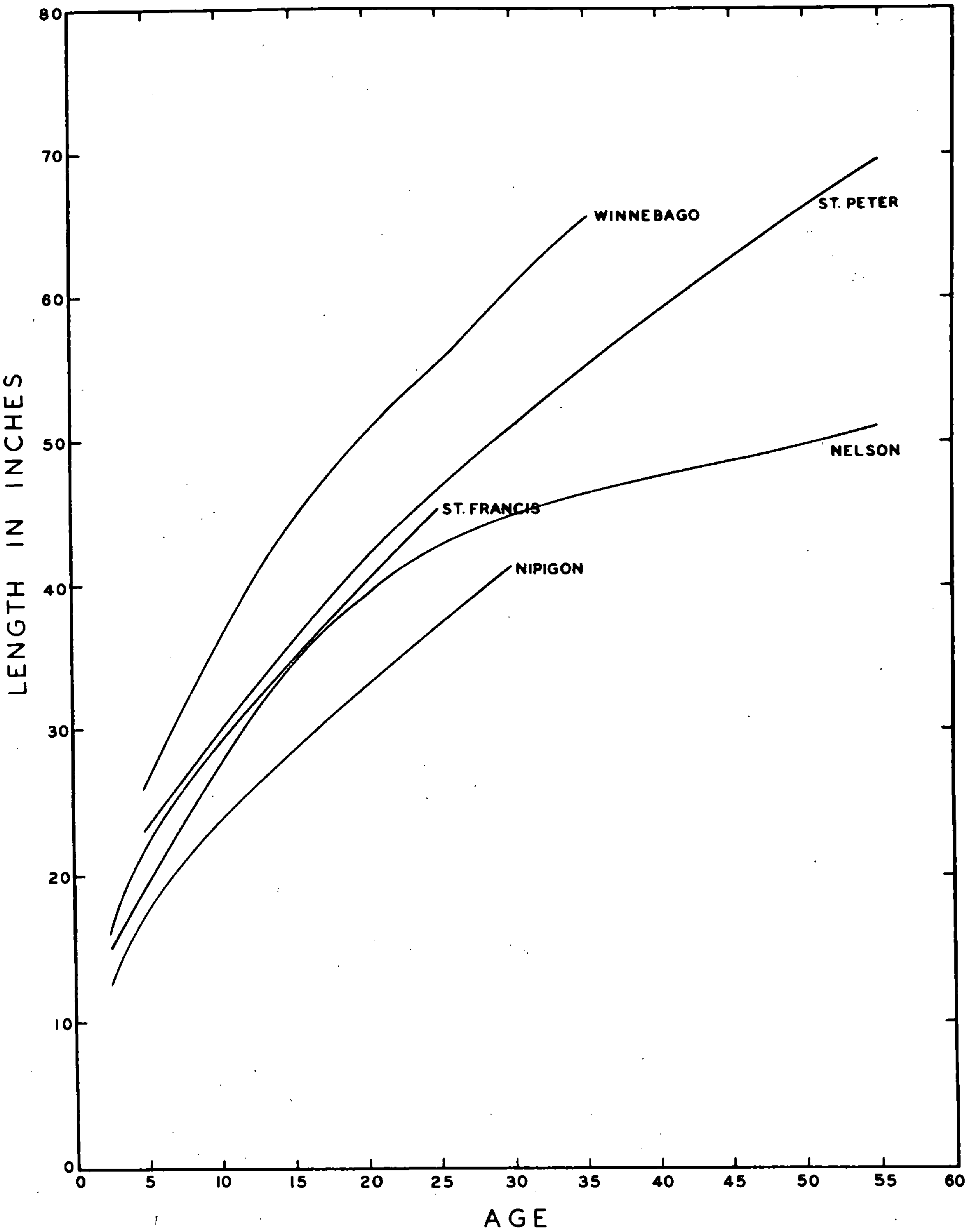

Figure 16. Comparison of Growth in Length of Lake Sturgeon from Several Regions.

These curves represent average empirical lengths. Males and females are considered together in all cases. All age determinations were made from cross-sections of the marginal spine of the pectoral fin with the exception of those of Lake Nipigon which were aged by means of otoliths.

The curve for growth in length of Lake Winnebago sturgeon cannot be compared directly with those for sturgeon of the other areas since it is based on total length while the others are based on fork length. Some comparisons of these curves could be made, however, if total lengths for each age group of Winnebago sturgeon were reduced by three to four inches. This assumption is based on data presented by Cuerrier and Roussow (1951) who used the factor 0.9166 to calculate fork lengths from total lengths for Lake St. Peter sturgeon. This agrees with measurements made on Nelson River sturgeon. The average difference between total and fork lengths of 100 Nelson River sturgeon of various sizes that were sampled in 1956 was 4.05 inches.

Even if the curve for Winnebago sturgeon was lowered by reducing each point on the curve, the curve for these sturgeon would still remain above the others.

The curves in Figure 16 show that Nelson River sturgeon grow slower than those from other regions with the exception of Lake Nipigon. This may be explained by the difference in latitude of these waters. Although the Nelson River is relatively productive, the growing season is quite short.

The growth rate of sturgeon is highest in Lake Winnebago which is the most southerly lake considered.

The curves for growth in weight of lake sturgeon of these areas is similar to those for length except that a greater difference in the rates of growth is apparent. The curves for Lake St. Francis and Lake St.

Peter are also interchanged, indicating that the sturgeon of Lake St. Francis grow faster in weight but slower in length than sturgeon of Lake St. Peter.

The curves for growth in length and weight of Nelson River sturgeon both exhibit a marked change in slope between age twenty to twenty-five. This correlates closely to the age of maturity of these sturgeon. The sturgeon of Lake St. Francis, Lake St. Peter and Lake Nipigon mature at a similar age to those of the Nelson River (Roussow, 1955; Cuerrier, 1949 and Harkness, 1923) but reproductive maturity is not reflected in the growth curves of these fishes.

V. REPRODUCTION OF NELSON RIVER STURGEON

Without some knowledge of the age of reproductive maturity, the time and place of spawning and the reproductive capacity of a species of fish, it is impossible to properly manage and regulate a commercial fishery on a sustained yield basis. These factors are of prime importance in the establishment of regulations pertaining to the type and size of fishing gear, minimum legal sizes of fish, fishing areas and seasons, and production limits.

Relatively little is known about reproduction in sturgeon, particularly the duration of each stage in the development of the gonad and the frequency of spawning. The investigations on Nelson River sturgeon that pertained to reproduction were designed mainly to determine the age and size at which these fish attain reproductive maturity. Some data were also obtained on the time and frequency of spawning.

A. METHODS AND MATERIALS

Each sturgeon sampled on the Nelson River was sexed and classified according to an arbitrary classification which described macroscopically the various stages in the development and maturation of the gonad. These classifications were as follows:

<u>MALE STURGEON</u>

1. IMMATURE: Testes small in comparison to fat body, gray and hard.
2. MATURE: Testes white or cream in color, lobed, much larger than fat body (see Figure 17).

   Subscript "S" after Stage 2 indicates that the sturgeon had spawned earlier that year (i.e. milt easily expressed from gonad).

FEMALE STURGEON

1. IMMATURE: Ovary very small in comparison to the fat body. Eggs minute and visible on the surface of the ovary only along a narrow longitudinal groove on the dorsal surface of the fat body.

2, 3, and 4. Gonad comprised mostly of ovary. Eggs evident on at least 1/3 to 1/2 of the surface of the gonad. Eggs pinhead or larger in size; white, pale yellow or darkening.

5. CAVIAR TOO FAT: Eggs are present throughout the gonad and are imbedded in a matrix of fat. They are grey or olive in color and are full or almost full size (2 mm. to 3 mm. in diameter) (See Figure 18).

6. CAVIAR: Eggs are full size and dark olive to black in color. They are no longer firmly attached to the ovary. Little or no fat is evident on the surface of the ovary.

Subscript "S" after stages 2, 3 and 4 indicates that the sturgeon has spawned out (i.e. a few unspawned eggs are left on the ovary or in the body cavity.

B. DEVELOPMENT OF THE GONAD

In the development of the sturgeon gonad, adipose tissue appears first as large paired bodies which run the length of the coelomic cavity. As the fish matures, testicular or ovarian tissue, which first appears as a narrow fold on the dorsal surface of the adipose body, invades and replaces the fat which almost disappears at reproductive maturity.

The gonad of a sturgeon (particularly the female) matures very slowly and the period between spawnings is of much longer duration than in most other fishes. This is suggested by the many stages of gonad development

Figure 17. Male Lake Sturgeon. The Enlarged Testes are Typical of Stage 2 (Mature).

