The Life History of the Shovelnose Sturgeon

Scaphirhynchus platorynchus

in the Missouri River

by

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It ranges from the Hudson Bay drainage of the Canadian plains southward to New Mexico, Arkansas, and Kentucky (Eddy and Surber 1947). The species was recorded in the Tombigbee River near Epes, Alabama, (Chermock 1955); in the Wichita River, Clay County, Texas, near its junction with the Red River; and below Denison Dam, Grayson County, Texas (Bonn and Kemp 1952). A 47 pound "shovelnose" was recorded in 1879 in Montana, near Fort Benton, but this specimen was probably a misidentified pallid sturgeon (Brown 1955). The shovelnose formerly was abundant in the Ohio River in Ohio, but now is generally restricted to an area between the Ohio-Indiana line and Scioto County, Ohio (Trautman 1957).

The shovelnose sturgeon is known to the layman by many common names such as the hackleback, sand, switchtail, or flathead sturgeon. Several of the common names are derived from its shovel-shaped snout which is flattened dorsoventrally. Its caudal peduncle also is flattened dorsoventrally and its body is covered with 5 rows of bony scutes which are keeled and contain spines. The dorsal surface of the shovelnose sturgeon is a uniform pale, yellowish-olive or brown color without spots or blotches and the ventral surface is white (Eddy and Surber 1947).

The shovelnose rarely exceeds a total length of 3 feet or a weight of 5 to 6 pounds. Its ventral surface is covered with a mosaic of dermal plates, and the bases of the outer barbels are in line with or ahead of the inner barbels which are heavily fringed and longer. The dorsal fin contains 30 to 36 rays and the anal fin contains from 18 to 23 rays. The pallid sturgeon which reaches a length of 5.5 feet and a weight of 47 pounds is a member of the same genus as the shovelnose and is sometimes confused with it. However, the belly of the pallid sturgeon is naked and the bases of outer barbels lie behind the inner barbels which are weakly fringed and short. The dorsal and anal fins of the pallid sturgeon contain 37 to 43 rays and 24 to 28 rays respectively (Bailey and Cross 1954).

According to Eddy and Surber (1947), the shovelnose sturgeon is marketed fresh or smoked. Since they are small most are smoked. The roe reportedly has been made into excellent caviar and it is often mixed with paddlefish or sucker roe.

According to Eddy and Surber (1947) the food of the shovelnose consists almost exclusively of immature aquatic insects including dragonfly nymphs. Trautman (1957) stated that sturgeons feed over the clean sand and gravel bottoms of chutes and bars or wherever there is considerable current and a clean bottom. Some Ohio fisherman reported that the shovelnose congregated wherever there were large quantities of small clams and snails (Trautman 1957). In a recent study of Missouri River shovelnose sturgeon (Held 1966), aquatic insect larvae from 7 orders and 29 families occurred in 97% of the stomachs, comprised 92.9% of the total number, and 89.1% of the total volume of all organisms injested. Two dipteran families, Chironomidae and Ceratipogonidae, numerically comprised 62.8% and 22.1% of all organisms, respectively. Volumetrically these same families constituted 25.8% and 20.5% of all organisms, respectively. Terrestrial arthropods occurred in 40% of the stomachs and as a group comprised [illegible] of the total volume of all organisms (Held 1966). In 74 shovelnose sturgeon stomachs collected from the tailwater [illegible] the Mississippi River dams, the total volumetric cont[illegible] consisted of 68% *Potamyia flava* larvae, 7% *Cheumatopsyche campyla* larvae, 17% *Hexagenia* naiads, and 8% [illegible] material which included immature Plecopterans, [illegible], and [illegible].

The shovelnose reportedly spawns in the spring, travel- [illegible] spawning sites are located [illegible] actual spawning [illegible] [illegible] if the sturgeon [illegible] [illegible] spawning sites the [illegible] [illegible] the Missouri River [illegible] [illegible] spawning success of [illegible] [illegible] impede upstream [illegible] [illegible] associated with them.

[illegible] are restricted to relatively [illegible] with a moderate current. They do not [illegible] [illegible] of the reservoir where the water [illegible] [illegible]. Sprague (1960) stated that after the [illegible] Lewis and Clark Lake in 1955, the [illegible] [illegible] index of shovelnose sturgeon [illegible] reservoir declined over [illegible] environmental factors [illegible]

[illegible] possible to separate the sample population into age groups. This method can be used only if the sample is comp[illegible] large number of individuals, collected in a short [illegible], and nonselective with regards to size and [illegible]. [illegible] method was not used in the present study [illegible] necessary for a valid age estimates [illegible].

[illegible], antlers, spines, operculum, [illegible] used frequently to deter[illegible] during previous years of li[illegible] [illegible] structure in [illegible] [illegible] than the [illegible] [illegible] absorption [illegible] [illegible]

[illegible]

calcareous [illegible] often show growth [illegible] from the acoustic[illegible]

[illegible] the determin[illegible]

[illegible]

[illegible] ...ones, *Notorus gyrinus* [illegible] [illegible] and channel catfish, *Ictalurus punctatus* [illegible], [illegible] and Smith 1949). Marzolf ([illegible]) [illegible] and spines to age channel catfish. [illegible] displayed fewer false [illegible] [illegible] than vertebrae. Sneed ([illegible]) [illegible] from the pectoral spine to age [illegible] ([illegible]), [illegible] and Cooper (195[illegible]), [illegible] ([illegible]) used the marginal ray of the [illegible] lake sturgeon. In a later study [illegible]

[illegible]

[illegible] annuli which were interpreted as being areas representing years of slow growth caused by developing gonads, in which more energy was used for reproduction leaving less for growth. These belts will be discussed later.

[illegible] hoped that the present study provided some valuable life history information on this primitive species. [illegible] hope this study will aid in evaluating the effects of multipurpose dams on this species and [illegible] in the promulgation of a management plan which [illegible] the shovelnose.

METHODS AND MATERIALS

Description of Study Area and Field Procedures:

The shovelnose sturgeon used in this study were taken from two areas. Area I was located approximately 13 miles west of Vermillion, South Dakota, in the Missouri River; s.w. corner of Sec. 7 and n.w. corner of Sec. 18, T 92 N, R 53 W, Clay County, South Dakota. Area II was approximately 20 miles west and 5 miles north of Vermillion, South Dakota, in the James River; T 93 N, R 55 W, in the n.e. corner of Sec. 3, Yankton County, South Dakota. A total of 325 shovelnose sturgeon was taken and all but two were removed from Area I.

The sturgeon were collected from March 27, 1967 until June 30, 1967 by means of gill nets which measured 300 feet long, 6 feet deep, with mesh sizes of 1 inch and 1.5 inches, bar measure; and a trammel net 300 by 6 feet with a mesh size of 1.5 inches, bar measure. The nets were set parallel to the current in water 15 centimeters to [illegible] meters deep. This type of set is classified as an "anchored" net by Dumount and Sundstrom (1961). Fish were removed from the net starting at the downstream end and working upstream toward the steel rod. Greater success in catching shovelnose sturgeon was achieved in overnight sets. No difference in the rate of catch could be attributed to water depth because fish were randomly distributed in all parts of the net. However, on several dates most of the catch was found in one area of the net, indicating that they did aggregate at a certain depth on these [illegible].

[illegible] were made to collect sturgeon during the [illegible] with a boat-mounted electrical shocker, powered by a Sears' 2500 watt gasoline-driven alternator, [illegible] sturgeon were collected by this means. A trawl ([illegible] of 3/4 inch, bar measure) and a bag seine ([illegible] of 1/4 inch, bar measure) also were used but [illegible].

[illegible] II were collected [illegible], and April 17th. This [illegible] the blue sucker, [illegible] sturgeon were [illegible] in an overnight set. [illegible] on several [illegible] April 17, but no sturgeon [illegible].

[illegible] the nets the sturgeon [illegible] and placed in [illegible]. The tanks were [illegible] problems [illegible] this procedure.

All specimens were weighed to the nearest one-half ounce on a Toledo scale with a maximum weight capacity of 24 pounds. Several length measurements were recorded for each fish. Standard length was measured from the tip of the snout to the point where the upper lobe of the heterocercal caudal fin makes its bend dorsad. Fork length was measured from the tip of the snout to the fork between the [illegible] and ventral lobes of the caudal fin. Total length was measured from the tip of the snout to the end of the caudal filament or to the end of the upper lobe of the caudal fin if the filament was absent. All three measurements were observed to the nearest millimeter.

[illegible] to weighing and measuring, the body cavity [illegible] on the ventral surface [illegible] fins to the anus. The [illegible] connective [illegible] nearest one-hundredth [illegible] balance (Model [illegible] containing 10 per cent [illegible] each fish was sexed [illegible]. All fish were [illegible] development [illegible] shovelnose sturgeon.

The anterior marginal ray of the right pectoral fin was removed and placed in a coin envelope. The following information was recorded on each envelope: identification number, total length, standard length, fork length, sex, maturity, filament length, gonadal weight, date collected, collection locality, type of gear used, and names of the collectors. The marginal ray of the left pectoral fin was also removed and placed in a separate coin envelope, but was not used in this study.

Many techniques have been used to section the spines or rays of fish. Cuerrier and Roussow (1951) placed the [illegible] pectoral rays of lake sturgeon in a vise and cut [illegible] 0.5 mm. thick with a fine-toothed [illegible] blade, [illegible] used by jewelers. The sections were placed [illegible] slides in glycerine and read with [illegible] at low magnification. [illegible] the marginal rays of lake [illegible] very fine saw blade. He cut sections [illegible] mm. thick and placed them in Canada balsam [illegible] slides. Probst and Cooper (1955) cut [illegible] sections of lake sturgeon [illegible], and read them under [illegible]sley (1957) used [illegible] suspended pectoral [illegible] solidifying fluid [illegible] days after which spines were washed, stained for approximately 12 hours, sectioned, and then mounted on slides. He also attempted to section spines, which had no previous preparation at a thickness of 0.5 mm. with an electrical saw. He concluded that the decalcifying method [illegible] better.

[illegible] the present investigation I attempted to "read" se[illegible] which were cut from dry rays with a jeweler's [illegible] placed in alcohol, glycerine, or water. This [illegible] preparing the sections did not prove as satis-[illegible] as the following procedure which was adopted after considerable trial and error. After the anterior marginal [illegible] were removed, they were stored in a refri[illegible] [illegible] were subsequently [illegible] [illegible] beaker. The [illegible] [illegible] sodium citrate and [illegible] ml. of formic acid [illegible] could be microtomed [illegible], but occasionally some would [illegible] solution for [illegible]

[illegible] were pl[illegible]

[illegible]

The rays were then mounted in a paraffin block but were not actually embedded in the paraffin. The standard procedure for paraffin embedding using the oven was tried, but it proved undesirable because the rays became hard and were difficult to microtome. After "mounting", the rays were placed in cold water for approximately 2 minutes before being sectioned on a Spencer rotary microtome. Sections were microtomed at a thickness of 50 microns and 8 to 10 selected sections were placed in xylene. A small amount of Canadian balsam then was placed on a microscope slide in preparation for the ray sections which later were taken from the xylene and placed in the balsam. The addition of cover slips and identification labels to the slides completed the preparation of the sections.

Roussow (1957) sectioned the pectoral rays as closely as possible to their point of articulation with the body because he believed sections made more distally might not contain annuli formed early in life. According to Querrier (1951) if sections are cut too far from the base of the ray, the interior rings laid down during the first years of the life of the fish will not be present. Thus, he also sectioned no farther than 13 mm. from the most proximal part of the anterior ray.

In the present study it was discovered that the annuli established during the first years of life were easier to read on the sections more distant from the base, and the annuli established later in life were easier to read on the sections taken near the base. Thus, the sectioning was begun approximately 20 mm. from the base and proceeding proximally, sections were taken at selected intervals along the 20 mm. basal section of the ray. All sec[illegible], usually 8 to 10, which were mounted were used to [illegible] the fish.

[illegible]he slides containing the sections were placed on a [illegible]projection apparatus which enlarged the sections [illegible] diameters. After the age of each fish was determined, [illegible] strip of paper called a nomograph strip (Carlander [illegible]44) [illegible] prepared which recorded the history of growth [illegible] by the p[illegible] of the annuli. All [illegible]ides [illegible] and then, after several days, [illegible] [illegible]e seco[illegible]. [illegible] determined ages and the [illegible] [illegible] the [illegible] on the nomographs for [illegible] [illegible]. If the ages or position [illegible] [illegible] agree on the nomograph strips the [illegible] [illegible] the third time. Agreement was reached [illegible] [illegible] after the third reading.