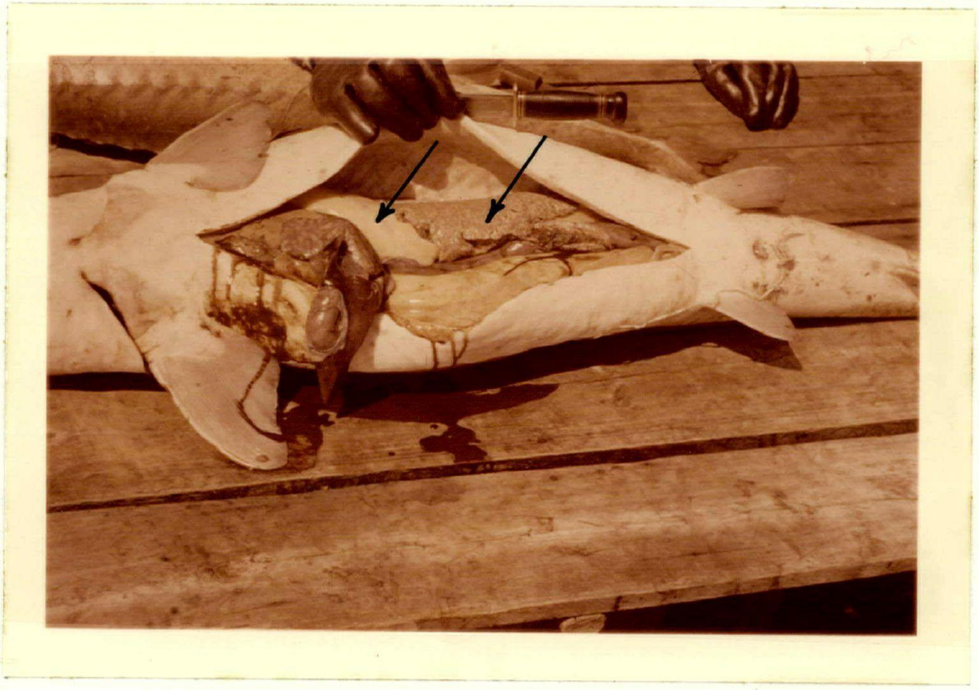

Figure 18. Female Lake Sturgeon. The Enlarged Ovaries are Typical of Stage 5 (Caviar Too Fat).

that are evident at any season of the year.

Cuerrier (1949) describes six stages in the development of both testis and ovary of lake sturgeon of Lake St. Peter in Quebec. He also refers to other workers who described from four to seven stages in the development of the gonad of various species of sturgeon. The first stage described is usually the immature state where the gonad is just beginning to develop. The last stage usually describes the spawned out state.

It was hoped that an analysis of data concerning these stages of development would provide some clue to the age of maturity and the frequency of spawning of Nelson River sturgeon.

C. THE TIME AND PLACE OF SPAWNING

The lake sturgeon spawns in fast water near rapids and falls in the spring. Bajkov (1930) states that Manitoba sturgeon usually spawn below rapids in ten feet of water while Cuerrier (1949) and Harkness (1936) say that eastern lake sturgeon spawn near rapids in shallow water. Bajkov (1933) adds: "the actual spawning takes place usually very close to rapids or waterfalls and very often under waterfalls in the white-boiling water." The eggs are swept downstream and usually come to rest on mud or clay (Harkness, 1936 and Cuerrier, 1949).

Bajkov (1930), Harkness (1936) and Williams (1951) claim that lake sturgeon sometimes spawn in lakes on shallow beaches.

The date of spawning of lake sturgeon in Canada is usually in May and/or June. Manitoba sturgeon usually spawn during the latter half of May and the first week of June. Rodd (1926) found some ripe females between June 10 and 20 at the north end of Lake Winnipeg but he saw no ripe males after June 15. Bajkov (1930) says that Lake Winnipeg sturgeon spawn from mid-May to the beginning of June.

Nelson River sturgeon appear to spawn slightly later than Lake Winnipeg sturgeon since an occasional ripe male has been taken in the Nelson River commercial fishery after June 10 in several years. Of specimens examined in 1955, 1956 and 1959, 7 out of 77 male sturgeon were ripe (milt present) on or before June 16. By June 21, however, only 5 of 83 males examined were ripe and of 30 males examined after June 21, none were ripe. Very few females sampled after June 10 in any year were in spawning condition.

It is of interest that the Indians of southern Manitoba claim that the sturgeon spawns when the oak trees begin to leaf out. Northern Manitoba Indians believe that the budding of the poplar heralds the spawning of sturgeon.

Harkness (1923 and 1936) states that lake sturgeon of Lake Nipigon spawn about June 1 at water temperatures of about 56°F. Cuerrier (1949) says that lake sturgeon of Lake St. Peter in Quebec spawn from mid-May to mid-June with the peak at the end of May (54° to 60° F). He adds that lake sturgeon of the Upper Ottawa River spawned between June 15 and 20 in 1947 (53° to 58° F). Vladykov (no date) says that Quebec sturgeon spawn from the end of May to the beginning of July (65° F) and Roussow (1957) says that they spawn in late May and the first three weeks of June at water temperatures of 9° to 18° C (about 48° to 64° F). Wirth (1959) reports that most sturgeon of the Wolf River in Wisconsin spawned in the first week of May in 1959. Williams (1951) claims that lake sturgeon of Michigan spawn at water temperatures of 60° to 70° F.

Although most sturgeon are spring spawners, it is apparent that some species also spawn in the fall. Barannikova (1954) suggests that certain races of <u>Acipenser guldenstadti</u> in Russia spawn in the fall and Derjavin (1922) refers to fall spawning races of <u>Acipenser stellatus</u>.

D. THE AGE OR SIZE OF REPRODUCTIVE MATURITY

The sturgeon matures at a very late age compared to most other species of fish. Although one Eurasian sturgeon is reputed to mature at three to five years of age (Roussow, 1957), most species of sturgeon do not mature before age ten to fifteen years. The age of maturity of various species of sturgeon is summarized in Table VIII.

TABLE VIII. The Age of Reproductive Maturity of Various Species of Sturgeon

Species of Sturgeon	Age of Maturity Males	Age of Maturity Females	Region	Reference
A. fulvescens	22-28	22-28	Ontario	Harkness, 1953
A. fulvescens	14	23	Quebec	Cuerrier, 1949
A. fulvescens	12-19	14-23	Quebec	Roussow, 1957
A. fulvescens	15	22	Wisconsin	Probst, 1954
A. transmontanus	11-12	11-12	California	Pycha, 1956
A. sturio	7-9	8-14	.	Roussow, 1957
A. sturio	10-11	14-15	Spain	Classen, 1944
A. guldenstadti	9	.	Russia	Kuzmin, 1954
A. guldenstadti	8-14	13-20	.	Roussow, 1957
A. schrencki	8-10	8-10	.	Roussow, 1957
A. stellatus	12-15	14-18	Russia	Derjavin, 1922
A. baeri	10-12	12-14	.	Roussow, 1957
A. ruthenus	3-7	5-12	.	Roussow, 1957
Huso huso	12-14	16-18	.	Roussow, 1957
Huso dauricus	.	18-20	.	Roussow, 1955

Nelson River lake sturgeon mature at slightly greater ages than those in Eastern Canada. This is suggested in Table IX where the number, by age groups, of Nelson River female sturgeon at each stage of reproductive maturity is summarized. These data are from samples obtained on the Nelson River in 1955 and 1956.

These data suggest that most Nelson River female sturgeon mature and begin to spawn between 25 and 30 years of age. Only two females under age 25 were spawned out and few "ripening" females were under 28 years of age. No immature females were over 30 years of age.

TABLE IX. The Frequency, by Age Groups, of Nelson River Female Sturgeon at Each Stage of Reproductive Maturity

Age Group	1 Immature	2, 3, 4 Developing	5, 6 Ripening*	S Spawned Out	Totals
17-19	2	.	.	.	2
20-22	7	.	1	.	8
23-25	22	5	.	2	29
26-28	7	3	3	2	15
29-31	2	6	3	.	11
32-34	.	8	6	3	17
35-37	.	8	6	2	16
38-40	.	2	5	2	9
41-43	.	5	7	.	12
44-46	.	6	9	1	16
47-49	.	5	10	2	17
50 & over	.	5	17	7	29
Totals	40	53	67	21	181

* It is assumed that females at Stages 5 and 6 would have spawned in one to two years.

These observations agree closely to those made by Kooyman (1955) who made a similar analysis of data obtained on the Nelson River in 1953 and 1954. He found that female sturgeon mature between the ages of 20 and 30 years, with the majority of fish still being immature at age 25.

The age at which Nelson River female sturgeon mature and spawn (25 to 30 years) corresponds to a round weight of about 24 to 29 pounds and a fork length of about 42 to 45 inches.

The male Nelson River sturgeon appears to spawn at an earlier age than the female. The exact age of maturity was very difficult to determine by macroscopic examination of specimens, however, because most of them were obtained well after the spawning period and few definitely mature males (those with milt) were sampled. The youngest of fourteen "ripe" males sampled in 1955, 1956 and 1959 was 20 years of age. Three of them were 22 to 23 years of age and the rest were 30 to 40 years of age. Of the other 181 males sampled in these three years, most of the individuals over 20 years of age appeared to be fully developed and mature. This suggests that most Nelson River males first spawn at about 20 years of age. This corresponds to a round weight of about 18 pounds and a fork length of about 38 inches.