[illegible] of the shovelnose sturgeon was [illegible] [illegible] of 30 spawning females using [illegible] [illegible] weigh[illegible] on an Ohaus-Dial-[illegible] [illegible] the ovaries and the egg [illegible] [illegible] for approximately [illegible]

Three subsamples of eggs were taken from each ovary, weighed separately, and the number of eggs in each subsample was counted. From the average of these three subsamples and the known weight of the ovary a simple proportionality was used to estimate the total number of eggs per female.

The length-weight relationship and ponderal index of the shovelnose sturgeon were determined using the formula given by Lagler (1966). All the calculations for the length-weight relationship were done with the help of an IBM 1620 computer.

RESULTS AND DISCUSSION

There were numerous problems associated with the age and growth portion of this study. The initial problem of finding a suitable technique for sectioning the rays proved formidable. As previously mentioned, I was successful in devising a technique whereby thin cross-sections of the marginal ray of the pectoral fin could be prepared for aging. However, the interpretation of the marks on the sections is subject to question and remains to be verified by other techniques.

Theoretically, in temperate climates most fish [illegible] on each bony or cartilaginous structure [illegible] called an annulus. [illegible] growth in the winter [illegible] the spring. Presumably this [illegible] marginal ray of the [illegible] differential deposition of calc[illegible] the ray. When growth [illegible] deposited while the [illegible] during winter or [illegible] marks. These [illegible] translucent [illegible]

In the present study the clear bands were interpreted as being formed during rapid growth and the translucent zones during decreased growth. Therefore, the translucent zones were considered the "true" annuli. Probst and Cooper (1955) and Roussow (1957) interpreted the translucent zones in the marginal rays of lake sturgeon as being annuli. Cuerrier (1951) soaked his ray sections in glycerine which caused the images to appear opaque in some areas and clear in others. The glycerine did not penetrate the summer growth zones very quickly and this made them appear dark while the winter growth zones appeared clear. All studies on lake sturgeon were able to distinguish annuli on sections from the marginal pectoral ray.

It is important in age and growth studies to know when the annulus is formed. Lake sturgeon in the Winnebago, Wisconsin area, collected in January and February had formed a new annulus (Probst and Cooper 1955). The sturgeons used in this study were collected between late March and June 30th, 1967, and the newly formed annulus, if present, was difficult to discern because most exhibited a wide peripheral "belt" containing 2 to 7 annuli (Figure 1 A_2). Therefore, I assumed that all sturgeon had formed an annulus before sampling started in the spring and the annulus next to the edge of the section was considered the 1967 annulus. On a few rays an annulus wasn't present on the edge of the section. Consequently, on these rays, the edge of the section itself was considered as the annulus location.

Perhaps the most vexing problem in this study was the interpretation of the marks on the ray sections. Fortunately, other investigators had published their aging interpretations of lake sturgeon rays. Roussow (1957) found belts consisting of several annuli in the cross sections of the marginal rays of lake sturgeon. These belts were interpreted as years of slow growth caused by preparation for spawning. Lake sturgeon, after reaching sexual maturity, required several years for the sex cells to develop and mature. During this developmental period, growth in length was small because most of the available energy was put into the developing gonads. Roussow discovered that females spawned for the first time at 14 to 23 years (mean = 18.1) with 7.0 to 9.5 years between spawning attempts. The males became mature at 9 to 13 years but did not spawn until they were 15 to 19 years old. A seven-year period usually separated spawning attempts by the males. He considered the 4 to 7 close annuli that make up the belts as representing decreased growth during gonadal development. Thus, after attaining sexual maturity the males and females did not spawn until 4 to 7 years later, making them at least 13 years old and possibly as old as 26 years before their first spawning attempt.

As previously mentioned, the cross sections of the marginal ray of the shovelnose sturgeon also contained belts (Figures 1 A_1 and B and 2 A_1 and B). Except for the marginal belt, these submarginal belts in most cases appeared to be made up of only two annuli. The marginal belts did appear to have as many as 7 annuli, however, these annuli usually were more widely-spaced and more easily counted in the branches of the cross section than annuli in the submarginal belts containing only 2 annuli (Figure 1 A_2). The center of the cross sectioned rays contained narrow translucent zones, which were assumed to be single annuli (Figures 1 C and 2 C). These single marks were less distinct than the annuli composing the belts and it is possible that I may have over looked an annulus or two in the center of the sectioned ray.

Most females contained 4 to 5 annuli (range 2 to 11) before the first submarginal belt was formed. The first 3 or 4 submarginal belts usually contained 2 annuli while the wide marginal belt contained 3 to 7 annuli.

The sectioned rays of males contained up to 8 annuli, usually 3 or 4, before the first belt was formed and each submarginal belt also contained 2 annuli. Males also exhibited a wide multiannular belt at the edge (Figure 2 A_2).

Females became sexually mature when 4 to 11 years of age and the males at 3 to 8 years old. Both sexes were

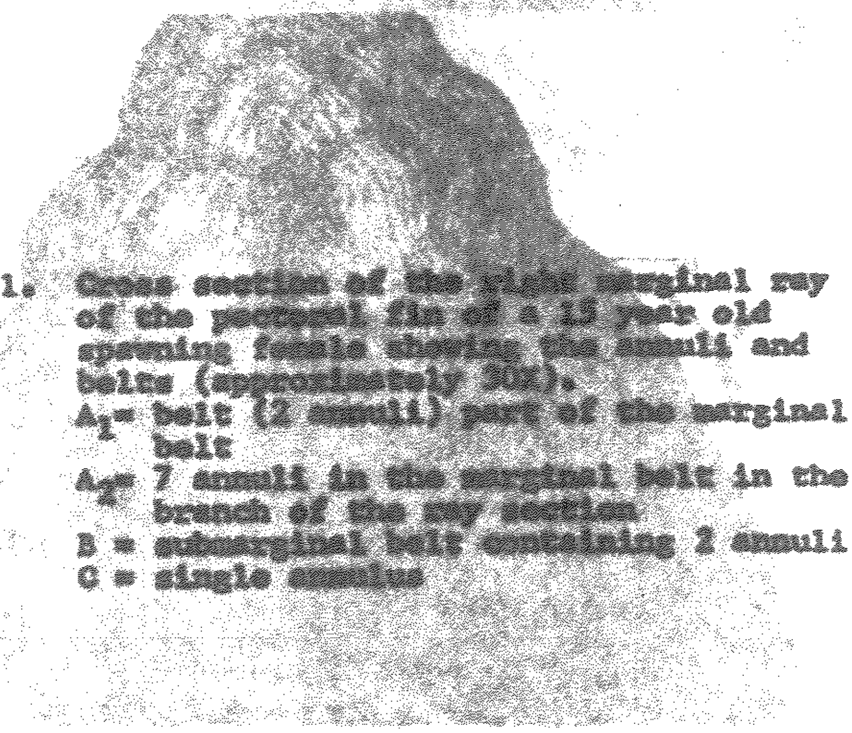

Figure 1. Cross section of the right marginal ray of the pectoral fin of a 15 year old spawning female showing the annuli and belts (approximately 30X).
A_1= belt (2 annuli) part of the marginal belt
A_2= 7 annuli in the marginal belt in the branch of the ray section
B = submarginal belt containing 2 annuli
C = single annulus

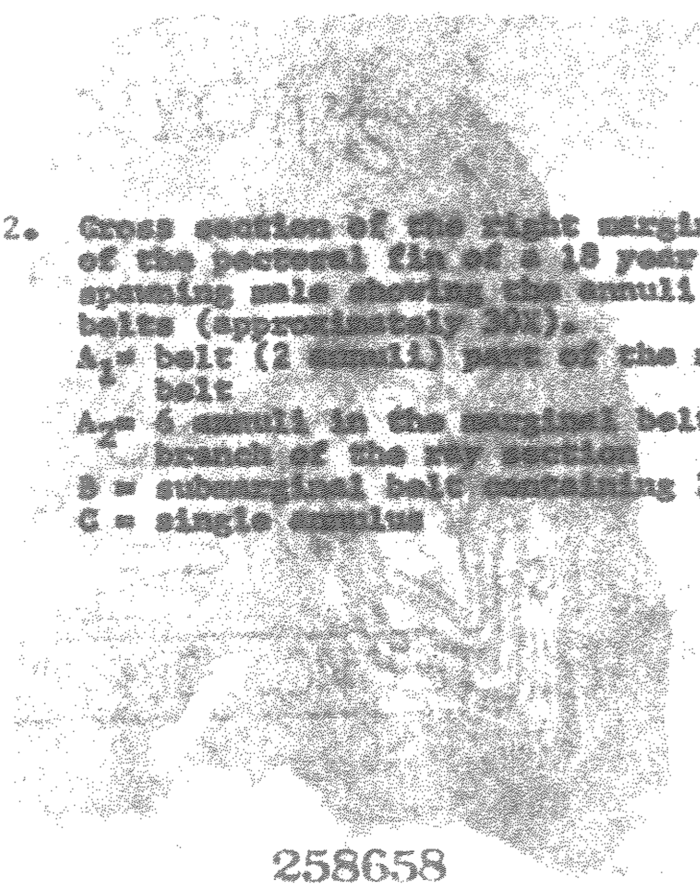

Figure 2. Cross section of the right marginal ray of the pectoral fin of a 18 year old spawning male showing the annuli and belts (approximately 30X).
A_1= belt (2 annuli) part of the marginal belt
A_2= 6 annuli in the marginal belt in the branch of the ray section
B = submarginal belt containing 2 annuli
C = single annulus

believed to spawn within 2 to 3 years after reaching sexual maturity, thus making them between 4 and 14 years old when the initial spawning attempt was made. The growth rate between submarginal belts (clear zones) was greater than the growth rate within submarginal belts. No single annuli were formed between the submarginal belts. If my interpretation is correct, after the initial spawning attempt, males and females spawn every other year (usually [illegible] to 5 times) until they reach a certain size (approximately [illegible] centimeters, fork length). Then growth slows markedly as spawning occurs either every year or irregularly. It is possible that spawning remains on an every other year cycle but due to reduced growth of older fish, the distance between belts is reduced causing these submarginal belts to appear as one marginal belt.

Of the [illegible] fish collected in 1967, 288 were aged. The other [illegible] were not because either the ray was [illegible] was [illegible] early attempts to stain, decalcify [illegible] [illegible]. The mean age of all fish in the sample [illegible] years, but the ages ranged from 8 to 27 years [illegible]. The mode of the sample population occurs [illegible]. Approximately 79 per cent of the [illegible] was considered to be 13 years [illegible] [illegible] aging interpretation used proves [illegible] the sample is representative of [illegible] [illegible] from most of the [illegible]