It is significant that these estimates of the age and size of reproductive maturity of Nelson River sturgeon correspond very closely to the inflections that appear in the curves for growth in length and weight of these sturgeon (Figures 6 and 13).

A comparison of the age and the size of reproductive maturity of lake sturgeon of several regions is presented in Table X.

TABLE X. The Age and Size at Reproductive Maturity of Lake Sturgeon of Various Regions

		MALES		
Region	Age (years)	Weight (lbs.)	Fork Length (ins.)	Reference
Nelson River	20	18	38	This paper
St. Lawrence River	14	8-10	30	Cuerrier, 1949
Ontario	22-28	.	35	Harkness, 1953
Quebec	.	11.5(youngest)	.	Vladykov, no date
Wisconsin	15	7-8	.	Probst, 1954

		FEMALES		
Region	Age (years)	Weight (lbs.)	Fork Length (ins.)	Reference
Nelson River	25-30	24-29	42-45	This paper
St. Lawrence River	23	25-30	40	Cuerrier, 1949
Ontario	22-28	.	40	Harkness, 1953
Quebec	.	17(youngest)	.	Vladykov, no date
Wisconsin	22	30	.	Probst, 1954

E. THE FREQUENCY OF SPAWNING IN STURGEON

It is generally conceded that no species of sturgeon regularly spawns each year but the interval between spawnings is not definitely known for any species. Several authors have voiced opinions on the periodicity of spawning in various species of sturgeon but few have presented conclusive evidence. Classen (1944 and 1947) states that male Acipenser sturio of Spain spawn each year while females spawn every two years. Cuerrier (1949) quotes Borodin as saying that there is a two year interval between spawnings in Acipenser oxyrhynchus and Acipenser guldenstadti. Cuerrier also quotes Menshikov who believes there is a two year cycle of spawning in Acipenser ruthenus.

Most biologists who have studied aspects of reproduction in the lake sturgeon conclude that the interval between spawnings varies from two to five years. Vladykov (no date) states that lake sturgeon spawn every two to three years and Harkness (1953) believes that there is a two to four year interval between spawnings. Wirth and Cline (no date) provide definite proof that at least some male lake sturgeon in Wisconsin spawn every year, - two marked males were observed on the spawning grounds in "ripe" condition in two successive years. Probst (1954) states that male lake sturgeon of Wisconsin spawn every second year and females spawn every fifth or sixth year.

Kooyman (1955) believes that the interval between spawnings of Nelson River female sturgeon is three to four years since less than 30% of mature specimens sampled in 1953 and 1954 were ripe or spawned out. He also suggested that older mature female sturgeon spawn more frequently than young ones.

Cuerrier (1949) is of the opinion that the male lake sturgeon of the St. Lawrence River spawns twice as often as the female. He bases this assumption on the fact that he observed twice as many males as females on the spawning grounds. He concludes that the male spawns every two to three years and the female spawns every three to five years.

Roussow (1957) states that there is a four to seven year spawning cycle in the female lake sturgeon of Quebec. He bases these observations on a study of growth stanzas in sturgeon. In the magnified image of a cross-section of the marginal "spine" of the pectoral fin, closely packed bands of annuli are often seen to alternate with widely spaced bands of annuli. Roussow assumed that the maturation of the gonad was enough of a strain on the physiology of the sturgeon that it was responsible for a decrease in growth rate. He therefore interpreted these growth stanzas as an indication of first and subsequent spawnings; i.e. he suggested that the end of each closely packed bank of annuli corresponded to the end of each spawning cycle and that the widely spaced band of annuli following, corresponded to the resting period prior to the next development and maturation of the gonads. In his analyses, Roussow did not consider the possible effect of extrinsic and other intrinsic factors which doubtlessly have a considerable effect on growth of sturgeon.

It is not possible to determine precisely the interval between spawnings of Nelson River sturgeon from the type of data obtained there in 1955, 1956 and 1959. Some of these data however can be used to make a reasonable estimate.

In Section V-A, five definite stages in the development and maturation of the ovary were described. Experienced sturgeon fishermen claim that these stages are recognizable at any season of the year but that spawning occurs only in the spring. It is therefore likely that the duration of each stage is relatively uniform, i.e. about one year. Females at Stage 6 (Caviar) in the late spring or early summer would therefore spawn the following spring. Those at Stage 5 (Caviar Too Fat) would spawn in about two years and those at Stages 1 to 4 would spawn in three to five years. This suggests that the average interval between spawnings of Nelson River female sturgeon is about four years.

A higher ratio of spawned out and caviar bearing females in the older age groups suggested that older sturgeon spawn more frequently than younger ones. (Those at Stages 5 and 6 also carry a batch of eggs at Stages 2 or 3.) The spawning frequency of various age groups of Nelson River female sturgeon is indicated in Table XI. These data were obtained on the Nelson River in 1955 and 1956.

TABLE XI. The Frequency and Ratio of Female Sturgeon, by Age Groups, at Each Stage of Gonad Development

Age Group	1	2, 3 & 4	5	6	Spawned out (S)	Average 5, 6 & S
24 & under	25 (.81)	3 (.10)	1 (.03)	.	2 (.06)	.03
25-34	16 (.31)	19 (.37)	9 (.17)	3 (.06)	5 (.10)	.11
35-39	.	26 (.37)	29 (.41)	8 (.11)	7 (.10)	.21
50 & over	.	5 (.17)	9 (.31)	8 (.28)	7 (.24)	.28

Since relatively few specimens are represented in each category, the average ratio of spawning or near-spawning females was calculated in the last column. From these data it appears that about 28% of female sturgeon of age 50 and over will spawn in any year. This suggests that older female sturgeon spawn every three to four years. By the same reasoning it would appear that 35 to 49 year old females spawn every five years. This method cannot be used to determine the frequency of spawning of younger sturgeon because a relatively high ratio are immature. It can be approximated however by excluding immature fish from the calculations. Thus, of 36 mature females of age 25 to 34, an average of about 6 were represented in each of Stages 5, 6 and S. This suggests that these sturgeon spawn every six years.

In attempting to determine the frequency of spawning of Nelson River female sturgeon by these methods it must be assumed that the sample obtained is representative of the population as a whole rather than either the spawning group or the non-spawning segment of the population. Since these specimens were captured at various depths and currents of water and in many different locations, it is reasonable to assume that they were representative of the population as a whole. The fact that all stages of development of the gonad were well represented provides further confidence that the whole population was adequately sampled.

No attempt was made to determine the spawning frequency of male sturgeon because few were still ripe at the time of sampling. It was therefore impossible to calculate the proportion of mature males that had spawned in any year.

VI. THE EFFECT OF THE COMMERCIAL FISHERIES ON NELSON RIVER STURGEON

Sturgeon were, at one time, found in great abundance in most of the waters of the Northern Hemisphere. Over-exploitations, dams, canals and pollution, however, are responsible for a very great reduction in numbers of all species of sturgeon. Only in small isolated bodies of water far from civilization, where a fishery is unprofitable, are sturgeon present in numbers which anywhere resemble their past abundance.

The important sturgeon fisheries of Russia and Eastern Europe are declining despite intensive research, fish culture and strict legislation (Roussow, 1955).

The once important sturgeon fisheries of Western Europe no longer exist. Meyr (1950) says that there was formerly a sturgeon run in all large German rivers but that they are now becoming extinct in those waters. Ehrenbaum (1926) suggests that pollution and shipping are important factors in the disappearance of German sturgeon and warns that the protection of sturgeon should not be relaxed. Classen (1947) says that sturgeon were once abundant in Spain but that they are now found only in the Guadalquivir River. He claims that dams are primarily responsible for their disappearance.

Nowhere have sturgeon been more depleted than in North America. Early explorers and settlers describe our waters as teeming with sturgeon. The rate of exploitation was low prior to 1800 but large numbers were killed during the latter half of the last century and the early part of this century (Roussow, 1955).

The depletion of sturgeon in the Great Lakes in the last century has been tremendous. Over 7,000,000 pounds were produced in 1880. By 1917, however, the annual production had fallen to 100,000 pounds (Roussow, 1955). Van Oosten (1936) stated that sturgeon are now merely "museum curiosities" in the Great Lakes.

Production in the St. Lawrence River is also decreasing rapidly (Roussow, 1955).

Evermann and Latimer (1910) said the Lake of the Woods was once considered the greatest sturgeon pond in the world. Over 7,500,000 pounds of sturgeon were taken from 1890 to 1900. Between 1900 and 1925, however, less than 1,000,000 pounds were produced and only 25,000 pounds were taken from 1925 to 1947 (Carlander, 1947). Evermann and Latimer (1910) and Carlander (1947) blame over-exploitation for the disappearance of these sturgeon.

The sturgeon of Lake Simcoe were reduced to the point of extinction by fishing (McCrimmon, 1956). From 1881 to 1898 a total of 136,500 pounds of sturgeon were produced. Since then, however, only one sturgeon has been reported and it was believed to have escaped from an impoundment during a flood.