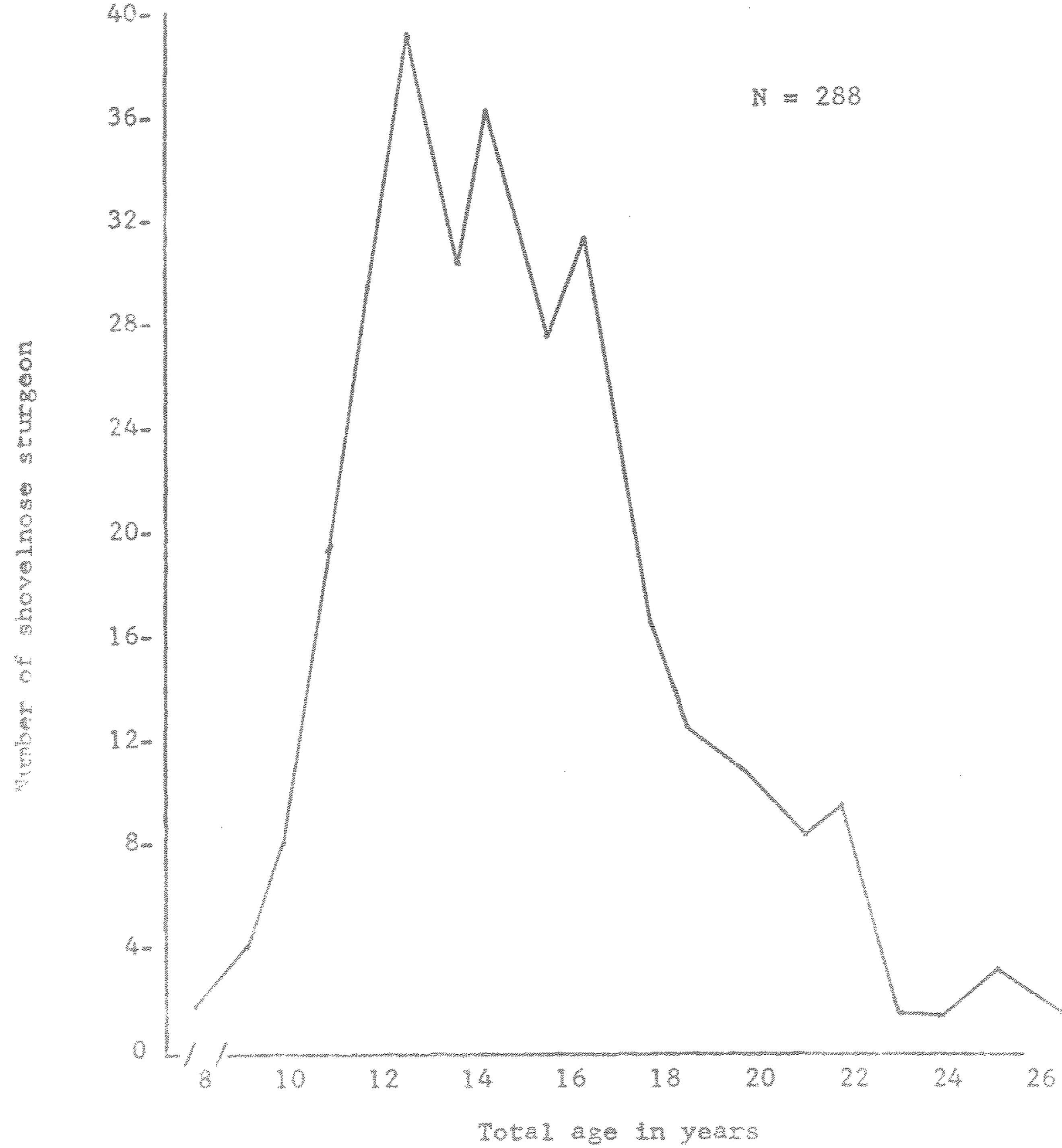

Figure 3. Total age of shovelnose sturgeon vs. number of shovelnose sturgeon collected in the Missouri River (March to June, [illegible]).

the Missouri River were spawned before the closure of Gavins Point Dam in 1955. The effect that this dam has had on sturgeon populations downstream is unknown but in the reservoir behind the dam the sturgeon population declined after impoundment (Sprague 1960).

One of the perplexing problems was why all the sturgeon were approximately the same length at time of capture even though they differed in assessed age as much as 10 years (Table 1). Admittedly the gill nets used to sample the population are selective as to the size they will catch in most species. However, in sturgeon this selectiveness is reduced because the scutes contain spines which easily become entangled in a gill net. If larger or smaller sturgeon had been present in the vicinity of the net sets, some would have been taken. According to [illegible] (1951) different mesh sizes in nets used by fishermen in Lake St. Francis did not [illegible] [illegible] for [illegible] lake sturgeon.

[illegible] net selection as the major explanation [illegible] phenomenon, perhaps the explanation may be found [illegible] pattern of the species. If shovelnose [illegible] length until they reach a certain [illegible] [illegible], the data in Table 1 and [illegible] [illegible] Figures 1 and 2 may be compatible. [illegible] size would not necessarily [illegible] [illegible]. [illegible] [illegible]

Table 1. Mean fork length in centimeters at time of capture. Number in () represents number of fish.

Age	Males	Female	Total
VIII	-------	49.6(2)	49.6(2)
IX	47.5(3)	50.0(1)	48.1(4)
X	51.7(2)	48.5(6)	49.3(8)
XI	51.0(10)	48.8(9)	49.9(19)
XII	49.9(13)	49.7(16)	49.8(29)
XIII	49.7(19)	51.5(20)	50.6(39)
XIV	49.5(15)	52.1(15)	50.8(30)
XV	49.0(15)	49.4(21)	49.[illegible](36)
[illegible]	49.1(16)	50.3(11)	49.6(27)
XV[illegible]	49.6(23)	50.9(8)	50.0(3[illegible])
[illegible]	49.7([illegible])	50.3(10)	[illegible]
[illegible]	5[illegible].9([illegible])	50.6(8)	50.7(1[illegible])
[illegible]	51.4(5)	52.5(6)	52.0(11)
[illegible]	48.8(2)	52.0(6)	51.2(8)
[illegible]	49.3(3)	52.0(6)	51.1(9)
[illegible]	-------	50.5(1)	50.5(1)
[illegible]	50.0(1)	-------	50.[illegible]
[illegible]	54.5([illegible]	51.3(2)	52.[illegible]
	-------	-------	-------
	-------	49.5(1)	49.[illegible]

interpretation would be the fact that most of the sturgeon assessed as 15 years old or older were heavier for their length than those fish believed to be younger than 15 years. This was determined by calculating the ponderal index of subsamples of the 288 sturgeon which were aged.

The ponderal index was determined for fish younger than 15 years (called "young") and for those older than 15 years ("old"). The 15 year old fish were not included in either calculation. The 15 year level was chosen since the mean age for the sample was 15.2 years. The calculated mean ponderal indices were as follows:

"young" male developers (24) $K_{F.L.}$ = 3.37

"old" male developers (19) $K_{F.L.}$ = 3.52

"young" female prespawners & developers (44) $K_{F.L.}$ = 3.30

"old" female prespawners & developers (38) $K_{F.L.}$ = 3.38

total "young" (68) $K_{F.L.}$ = 3.33

total "old" (57) $K_{F.L.}$ = 3.52

n addition, a subsample of the lengths and weights of 0 shovelnose sturgeon was taken at random from the 288 ged shovelnose and the ponderal index of this group s determined. No attention was paid to their sex state of maturity. The ponderal index of this subsample [illegible] follows:

oung" (21) $K_{F.L.}$ = 3.26

[illegible] (19) $K_{F.L.}$ = 3.50

Alth[illegible] these differences are not great, they at least were consistent. The fish which were considered older were also the heaviest for their length. Perhaps sturgeons do not increase much in length once they reach about 50 centimeters in fork length. Growth may express itself in these older fish in the form of increased girth and weight.

Most fish exhibit indeterminite growth which means that growth (length) usually continues throughout the life of the individual. However, there are a few exceptions to this rule such as the male guppy, Lebistes reticulatus, which grows in length until reaching sexual maturity and then appears to stop growing. Therefore there is a precedent for this phenomenon in fish.

Arguing against my interpretation would be the work of Monson and Greenbank (1947) who found many shovelnose sturgeon in the Mississippi River much longer than any found in the present study. Perhaps the Mississippi River population and Missouri River population belong to different subspecies, but there is no direct evidence to substantiate this. Nevertheless the hypothesis that the Missouri River shovelnose reaches a certain length and then grows very little is at least tenable, although other explanations are equally as possible. For example, if the marks on the pectoral ray cross sections are not annuli or at least not all of them are annuli, then the age distribution suggested by Table 2 could be explained as a manifestation of random sampling from a population of fish in which all of the fish are approximately the same age and size.

Attempts to back calculate growth were confronted with procedural difficulties as well as interpretation uncertainties. The small size of the projected marginal ray image combined with the apparent slow growth of the sturgeon resulted in the annuli being very close to each other. This was especially true in the region of the belts. In the opinion of the author, back calculating growth from these marks would have resulted in a large experimental error making the back calculated growth data meaningless. Therefore, the back calculated growth data were not included.

<u>Reproduction</u>: Roussow (1957) classified lake sturgeon into several groups according to gonadal development. Females were considered as "virgin", ripe, running, spent, degenerate or sick. Males were classified as unripe, ripe, running, spent, degenerate or sick. With this type of classification some subjectivity was introduced into the classification. I attempted to be more objective by comparing the ratio of the gonadal weight to the total body weight and used this ratio (expressed as percentage) to classify the fish (Table 2). Females were classified as spawners when the ovaries (with associated connective tissue) constituted over 7.7% of the total body weight, mean of [illegible].5%. The term spawners was intended to denote

Table 2. Percentage of gonadal weight to total body weight for the different gonadal developmental stages and sexes.

	Females			Males	
	Spawners	Prespawners	Developers	Spawners	Developers
Number	63	19	84	103	54
Mean	14.49%	3.88%	1.79%	2.41%	0.90%
Range	7.18% - 22.45%	3.03% - 5.27%	0.68% - 2.99%	0.98% - 6.01%	0.30% - 1.67%
Standard Deviation	3.07	0.68	0.58	0.77	0.32

fish which would spawn that year. Unfortunately this could not be verified by direct observation since no fish were observed to have spawned by the end of June when the study was terminated. However, the eggs in the ovaries were very dark and large and according to Roussow (1957) this indicates at least in lake sturgeon, that the eggs are mature and will be spawned that season. Female prespawners were those in which the ovary was filled with smaller white or yellow-colored eggs which constituted more than 3% but less than 6% of the total body weight. Presumably these eggs were starting their second year of development (if sturgeon spawn every other year). Developers was the term applied to all females whose ovaries constituted less than 3% of the total body weight. These fish had small white eggs which presumably were entering their first full season of development.

The males were classified into only two categories, spawners and developers. Spawners exhibited a testes weight which represented between 0.98% and 6.01% of their total body weight, mean = 2.41%. These testes appeared creamy white and were easily removed from the body cavity. The developers had small white testes which constituted between 0.3% and 1.67% of the total body weight, mean = 0.[illegible]. Of the 323 shovelnose sturgeon, 63 females and 103 males were classified as spawners (Table 2). This category would correspond to Roussow's category of ripe and would have probably spawned in the summer of 1967. The prespawner females would not have spawned in 1967, but probably in 1968. The female and male developers would have spawned sometime after 1968.

Sex Ratio: There were 166 (51.4%) females and 157 (48.6%) males in the sample of 323 shovelnose sturgeon. These were divided into 63 female spawners, 19 prespawners, 84 developers; and 103 male spawners and 54 developers (Table 2). From the sample data, the Missouri River shovelnose population was considered to have a 1:1 sex ratio.

The sex ratio of the lake sturgeon collected near Winnebago, Wisconsin, was approximately 50% females and 50% males in those fish smaller than 59 inches total length and younger than 29 years. Beyond this size and age, females predominated and made up 96% of the fish older than 30 years (Probst and Cooper 1955). Evidently in the lake sturgeon the female is the longer-lived sex. Whether this is true in shovelnose sturgeon could not be determined from the data.

Spawning and Fecundity: According to Eddy (1957) the shovelnose spawns in the spring, moving upstream to gravel beds where they deposit their eggs. Lake sturgeon have been observed swimming upstream to spawn in groups which were composed of sturgeon of different sizes, ages, and stages of sexual maturity. The number of male and female spawners was almost equal (Roussow 1957). Spawning peaked in the Quebec area between the end of May and the first three weeks of June. The water temperature during this period varied between 9°C. and 18°C. On June 20 "spent" sturgeons were collected (Roussow 1957).

The shovelnose sturgeon in this study were collected from March 27, 1967 until June 30, 1967, but no spent females or males were collected. In fact the gonadal weight percentages did not change during this three month period. The water temperature fluctuated greatly during this period due to the unusual spring weather. The surface temperature varied from 4.5°C. on March 27 to 15.5°C. on April 17, 9.0°C. on April 22, and 24.0°C. on June 30.

The actual location, time or frequency of shovelnose sturgeon spawning has not been observed in the Missouri River, or any other place for that matter. According to Trautman (1957) the shovelnose sturgeon avoids the smaller tributaries of the Ohio River. This seems to be the case in the James River, a tributary to the Missouri River. Shovelnose sturgeon were caught in the James River, but not in great numbers as one would expect in a spawning run. Nets were set during the same time period in both the James and Missouri Rivers but only two shovelnose sturgeon were collected from the James. Both were male "developers".

Fecundity: In a broad sense, fecundity may be defined as the reproductive potential of a fish. According to

Wagner and Cooper (1963) fecundity is the number of mature eggs found in the ovary that presumably will be spawned in one season. Nikolsky (1963) differentiated between individual and absolute or total fecundity. The latter term was defined as the total number of eggs contained in the ovary regardless of whether the eggs were spawned in that season. Absolute fecundity was determined for the shovelnose in this study.

Many factors must be considered in determining the fecundity of a species. Fecundity varies with the reproductive behavior of the species. It is high in species that produce pelagic eggs, intermediate in species that deposit their eggs on vegetation, and low in species that hide or protect their eggs. Also, marine fish usually have a higher fecundity than fresh-water or anadromous species. Within a species, fecundity varies with size and age. In the sturgeon, *Acipenser stellatus* Pall., as length increased from 100 cm. to 200 cm. the number of eggs increased from 40,000 to 258,000 (Nikolsky 1963). In the majority of fish species, the number of eggs gradually increases with age, and then, as the individual approaches senility, it begins to decrease. Fecundity also depends upon the physiological condition of the spawners which in turn is dependent upon the number of individuals in a population, available food, etc. Thus, fecundity represents an adaptive response of the population to environmental conditions or changes. For example, the white sturgeon's fecundity is adapted to a relatively low predation rate on its eggs and young (Nikolsky 1963). Since so many variables effect fecundity, the present data on shovelnose sturgeon fecundity will apply only to the shovelnose population in the Missouri River, although it generally will apply to the species over its entire range.