Other reports of serious depletion of sturgeon by over-fishing concern the St. John River, the Fraser River and certain rivers in California. Rodd (1926) reports a 97% reduction in production on the St. John River between 1880 and 1886 and a 98.3% reduction in production on the Fraser River between 1897 and 1905. Pycha (1956) comments on the serious depletion of sturgeon in California waters.

The history of the sturgeon fishery in Manitoba is little different from that in other parts of North America. Few sturgeon were taken in Lake Winnipeg, Manitoba's principal sturgeon producer, before completion of a railroad in 1887 which linked Manitoba to the Eastern markets. Thereafter, production rose gradually as prices and markets expanded. By

1896 the annual production was approximately 175,000 pounds and by 1900 production had reached a peak of 981,500 pounds. This high rate of exploitation resulted in depletion of sturgeon stocks and production began to decrease despite good prices. This prompted closure of the fishery in 1910 when only 30,000 pounds were taken (Harkness, 1936).

The fishery was recommended in 1916 due to the war need. Production in that year amounted to 118,600 pounds but fell to 7,500 pounds by 1920. Rising prices from 1922 to 1928 resulted in another production increase to 1924 after which it decreased drastically (Harkness, 1936).

Lake Winnipeg sturgeon stocks never recovered from the over-exploitation of these early fisheries. More recent fisheries all failed after a relatively short period and production was very low in comparison to that at the turn of the century.

The Nelson River was first fished for sturgeon in 1907 but it wasn't until 1917 that they were fully exploited (see Figure 1).

The second major sturgeon fishery persisted for most of the 1920's; a period during which sturgeon prices rose steadily. Production, however, followed the trend of rising prices only to 1924 and fell drastically thereafter due to depletion of stocks. This resulted in the closure of this fishery in 1929.

The Nelson River was again opened for sturgeon fishing in 1937. Despite a steady rise in prices, production began to fall after 1941. Depletion of stocks prompted the closure of this fishery in 1946.

The most recent fishery commenced in 1953 and terminated in 1960. Production remained relatively steady to 1957 but decreased markedly in each of the last three years. Since sturgeon prices and fishing effort was high throughout this period, the failure of the fishery is also attributed to depletion of sturgeon stocks.

It is evident from the low production totals of the last two fisheries that Nelson River sturgeon stocks never fully recovered from the serious depletion of the 1920's.

All other major sturgeon fisheries in Manitoba; the most important of which are the Winnipeg, Saskatchewan and Churchill River fisheries, also failed after relatively short periods of time. In each case, the production totals of the more recent fisheries fell far short of the amounts taken in the first major fishery when virgin stocks were exploited.

A. THE EFFECT OF THE PRESENT FISHERY ON STOCKS OF NELSON RIVER STURGEON

The failure of each sturgeon fishery on the Nelson River is obviously the result of depletion of stocks. Annual recruitment and growth increment has been insufficient to sustain these fisheries at the rate of exploitation that prevailed.

If this hypothesis is valid, it is to be expected that the fishery has had a profound effect on the age and size structure of the population, the catch per unit of effort of the commercial fishery, and the year class strength. These are discussed in the following sections.

(a) Changes in the Age Structure of Nelson River Sturgeon from 1953 to 1959.

The age composition of the Nelson River sturgeon sampled from the commercial fishery from 1953 to 1956 and 1959 is presented in Table XII and Figure 19. The curves in Figure 19 which represent the percent frequency of specimens by age groups have been smoothed by means of a moving average involving five mid-points of age groups.

TABLE XII. The Age Composition of Sturgeon Sampled from the Nelson River Commercial Fishery from 1953 to 1956 and 1959.

	Males						Females						
Age Groups	1953	1954	1955	1956	1959	All Years	1953	1954	1955	1956	1959	All Years	Combined
15 & under	.	.	1	1	.	2	.	.	1	.	.	1	3
16-18	2	1	1	1	1	6	1	.	.	1	.	2	8
19-21	2	4	5	13	4	28	2	.	5	1	2	10	38
22-24	2	6	9	19	7	43	.	3	13	8	3	27	70
25-27	4	6	7	12	1	30	2	4	13	5	4	28	58
28-30	6	8	5	8	1	28	6	1	13	1	2	23	51
31-33	5	13	9	4	1	32	12	8	9	4	4	37	69
34-36	5	13	13	9	3	43	7	10	14	1	2	34	77
37-39	4	13	5	8	1	31	6	20	7	2	.	35	66
40-42	2	14	6	5	4	31	9	7	10	3	1	30	61
43-45	8	20	6	7	1	42	7	16	11	4	1	39	81
46-48	.	8	3	5	1	17	2	15	16	4	.	37	54
49-51	.	4	1	.	.	5	1	9	7	5	2	24	29
52-54	.	3	2	.	.	5	.	2	5	1	.	8	13
55-57	.	.	1	.	.	1	1	3	1	2	.	7	8
58-60	.	.	.	.	.	.	.	.	.	.	.	.	.
61-63	.	.	.	.	.	.	.	2	2	1	.	5	5
64 & over	.	1	.	.	.	1	3	10	2	5	.	20	21
Totals	40	114	74	92	25	345	59	110	129	48	21	367	712

Summary of Data Presented in Table XII

	1953	1954	1955	1956	1959	All Years
Modal Age of Males	44	44	35	23	23	23 & 35
Mean Age of Males	35.0	37.2	33.2	30.1	29.7	33.7
Modal Age of Females	32	38	47	23	26 & 32	44
Mean Age of Females	40.8	44.3	37.2	40.9	31.1	40.0
Mean Age of Both Sexes	38.5	40.7	35.8	33.8	30.6	37.0

Note: Mean ages were calculated on the basis of grouped data.

These data indicate that the age of sturgeon sampled from the Nelson River commercial fishery has decreased noticeably from 1953 to 1959. This is most apparent in the case of the males where the trend to younger fish is more regular and pronounced.

The general trend is well illustrated in Figure 19. The shape of the curves indicates a pronounced increase in the number of young fish taken from year to year. The depression that develops near the peak of the

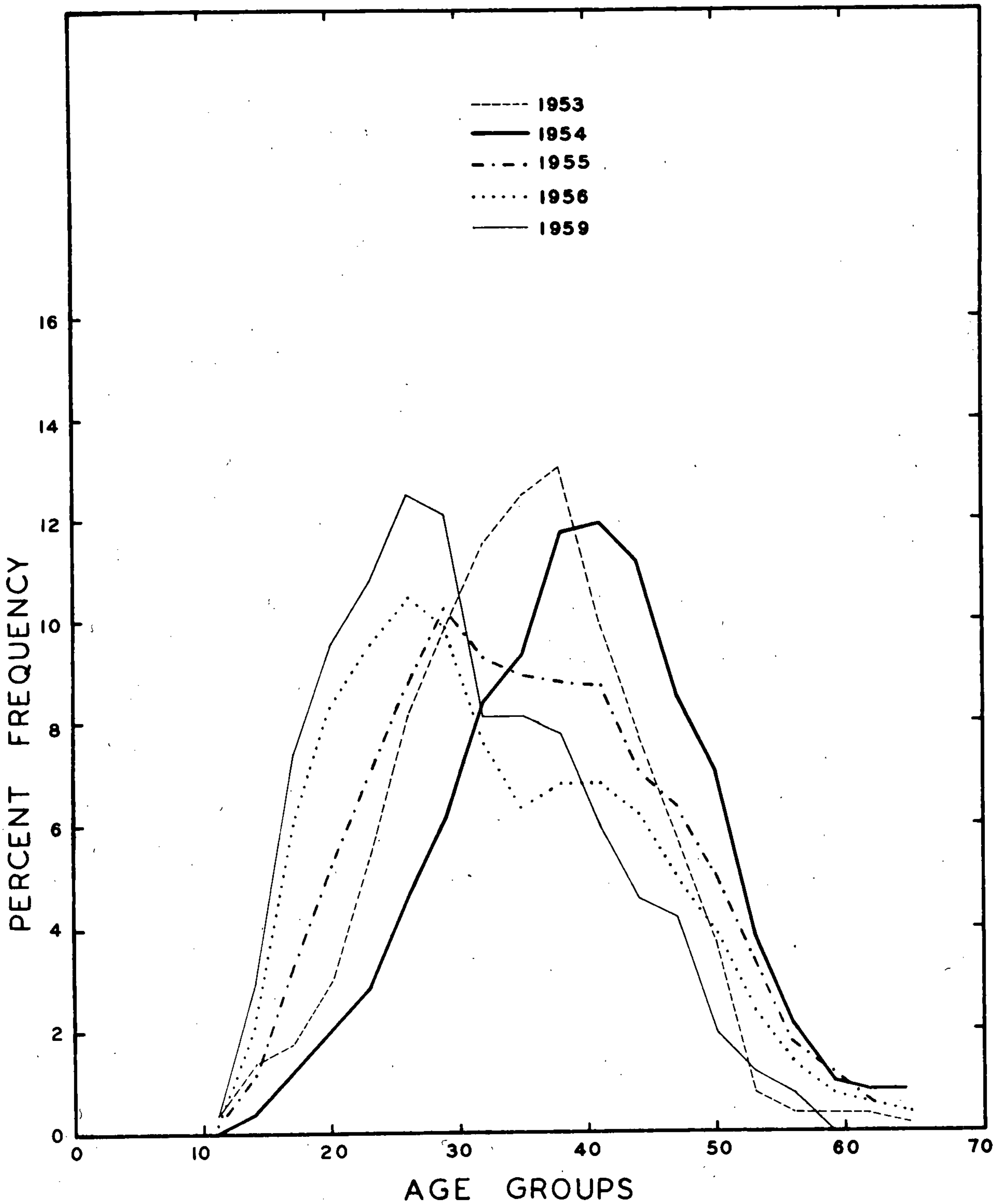

Figure 19. The Age Composition of Sturgeon Sampled from the Nelson River Commercial Fishery from 1953 to 1956 and 1959.

curve in 1955 and continues through 1956 and 1959 illustrates the effect of the fishery on fish of age thirty to forty. These are the age groups which were most vulnerable to the twelve inch gill nets which were used in this fishery.