The first 30 spawning females of the 63 collected were used to determine fecundity. The percentage of the ovarian weight to total body weight for the 30 spawning females ranged from 9.30% to 21.50% (Table 3). The mean egg count per fish was 9,210 with a range of 6,709 to 13,637 and a standard deviation of 1,390 (15.09%). The mature eggs ranged in color from dark black to dark gray with a mean diameter of 2.45 mm., based upon the measurements of 40 eggs taken from 10 females. The size of the eggs did not vary greatly within an ovary or between females. Shovelnose eggs were larger than the average-sized eggs of the sterlet, Acipenser ruthenus L., which were observed to range between 1.3 to 2.0 mm. in diameter (Nikolsky 1963).

Length-Weight Relationship: The fork length in centimeters and total body weight in grams were used to compute the length-weight relationship for the shovelnose sturgeon in the Missouri River (Figure 4). Separate length-weight relationships were computed for all females; female spawners female developers and prespawners (combined), all males;

Table 3. Total egg counts, ovarian-body weight ratios, water temperatures of 30 aged females. The shovelnose sturgeon collected in the Missouri River from March 29 to April 8, 1967.

Date	Total Body Wt.(g)	Ovary Wt. / Body Wt. %	No. of eggs per 100 g. Body Wt.	Age	Water Temp. (C.)	Cal. No. of eggs/ female
3/29	779.63	18	860	14	5	6,709
3/29	538.65	15	2,191	--	5	11,808
3/29	396.90	12	1,992	--	5	7,909
3/30	510.30	18	2,276	--	7	11,606
3/30	510.30	11	2,089	--	7	10,654
3/30	453.60	15	1,812	22	7	8,228
3/30	581.18	11	1,428	14	7	8,298
3/31	340.20	17	2,460	15	7	8,363
3/31	496.13	12	1,525	22	7	7,563
3/31	396.90	15	2,128	15	7	8,447
3/31	708.75	18	2,206	14	7	15,637
3/31	411.08	12	2,508	--	7	10,306
4/1	496.13	16	2,076	21	7	10,297
4/2	411.08	12	1,777	16	8	7,302
4/6	467.78	9	2,056	16	10	9,620
4/6	425.25	17	1,926	15	10	8,186
4/6	481.95	13	1,811	15	10	8,729
4/6	481.95	12	1,599	27	10	7,711
4/6	311.85	15	2,279	--	10	7,109
4/6	481.95	17	1,807	15	10	8,710
4/6	396.90	16	2,289	10	10	9,088
4/6	538.65	22	2,458	14	10	13,251
4/6	581.18	13	1,309	12	9	7,603
4/7	411.08	14	1,720	16	9	7,068
4/7	708.75	15	1,811	19	9	12,839
4/7	552.83	16	1,786	20	9	9,877
4/7	538.65	15	1,609	13	9	8,670
4/7	425.25	16	1,787	15	9	7,593
4/7	425.25	16	1,713	10	9	7,281
4/8	496.13	17	1,981	14	9	9,827
mean	(------)	(17)	(-----)	(--)	(--)	(9,210)