The seriousness of this depletion is emphasized by the fact that a change in age composition can be demonstrated in as short a period as six years. This is especially so in the case of this particular species where the number of fish in the fishable population is always large in relation to the number of recruits.

(b) Changes in the Size Structure of Nelson River Sturgeon from 1953 to 1959.

The size composition (round and dressed weights) of Nelson River sturgeon sampled from the commercial fishery from 1953 to 1959 is presented in Table XIII and XIV.

TABLE XIII. The Size Composition (Round or Live Weight) of Sturgeon Sampled from the Nelson River Commercial Fishery from 1953 to 1956 and 1959.

Weight Group	Males						Females						
(Lbs.)	1953	1954	1955	1956	1959	All Years	1953	1954	1955	1956	1959	All Years	Combined
8 only	.	.	.	.	1	1	.	.	.	.	.	.	1
9 only	.	.	.	1	.	1	.	.	.	.	.	.	1
10-12	.	.	3	2	1	6	1	.	.	1	.	2	8
13-15	.	2	6	5	2	15	1	1	4	.	.	6	21
16-18	3	15	11	19	6	54	.	4	8	3	.	15	69
19-21	7	32	13	15	4	71	3	9	10	3	3	28	99
22-24	12	24	14	19	6	75	2	8	13	4	6	33	108
25-27	6	17	6	11	4	44	3	7	10	4	3	27	71
28-30	5	12	5	11	2	35	9	16	15	4	3	47	82
31-33	3	10	5	3	.	21	7	15	12	3	2	39	60
34-36	2	3	.	2	1	8	9	17	12	8	1	47	55
37-39	1	.	1	1	.	3	5	7	7	1	1	21	24
40-42	1	.	1	1	.	3	7	7	14	4	2	34	37
43-45	.	1	.	.	.	1	2	4	5	3	1	15	16
46-48	.	.	.	1	.	1	3	4	2	2	.	11	12
49-51	.	.	.	.	.	.	2	1	.	1	1	5	5
52-54	.	.	.	.	1	1	2	4	4	2	1	13	14
55-57	.	.	.	.	.	.	1	3	3	.	.	7	7
58-60	.	.	.	.	.	.	1	1	.	1	.	3	3
61-63	.	.	.	.	.	.	.	.	1	1	.	2	2

TABLE XIII continued

Weight Group (Lbs.)	Males 1953	1954	1955	1956	1959	All Years	Females 1953	1954	1955	1956	1959	All Years	Combined
64-66	.	.	.	.	.	.	.	1	.	.	.	1	1
72 only	.	.	.	.	.	.	.	1	.	.	2	3	3
74 only	.	.	.	.	.	.	.	.	1	1	.	2	2
77 only	.	.	.	.	.	.	.	1	.	.	.	1	1
84 only	.	.	.	.	.	.	.	.	.	1	.	1	1
86 only	.	.	.	.	.	.	.	.	.	1	.	1	1
90 only	.	.	.	.	.	.	.	1	.	.	.	1	1
97 only	.	.	.	.	.	.	1	.	.	.	.	1	1
100 only	.	.	.	.	.	.	.	1	.	.	.	1	1
101 only	.	.	.	.	.	.	.	.	1	.	.	1	1
122 only	.	.	.	.	.	.	.	1	.	.	.	1	1
Totals	40	116	65	91	28	340	59	114	122	48	26	369	709

Summary of Data Presented in Table XIII

	1953	1954	1955	1956	1959	All Years
Modal Wt. of Males	23	20	23	17 & 23	17 & 23	23
Mean Wt. of Males	25.3	23.6	21.9	22.6	22.0	23.1
Modal Wt. of Females	29 & 35	35	29	35	23	29 & 35
Mean Wt. of Females	36.0	35.9	32.6	36.6	33.6	34.7
Mean Wt. of Both Sexes	31.7	29.7	28.8	27.4	27.6	29.2

Note: Mean round weights are calculated on a basis of grouped data.

TABLE XIV. The Size Composition (Dressed Weight) of Sturgeon Sampled From The Nelson River Commercial Fishery Between 1953 and 1959.

Weight Group In Pounds	1953	1954	1957	1958	1959
10-12	4	40	154	169	40
13-15	21	19	124	118	41
16-18	20	23	96	99	13
19-21	12	19	53	48	7
22-24	16	18	27	42	8
25-27	8	13	26	26	1
28-30	4	4	12	17	2
31-33	4	3	8	8	2
34-36	2	5	3	7	1
37-39	.	2	.	1	1
40-42	.	.	1	4	1
43-45	.	1	2	6	1
46-48	.	2	.	1	1
49-51	.	1	.	1	.
52-54	1	.	.	1	1
55-57	.	.	.	2	.
58-60	.	.	2	.	.
63 only	.	1	1	.	.
64 only	.	.	.	1	.
67 only	.	1	.	.	.
76 only	.	.	.	1	.
79 only	.	.	1	.	.
Total No.	92	152	510	552	120
Total Weight (lbs.)	1861	3010	8517	9655	1965
Mean Weight (lbs.)	20.2	18.1*	16.7	17.5	16.4

* This figure includes data on 625 other sturgeon whose individual weights were not available.

Note: Mean dressed weights were calculated on the basis of grouped data.

It is readily apparent from these data that the average size of Nelson River sturgeon has decreased between 1953 and 1959. This trend is most evident in the dressed weight statistics which include by far the greatest number of samples.

The seriousness of this depletion is again emphasized by the fact that a change in size composition can also be demonstrated in as short a period as six years.

(c) The Catch Per Unit of Effort

The catch per unit of effort; the production in pounds (dressed weight) of sturgeon per fisherman per year, in the past two periods of commercial fishing on the Nelson River is summarized in Table XV.

TABLE XV. The Average Catch Per Unit of Effort in the Nelson River Sturgeon Fisheries of 1937 to 1946 and 1953 to 1960

Year	Production (Pounds)	No. of Fishermen	Ave. Catch Per Man (Pounds)
1937	15,000	17	880
1938	30,000	19	1580
1939	26,000	20	1300
1940	26,400	24	1100
1941	25,200	21	1210
1942	15,400	25	620
1943	10,600	30	350
1944	9,200	27	340
1945	13,400	29	460
1946	5,800	44	130
1953	27,000	33	820
1954	30,900	39	790
1955	24,400	46	530
1956	27,600	50	550
1957	26,100	59	440
1958	16,600	53	310
1959	9,500	41	230
1960	3,500	49	70

Note: Production figures are rounded off to the nearest 100 pounds and average catches are rounded off to the nearest 10 pounds.

It is readily apparent from these data that the catch per unit of effort in both periods of fishing decreased steadily and substantially. It is also apparent that fishing success in the 1937 to 1946 fishery was almost twice that of the 1953 to 1960 fishery. Statistics regarding fishing effort in the fishery of 1921 to 1927 are not available. Nevertheless, the very high production figures of this period suggest that fishing success was much higher than either of the two last fisheries.

It is very unlikely that this decline in the annual catch per fisherman is the result of changes in fishing intensity. An eightfold rise in the price paid to fishermen for sturgeon from 1937 to 1946 and a slight increase from 1953 to 1960 should have increased the incentive to fish during these periods. The average proficiency of the fishermen should also have increased during each period of fishing because the majority of the fishermen were local residents who took out licenses every year.

Neither should government restrictions have influenced the fishing intensity. The length of the fishing season was reduced only once during the course of either fishery (a 15% decrease in 1946). The production limit was also decreased only once during the course of either fishery (1946) and this had no effect because production was lower than the limit that year too. No changes were made in regulations regarding mesh size of gear or the number of nets allowed per license.

It is also very unlikely that the steady decline in fishing success was due to changes in the catchability of the sturgeon. It is true that variations in water levels or in the date of spawning can effect the dispersal or concentration of the sturgeon and hence, their vulnerability to capture. Certain combinations of water levels, temperature and currents can also influence the amount of floating and semibuoyant debris and drifting filamentous green algae which can very greatly reduce the efficiency of the fishing gear. These factors however should be expected to produce only random variations in the catch per unit of effort.

The very noticeable and orderly decrease in catch per unit of effort within each fishery and even between fisheries along with the failure of the last three fisheries suggests that the sturgeon of the Nelson River have been over-exploited and serious depletion of stocks has resulted. This depletion was so great in each of the last three fisheries that the effect is evident from one fishery to the next despite the fact that they were separated by six or seven year closures.

(d) Year Class Strength

Year class representation by sturgeon sampled from the Nelson River sturgeon fishery from 1953 to 1956 and 1959 is illustrated in Figure 20. The few representatives of year classes prior to 1890 and after 1940 have been omitted. The time and duration of each commercial fishery to 1940 is indicated by the horizontal bars above the histogram.

The poor representation of year classes prior to 1910 and after 1935 can be attributed to high natural mortality among older sturgeon and to the low selectivity of the fishing gear for very old or very young sturgeon.

If annual recruitment of young sturgeon from 1910 to 1935 had been equal, one would expect the representation of these year classes in recent samples to be in proportion to the length of time they had been exposed to a uniform mortality. The 1910 to 1935 year classes were vulnerable only to the last two fisheries. All of these year classes were vulnerable to the 1953 to 1960 fishery but only those up to about 1924 were vulnerable to the 1937 to 1946 fishery. One would therefore expect the year class distribution of recent samples (as in Figure 20) to be at a peak in the early 1920's, fall off uniformly but rather abruptly on the left for older year classes and uniformly but more gradually on the right for more recent year classes.

Since this is only partly so, it is evident that changes in the fishery account only in part for the relative representation of year classes. The differences that are apparent in the strength of year classes from 1910 to 1935 are therefore most likely due to changes in annual recruitment of young sturgeon.

There is also some evidence that recruitment was low during periods of intense fishing which suggests that recruitment of young sturgeon

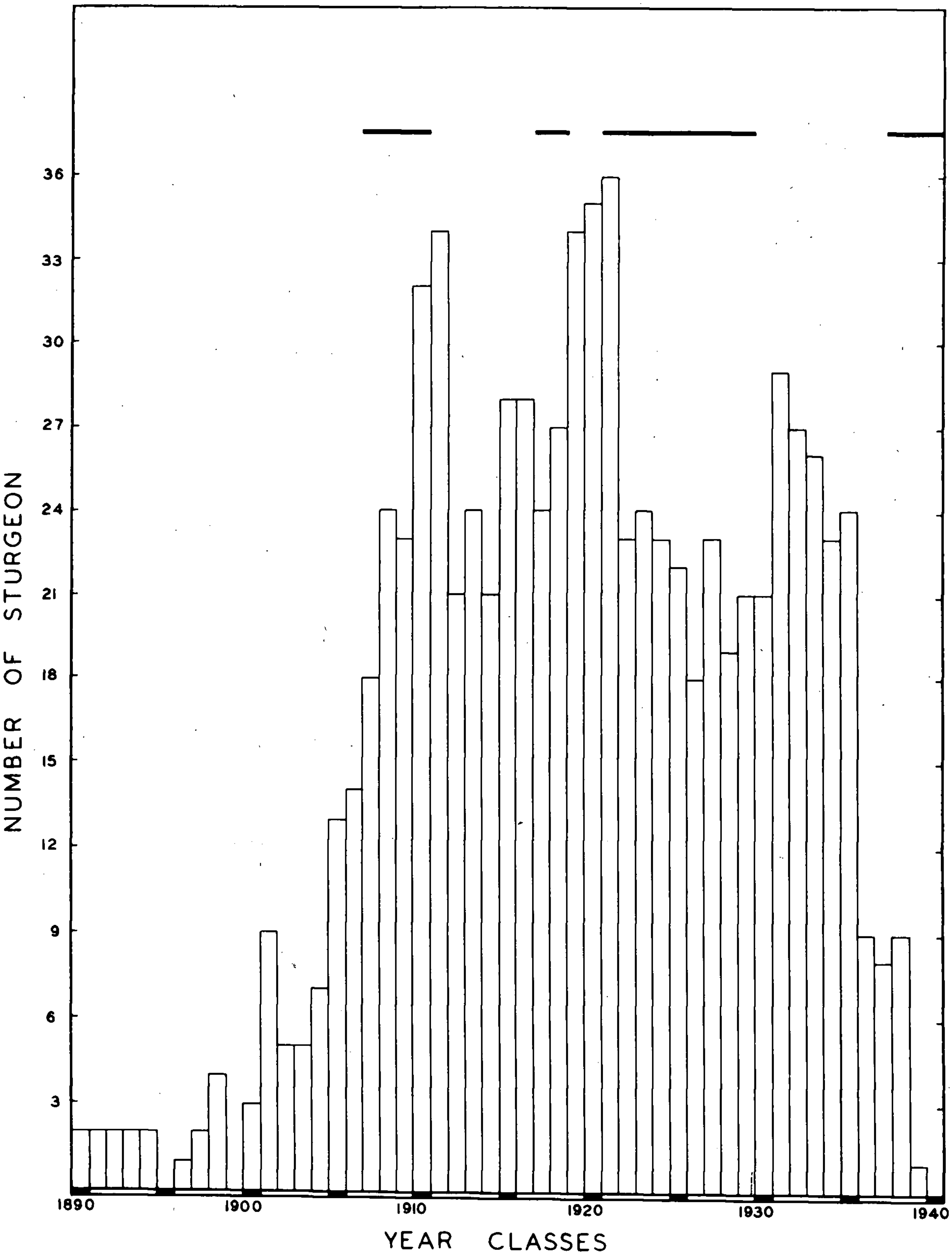

Figure 20. Year Class Representation of Sturgeon Sampled from the Nelson River Commercial Fishery from 1953 to 1956 and 1959.

is directly related to the size of the adult population.

These apparent changes in the age and size structure of the Nelson River sturgeon population, fishing success and strength of year classes could possibly be due to bias or random variations in the sample or to changes in regulations or fishing methods and intensity. This is very unlikely the case, however, because samples were obtained in roughly the same manner and areas each year and the fishery itself never changed markedly. Some of these data also relate to the fishery as a whole rather than to samples only. Furthermore, this trend to sturgeon of smaller size and age and to poorer catches is quite orderly and consistent and is established by several lines of numerous data.

It is therefore concluded that the changes that are apparent in the samples are true reflections of changes that have occurred in the sturgeon population and that they are the result of depletion of stocks by the commercial fishery.

B. DISCUSSION

It is quite obvious that Nelson River sturgeon have been very seriously depleted in numbers over the past forty years and that over-exploitation by the commercial fishery is responsible. Several aspects of the life history, the habits and the value of this atypical species of fish renders it highly susceptible to depletion.

The lake sturgeon is a relatively slow growing fish with an exceptionally long life span. Though they can become very numerous, natural population turnover is very slow. An abnormally low rate of recruitment is apparently compensated for by an abnormally low rate of natural mortality.

The reproductive capacity of this species is fairly low despite the large numbers of eggs laid by the average female. (Cuerrier, 1949, determined that each female produced an average of 5831 eggs per pound of body weight.) They mature at a very late age and subsequent spawnings are at intervals of several years.

The high market value of sturgeon (about one dollar per pound for their flesh and several dollars per pound for caviar) provides a very strong incentive to employ maximum fishing effort. A fisherman can realize a good profit at daily catches as low as two or three sturgeon.

Sturgeon are also very vulnerable to capture at certain times of the year. They congregate at falls and in river channels in the spring, shallow bays in the summer and deep holes in the winter.

VII. FUTURE MANAGEMENT OF THE NELSON RIVER STURGEON FISHERY

The Nelson River can be expected to produce a sustained yield of sturgeon in the future only if this species is offered much more protection and if the fishery is very carefully and strictly managed.

Present stocks of Nelson River sturgeon are obviously much too low to support a profitable commercial fishery. Further depletion may also reduce the population to a level where natural reproduction is insufficient to increase or even sustain the population at its present size. These sturgeon should therefore be completely protected for a period of at least ten years to allow stocks to increase to a size that will support a profitable commercial fishery on a sustained yield basis.

A. PRODUCTION LIMITS

Even though Nelson River sturgeon are protected for a period of years, future production limits will have to be greatly reduced if a sustained yield is to be realized. The failure of the last two fisheries reveals that this river is incapable to yielding even 25,000 pounds of sturgeon (dressed weight) per year.

The best evidence available suggests that the average annual recruitment to the Nelson River sturgeon fishery in the past thirty years was about 10,000 pounds.