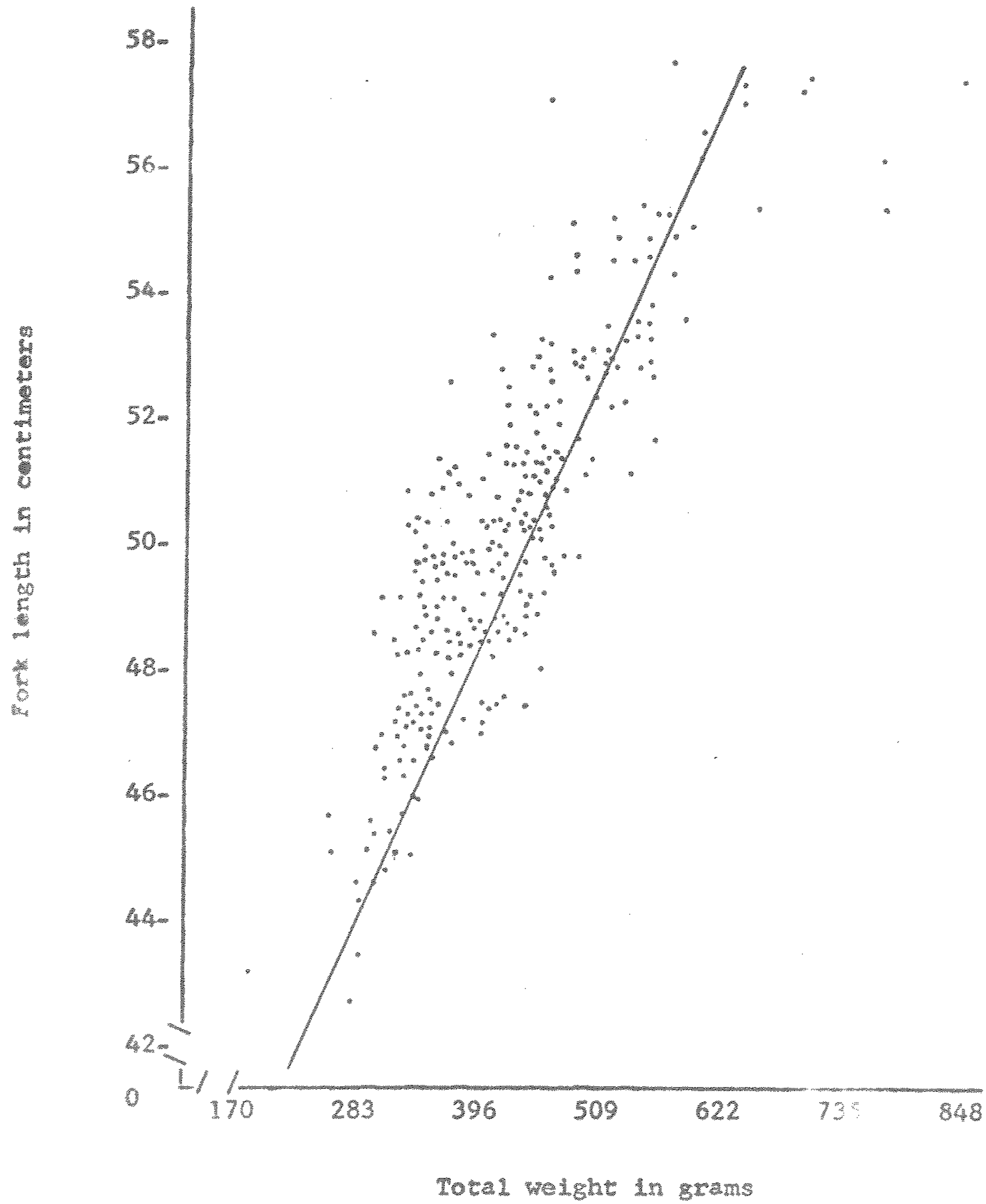

Figure 4. Total weight of shovelnose sturgeon v.s. fork length of shovelnose sturgeon collected in the Missouri River (March - June, 1967). The line represents the calculated length-weight relationship for all fish (318) sexes combined.

male spawners, male developers, and all fish combined. The last seven fish collected on June 30 were not included in any of the length-weight relationships. Thus, a total of 318 fish were used and all but two came from the Missouri River.

The resulting length-weight relationships were as follows:

all females (162) log W= -1.83969 + 2.63469 log L.

female spawners (61) log W= -1.62967 + 2.52739 log L.

female developers and prespawners (101) log W= -1.72037 + 2.55491 log L.

all males (156) log W= -2.47245 + 3.00294 log L.

male spawners (102) log W= -2.31956 + 2.91339 log L.

male developers (54) log W= -2.79452 + 3.19190 log L.

all fish (318) log W= -2.10983 + 2.79128 log L.

Ponderal index: This term is defined as the relative well-being, relative plumpness or relative robustness of a population of fish. It is called by several names, coefficient of condition, condition factor, or ponderal index. This ratio is used to compare populations and is based on the cube law which is expressed by the equation $K_{F.L.} = \frac{W}{L^3} \times 10^3$ (Lagler 1966). The ponderal index of the shovelnose sturgeon in the Missouri River was as follows

female developers and prespawners (101) $K_{F.L.} = 3.36$

male developers (54) $K_{F.L.} = 3.41$

female developers, female prespawners, and male developers combined $K_{V.L.}$ = 3.37

SUMMARY AND CONCLUSIONS

1. A total of 325 shovelnose sturgeon were netted in the Missouri and James Rivers between late March and June 30, 1967. The sturgeon were vulnerable to capture in overnight sets of gill and trammel nets. The rate of catch was independent of water depth. Preference was noted for the swift-water, sandy-bottomed areas of the Missouri River over the slower-moving, silt-bottomed James River.

2. A satisfactory method of preparing the marginal rays of the pectoral fin for aging was devised. All rays were decalcified in a sodium citrate and formic acid solution, sectioned with a microtome, and the sections mounted on glass slides.

3. The marks formed on the cross sections of the pectoral fin marginal rays were interpreted as annuli.

4. After several years of life the annuli were aggregated into "belts", submarginal and marginal. The belts were interpreted as times of slow growth caused by the maturation of the sex cells. Female shovelnose exhibited 4 to 11 single annuli and males 3 to 8 single annuli before the first submarginal belt was formed. Each submarginal belt consisted of two annuli. If the

first spawning attempt occurred after the first submarginal belt was formed, sturgeon ranged from 5 to 13 years old at the first spawning attempt.

5. In most sturgeon 4 to 11 single annuli and 4 or 6 submarginal belts preceded a marginal belt containing 3 to 7 annuli. No single annuli were formed between submarginal belts. If my interpretation of the marks on the section is correct, male and female shovelnose sturgeon in the Missouri River spawn 2 to 3 years after reaching sexual maturity and then every other year. The marginal belt of 3 to 7 annuli probably represents several submarginal belts established close together which, due to the decreased growth rate of the older sturgeon, appear as a single large belt.

6. The mean age of the 288 shovelnose was 15.2 years, mode = 13 years, and the range from 8 to 27 years.

7. Shovelnose sturgeon grew slowly but steadily until they reached a fork length of approximately 50 centimeters. After attaining this length, growth in length was very slight although the girth and weight of the older fish increased, as evidenced by the ponderal index of older fish.

8. Based upon the ratio of the gonadal weight to the total body weight, the 288 sturgeon were categorized into the following groups:

female spawners 63

male spawners	188
female prespawners	19
female developers	84
male developers	54

9. The sex ratio of the Missouri River shovelnose population was 51.4% females and 48.6% males, approximately a 1:1 ratio.

10. Females and males in spawning condition were collected from March 29, to June 30, 1967. During this period the surface water temperature ranged from 5°C. to 24°C. No spent males or females were collected so if spawning occurred in 1967 it occurred after the study was terminated.

11. The mean total egg count per spawning female was 9,210 (range 6,709 to 15,637). These data were based on 30 spawning females collected from March 29, to April 8, 1967. The mean egg diameter was 2.45 mm. based on measurements of 40 eggs taken from 10 females.

12. The length-weight relationships for different categories of sturgeon were as follows:

All Females	log W= -1.83969 + 2.63469 log L.
Female Spawners	log W= -1.62967 + 2.52739 log L.
Female Developers and Prespawners	log W= -1.72037 + 2.55491 log L.
All Males	log W= -2.47245 + 3.00294 log L.
Male Spawners	log W= -2.31956 + 2.91339 log L.
Male Developers	log W= -2.79452 + 3.19190 log L.

Females were slightly heavier for their length than males.

13. The ponderal index or degree of relative plumpness was consistently higher for the "older" fish regardless of sex or state of maturation. For example, the "young"

sturgeon less than 15 years of age had a K factor of 3.26 while the "old" sturgeon (over 15 years) had a K factor of 3.50.

14. The population of shovelnose sturgeon in the Missouri River is inhabiting an environment altered by man. This species may be particularly vulnerable and adversely affected by man's activity. Their slow rate of growth, spawning habits, and the long period of time required for the attainment of sexual maturity may be detrimental to the perpetuation of the species in their present environment. Therefore, a management plan may be needed to prevent this primitive species from becoming extinct.

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