It is evident from Table XV that the catch per unit of effort was quite similar in the last few years of the fisheries of 1937 to 1946 and 1953 to 1960. If the catch per unit of effort in both fisheries is comparable, it is reasonable to assume that the sturgeon population was equal or similar in size in 1946 and 1960; the years that each of these fisheries collapsed. It would then follow that the production from 1953 to 1960 would be equal or similar to the recruitment to the fishery from 1947 to 1960. Since the total catch from 1953 to 1960 was 165,600 pounds, the average annual recruitment to the fishery in the fourteen year period from 1947 to 1960 must have been about 12,000 pounds.

This figure would be, at best, the maximum annual recruitment to the fishery. The catch per unit of effort in the last year of the 1953 to 1960 fishery was considerably lower than that of the 1937 to 1946 fishery. The average catch per unit of effort in the 1953 to 1960 fishery (450 pounds per licensee per year) was also 65.2% lower than that for the 1937 to 1946 fishery (690 pounds per licensee per year). This would suggest that the sturgeon population was smaller at the end of the 1953 to 1960 fishery than at the end of the 1937 to 1946 fishery and that recruitment to the fishery was considerably less than 12,000 pounds per year from 1947 to 1960.

The fishing effort expended during the 1921 to 1929 fishery is unknown. The value of sturgeon during this fishery was quite high however, so it is very likely that fishing effort was as great as that from 1937 to 1946 and that the sturgeon were reduced to as low a level of abundance in 1929 as in 1946. The total catch from 1937 to 1946 should therefore be equal or similar to the recruitment to the fishery in the seventeen year period from 1930 to 1946. As the total catch from 1937 to 1946 was 177,000 pounds, the average annual increment to the fishery should have been about 10,000 pounds.

It is very likely that the average annual recruitment to the fishery in the past thirty years would be closer to the 10,000 pound estimate than the 12,000 pound estimate. This figure may have been the maximum possible recruitment to the fishery at the low level of abundance at which the sturgeon population has been held during this period.

It is therefore recommended that future sturgeon production limits on the Nelson River be limited to 10,000 pounds (dressed weight) per year. It should be pointed out that this limit would apply only to that portion of the Nelson River which was fished during the course of the last fishery. From 1953 to 1960, fishing was permitted on a 280 mile stretch of the Nelson River and the lakes through which it flows; from Whitemud Falls (54° 45' N, 97° 53' W) to the junction of the Nelson and Weir Rivers (56° 55' N, 93° 22' W). It is estimated that about 75% of the production from 1953 to 1960 was taken from a 75 mile portion of the river which included Sipiwesk Lake; a 12 mile stretch of river above and a 25 mile stretch of river below.

The annual harvest may possibly be increased in ten to twenty years if a ten year closure allows stock to build up to a much higher level. This is based on the assumption that the rate of reproduction and recruitment would be greater at higher population densities.

It is doubtful that a profitable commercial fishery would be feasible at an annual production limit as low as 10,000 pounds. If such is the case, it would be permissible to take substantially larger annual limits for a period of years if each period of fishing was interrupted by a period of closure so designed that the average long term annual production was no greater than 10,000 pounds. The cumulative catch during each of these periods of fishing should not exceed 100,000 pounds nor should the annual catch exceed 35,000 pounds.

Thus, if present stocks were allowed to increase for ten years by completely protecting the sturgeon, future annual limits of 20,000 pounds for five year periods would be permissible if each five year period of fishing was interrupted by a five year period of closure. Similarly, annual limits of 25,000 pounds for four year periods would be permissible if each period of fishing was interrupted by a six year period of closure and annual limits of 30,000 to 35,000 pounds for three year periods would permissible if each period of fishing was interrupted by a seven year period of closure.

B. THE MINIMUM LEGAL SIZE OF STURGEON

A restriction governing the minimum legal size of sturgeon has been in effect in past fisheries to protect immature sturgeon and to discourage the capture of small sturgeon which are low in market value. The minimum legal size of sturgeon in the 1953 to 1960 Nelson River fishery was 18 pounds round weight and 10 pounds headless dressed weight.

From data presented in Tables IX and XIII it is evident that this regulation offered little, if any, protection to immature sturgeon.

It is common practice in fisheries management to impose restrictions regarding fishing gear specifications and/or the minimum legal size of fish that protect immature fish and insure that a large proportion of the adult population is allowed to spawn at least once before being selected for by the fishery. Since there is evidence that the rate of recruitment to stocks of Nelson River sturgeon is related to the size of the adult population, it would seem that protection of immature sturgeon is very important.

If all Nelson River sturgeon are to be allowed to spawn at least once, the minimum legal size would have to be raised to about 29 pounds round weight. Such a regulation would impose considerable hardship upon the fishermen since 53.3% of 709 sturgeon sampled from the fishery from 1953 to 1959 were below 28 pounds round weight. It is therefore recommended that the minimum legal size of Nelson River sturgeon be set at 25 pounds round weight. This would correspond to a headless dressed weight of about

15 pounds. This figure would afford complete protection to all immature male sturgeon and to a much larger proportion of the immature female sturgeon.

Even this limit may impose some hardship upon the fishermen. The 655 sturgeon sampled from the fishery from 1953 to 1956 indicated that 42% of the total number of fish taken in this period were under 25 pounds round weight. These sturgeon, however, accounted for only 28% of the total catch by weight.

Once the fishery is stabilized, a 25 pound minimum legal size should no longer effect the fishery. Recruitment to a 25 pound size group should be little less than recruitment to an 18 or 20 pound size group in such a large and long lived species of fish.

It would be advantageous if future restrictions regarding the minimum legal size of sturgeon were based on a measurement of length rather than weight. Past experience has revealed that the relationship between round and dressed weights is very variable because of differences in the "condition" and/or the stage of reproductive maturity of individual sturgeon. In the last fishery, for instance, the minimum legal size of sturgeon was 18 pounds round weight and 10 pounds headless dressed weight. Data collected on the Nelson River in 1953 and 1954 revealed that one 18 pound sturgeon dressed out to 12 pounds and four dressed out to 11 pounds. Of twenty-four 20 pound sturgeon sampled; one dressed out to 11 pounds, twelve dressed out to 12 pounds, eight dressed out to 13 pounds, two dressed out to 14 pounds and one dressed out to 15 pounds. Of fifteen 25 pound sturgeon sampled; one dressed out to 13 pounds, three dressed out to 15 pounds, three dressed out to 16 pounds, seven dressed out to 17 pounds and one dressed out to 18 pounds. Such variability in round and dressed weight makes enforcement of the minimum legal size limits very difficult. The end result is that many "borderline" sturgeon are killed and dressed as a final test to determine whether or not they are legal fish.

A length measurement that is applicable to both live and headless dressed sturgeon would be most satisfactory as a criterion for the minimum legal size of sturgeon. One such measurement that is applicable to live sturgeon is: from an easily defined point on the dorsal fin or the fork of the caudal fin to the most posterior limit of the pectoral girdle (the most posterior edge of the cleithrum, which lies beneath the skin in a mid-lateral position, is easily located by touch). A corresponding measurement applicable to headless dressed sturgeon is: from the dorsal or caudal fin to the mid-lateral point of the anterior cut edge of the skin. These measurements would be identical on any fish because the cut that is made to remove the head and pectoral girdle is made as close to the pectoral girdle as possible.

C. FISHING GEAR

In the course of the past two Nelson River sturgeon fisheries, small and immature sturgeon have been protected by a restriction governing the mesh size of fishing gear as well as the minimum legal size of fish. This restriction specified twelve inch (extension measure) gill nets.

It is evident from data presented in Tables IX and XIII that the twelve inch gill net afforded little protection to immature female sturgeon in the last fishery. Although the average size of sturgeon caught from 1953 to 1956 was 28.9 pounds, this mesh size efficiently captured sturgeon as small as 16 pounds round weight. Over 40% of the total number of sturgeon taken during this period were under 25 pounds round weight.

If the reproductive capacity and recruitment of Nelson River sturgeon is to be increased; the legal size of gill nets should be increased regardless of whether the minimum legal size of sturgeon is increased. Many sub legal sturgeon are retained by the fishermen for food or for local sale.

The optimum mesh size for future sturgeon fisheries can only be estimated because no information on the size selectivity of gill nets greater than twelve inches is available. It is the writer's opinion that either thirteen or fourteen inch mesh would allow an adequate escapement of immature females. The advantages to the sturgeon population and the disadvantages to the fishery of these mesh sizes would be tested most easily and conclusively by applying one of these mesh sizes to the next fishery. It is therefore recommended that fishing gear in the next Nelson River sturgeon fishery be restricted to thirteen inch (extension measure) gill nets.

D. FISHING SEASONS

Data presented in Section V-C indicate that Nelson River sturgeon have not wholly completed their spawning activities by June 10, the date at which the Nelson River sturgeon fishery usually commences. This would suggest that some sturgeon at least, are caught before they have spawned; perhaps for the first time. It is therefore recommended that the opening of future sturgeon fisheries be postponed to at least June 15 to allow a greater percentage of fish to spawn.

VIII. THE MANAGEMENT OF OTHER STURGEON FISHERIES IN MANITOBA

Since all other sturgeon fisheries in Manitoba, both past and recent, have failed and as very little is known of the biology of these sturgeon, it would seem wise as a first step to apply the conclusions and recommendations of this study to other sturgeon fisheries in Manitoba.

A. PRODUCTION LIMITS

The Sipiwesk Lake area of the Nelson River, which is the main sturgeon producing portion of that river, can be expected to produce a sustained yield of about 7,500 pounds of sturgeon per year. Since the area of this portion of the river is about 190 square miles, it can be expected to yield about 40 pounds of sturgeon per square mile per year. Other Manitoba waters at the same latitude and of comparable fertility can therefore be expected to produce a similar annual yield. More northerly waters with shorter open water seasons may be expected to produce slightly less and southern Manitoba waters may be expected to produce considerably more (possibly 50 to 75 pounds per square mile per year).

B. THE MINIMUM LEGAL SIZE OF STURGEON AND OF FISHING GEAR

It was concluded from Nelson River studies that recruitment of sturgeon may be increased by raising the minimum legal size of round (live) sturgeon from 18 to 25 pounds and the legal size of gill nets from 12 inches to 13 or 14 inches (extension measure).

It is likely that sturgeon of more northerly waters mature at a greater age and that those of southern Manitoba mature at an earlier age.

The size at which they mature, however, is very likely similar throughout Manitoba. It is therefore recommended that the legal size of sturgeon and of fishing gear in other sturgeon fisheries in Manitoba be raised to comply with that suggested for the Nelson River fishery.

C. FISHING SEASONS

It was recommended that the opening date of future Nelson River sturgeon fisheries be changed from June 10 to at least June 15 to allow a greater percentage of sturgeon to finish spawning. Since sturgeon of more northerly waters spawn at a later date, the opening date of sturgeon fisheries on these waters should be delayed according to the best information available on prevailing temperatures and the time of spring breakup.

Southern Manitoba sturgeon fisheries could safely be opened five to ten days earlier than the Nelson River fishery.

IX. FUTURE RESEARCH ON LAKE STURGEON

It is quite evident that relatively little is known about the life history, the biology and the habits of the lake sturgeon. Much more knowledge will be required before a game or commercial fishery for this species can be managed properly to insure a sustained yield.

Some of the more important questions to be answered concern the reproductive capacity and the rate of recruitment to stocks at various levels of population density. The practicality of artificial propogation of this species may also be considered.

Further studies regarding the spawning of lake sturgeon is warranted. These should include the time and place of spawning, the age of maturity and, most important of all, the periodicity of spawning.

Spawning and nursery ground investigations should also be undertaken to assess the amount of predation on eggs and fry and the effect upon juvenile sturgeon of other gill net fisheries which use much smaller mesh sizes.

SUMMARY

Lake sturgeon of the Nelson River in Northern Manitoba have been exploited by the commercial fishery intermittently since 1907. The failure of two fisheries between 1921 and 1946 indicated the need for a program of biological research which would provide a basis for the future management of this economically important species.

A resumption of the Nelson River sturgeon fishery in 1953 which followed a six year closure afforded an opportunity to study this species. From 1953 to 1956 and 1959, 791 sturgeon were sampled from the commercial catch in the Sipiwesk Lake area of the Nelson River by biologists of the Provincial Fisheries Branch. Each specimen was weighed, measured and sexed and the marginal "spine" of the pectoral fin was retained for the purpose of age determination.

Preliminary studies were conducted to determine the location on the pectoral "spine" of the best cross-sections for purposes of aging and back-calculation of growth. It was concluded that annuli were most easily differentiated in cross-sections obtained about half to three-quarters of an inch from the proximal end of the spine. The easiest and best measurement on this cross-section for back-calculation of growth was the radius of the spine from the centre of ossification to the posterior edge of the spine, along the acute angles formed by the annuli in this area.

For purposes of back-calculation of growth in length of Nelson River sturgeon, the relationship between growth in length of the pectoral "spine" to growth in length of the fish was determined by the method of least squares. The equation for this relationship is $x = 14y + 2.2$ where x is the fork length in inches and y is the average radius of the pectoral spine.

In the determination of size at any previous age, best results were obtained by back-calculating along a line which converged with the intercept.

Growth in length of Nelson River sturgeon was determined by averaging empirical lengths by age groups, by averaging back-calculated lengths by age groups and by cumulatively totalling average annual calculated increments of growth for a number of specimens. The last method appeared to provide the best representation of growth in Nelson River sturgeon.

It is readily apparent that the Nelson River female sturgeon grows faster and lives longer than the male. The average annual increment in size to age 20 in both sexes is about 0.9 pounds, round weight, and 1.9 inches, fork length. From age 20 to 50 years, the average annual growth increment in males is 0.4 pounds and 0.4 inches while that for females is 0.7 pounds and 0.5 inches. Beyond age 50 years, the average annual increment in round weight of females increases to about 1.0 pounds.

A very noticeable change in the rate of growth in weight and length at age 20 to 25 years in both sexes correlates very closely with reproductive maturity of these fish. There is no indication of any asymptotic size in Nelson River sturgeon.

The relative growth of Nelson River sturgeon for the years 1915 to 1950 was determined from back-calculated data. Noticeable fluctuations in relative growth were apparent. Although it appears that growth may have been slightly greater in years of low water and/or years when population density was low; the correlation of these data is not sufficiently consistent to be significant.

The length-weight relationship of male Nelson River sturgeon is: $\log W = -3.55 + 3.002 \log L$. That for the female is: $\log W = -3.84 + 3.204 \log L$. (W is round weight in pounds and L is fork length in inches).

There is a straight-line relationship between dressed weight and round weight. A simple rule of thumb for this relationship is: dressed weight = 2/3 round weight.

The rate of growth of Nelson River sturgeon was compared to that of lake sturgeon from Ontario, Quebec and Wisconsin. Nelson River sturgeon grow slower than lake sturgeon of Lakes St. Peter and St. Frances in Ontario and Lake Winnebago in Wisconsin but grow faster than those of Lake Nipigon in Ontario. The growth curves for lake sturgeon of these other waters do not exhibit the noticeable change in slope that is typical of Nelson River lake sturgeon.

Nelson River sturgeon spawn in late May to early June. The average female matures and spawns for the first time at age 25 to 30 years. This corresponds to a round weight of 24 to 29 pounds and a fork length of 42 to 45 inches. All or most males are mature by age 20 years which corresponds to a round weight of about 18 pounds and a fork length of about 38 inches.

Nelson River sturgeon do not spawn every year. The best information available suggests that the female sturgeon spawns every three to six years. Older fish appear to spawn more frequently than young ones. The frequency of spawning of Nelson River male sturgeon is unknown but it is very unlikely that they spawn every year.

Over-exploitation, dams, and pollution have greatly reduced or eliminated sturgeon throughout the world. All major sturgeon fisheries in Manitoba, including the Nelson River fishery, failed after a relatively short period and the production in more recent fisheries has always fallen far short of the amounts taken in initial fisheries when virgin stocks were exploited. The depletion of Manitoba sturgeon is attributed solely to over-exploitation by the commercial fishery. The failure of the last three commercial fisheries on the Nelson River, variations in strength of year classes from 1910 to 1935, an orderly decrease in the catch per unit of effort in the last two fisheries and changes in the age and size structure of the sturgeon population during the most recent fishery is ample evidence that depletion of stocks has occurred and that it is a result of over-exploitation by the commercial fishery.

Lake sturgeon are vulnerable to depletion for several reasons. They are relatively slow growing fish and the rate of recruitment is low. They have a very high market value and are easily caught during certain seasons when they congregate in well defined areas. For these reasons it is readily evident that the Nelson River sturgeon fishery can be managed on a sustained yield basis only if sturgeon stocks are afforded much more protection than in the past.

It is recommended that regulations in any future fishery on the Nelson River be changed to afford such protection. These regulations pertain to production limits, fishing seasons, and the minimum legal size of fish and fishing gear. This fishery is closed at present and should remain closed for at least ten years to allow sturgeon stocks to increase to a level which will insure a higher rate of recruitment and an economical rate of yield to the commercial fishery.

PRODUCTION LIMITS. It is recommended that future production limits on the Nelson River be reduced to no more than 10,000 pounds (dressed weight) per year. This limit could be increased substantially for short periods as long as the cumulative production for each ten-year period does not exceed 100,000 pounds.

FISHING SEASONS. It is recommended that future fishing seasons be postponed until at least June 15 to allow a larger number of adult sturgeon to finish spawning.

THE MINIMUM LEGAL SIZE OF STURGEON. It is recommended that the minimum legal size of sturgeon in the future be increased to at least 25 pounds round weight (or its equivalent if a measurement of length is adopted as a size criterion).

FISHING GEAR. It is recommended that the minimum legal size of gill nets in the future be increased to at least 13 inches, extension measure.

It is also recommended that regulations in future sturgeon fisheries in other parts of Manitoba be revised to conform to those suggested for the Nelson River. Minor changes in production limits and fishing seasons would be in order for areas that differ markedly in basic productivity and climate from that of the Nelson River.

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