Age and Growth of the Goldeye *Hiodon alosoides* (Rafinesque) of Lake Texoma, Oklahoma[1]

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Limited investigations have been previously made on the growth of the goldeye in northern United States and Canada. Bajkov (1) aged an unknown number of goldeye in Manitoba. Van Oosten and Deason (24) aged 10 goldeye from lower Red Lake, Minnesota. Eddy and Carlander (7) aged 625 goldeye from Red Lake, Minnesota. No previous study on the age and growth of the goldeye in Oklahoma or elsewhere in the southwest has been published.

Materials and Methods

Gill nets were used in collecting most of the goldeye used in this study, although some were caught by angling, and one young-of-year fish was collected with a 25-foot, 1/4-inch bar-mesh bag seine. Fyke nets were used

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during the 1949 field work, but no goldeye were taken by this method. Age and growth calculations were made for 74 of the 89 goldeye collected in 1948, and for 817 of the 970 collected in 1949. Collections were made at seven widely separated stations on the lake in 1948 and at eight stations in 1949.

Gill nets included: "experimental nets", 125 x 6 feet, divided into five 25-foot lengths of 3/4-, 1-, 1 1/4-, 1 1/2-, and 2-inch bar mesh; and nets 210 x 8 feet, of 1-, 1 1/2-, 2-, and 2 1/2-inch bar mesh respectively. Generally, nets were set in the evening and were lifted the following morning.

In 1948, standard lengths were taken in inches to the nearest 1/16 inch. Weights were recorded in grams, using a spring platform-balance, with a capacity of 500 grams and calibrated in one gram intervals. In 1949 both standard- and total-lengths were taken to the nearest millimeter on a standard fish measuring board according to the suggestions of Carlander and Smith (4). The same type of balance was used in 1949 as was used in 1948.

Most of the fish collected in 1948 were not sexed. However, before the 1949 collections were made it was learned that goldeye could be sexed externally by the shape of the anal fin. This sexual dimorphism was mentioned by Jordon and Thompson (16) and Hinks (13) although the difference was not illustrated in either paper. In the female the lower edge of the anal fin is slightly concave or almost straight; in the male there is a large lobe at the front of this fin, giving the anterior lower edge a convexly curved contour (Figure 1).

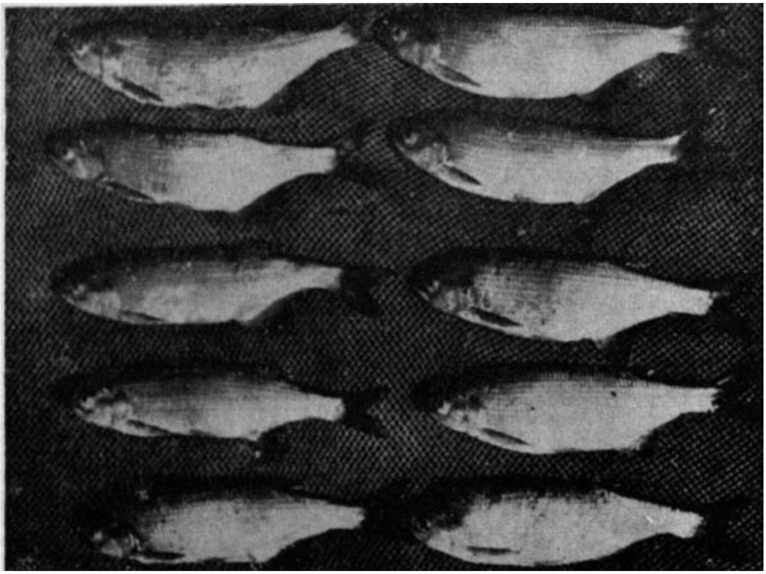

FIGURE 1. Dimorphism of the Anal Fin in the Male and Female Goldeye. Males are shown on the right, females on the left.

Scale samples were taken from below the lateral line just posterior to the tip of the pectoral fin when the latter was compressed against the side of the body. These were placed in envelopes on which pertinent data were recorded.

In the laboratory an attempt was first made to mount the scales in glycerin gelatin, following a formula advocated by Van Oosten (23). However, this method proved to be impractical, bceause proper materials were not available. Thereafter, scales to be read were soaked in water, cleaned with a small brush of camel's hair, and temporarily mounted in water between two microscope slides. Examination of the samples was made at a magnification of x43.0 on a micro-projector similar to that described by Van Oosten, Deason, and Jobes (25) and pictured by Lagler (17).

Conversion factors based on 996 fish were determined by the use of a method described by Beckman (2). They were as follows: standard-length to total-length—1.226; total-length to standard-length—.8158. The 1948 fish samples were converted from standard-length to total-length.

Gill Net Selectivity

The primary concern in collecting a sample of fish for an age and growth study is to get a random sample of the actual population; that is, to get numbers of each length and age in the proportion in which they occur in the population. The use of gill nets has resulted in many ideas concerning their influence on age and growth data. Hile (12) gives an adequate review of the previous literature on the subject. He concluded that "The action of a net of specified mesh depends first upon the range of length and abundance of fish within the population, and second upon the morphological characteristics that determine in what manner the fish is held captive."

The selectivity of the gill nets in taking the larger and older fish is apparent (Table I). No young-of-year fish were captured, even with 3/4-inch mesh, and relatively small numbers of age-groups I, II, and III were caught.

TABLE I

Length Frequencies of Lake Texoma Goldeye Taken by Different Gill Net Mesh Sizes for 1948 and 1949.

	Net Size in Inches									
Standard-Length	Exp. 1 3/4	Exp. 2 1	Exp. 3 1 1/4	Exp. 4 1 1/2	Exp. 5 2	1	1 1/2	2	2 1/2	Total
130-139	1									1
140-149	1									1
150-159							1			1
160-169										
170-179		1						1		2
180-189		3					12	3		18
190-199		5	1			7	4			17
200-209		7	9			13	1			30
210-219		7	2			21	1			31
220-229		3	4			12	3	1		23
230-239		1	4	5	1	3	29			43
240-249		4	7	13		9	63	4		100
250-259			10	12	1	16	106	5		150
260-269	1	2	2	7	1	6	161	1		181
270-279		1	4	6	1	4	164	4		184
280-289			2	12	1	4	98	3	1	121
290-299				2			33	1		21
300-309							5	2		7
310-319							1			1
320-329										
330-339							1			1
Totals	3	34	45	57	5	95	683	25	1	948
Average Length	181	214	238	261	232	264	252	280		

Prichard (18) used six different sizes of mesh to catch Lake Ontario chubs and on the basis of his study concluded, "The difference of 1/4 of an inch in the size of mesh may mean to a fisherman either a profitable or 'starvation' industry." Prichard's conclusion would also hold true for Lake Texoma goldeye where a 1 1/2-inch mesh net took 740 out of the 948 fish taken on which data were recorded (Table I). A 1/2-inch increase in the size of the bar mesh resulted in a decrease to only 30 fish captured.

The mode of the lengths of the fish caught in meshes up through 1 1/2 inches increases as the mesh size increases (Table I). This indicates, to a certain extent at least, a more random sample than if the modes had not changed. Evidence that the larger fish were adequately sampled is shown by the overlap in the modes of fish taken by the 1 1/2- and 2-inch mesh nets; also, the number of fish captured in the larger mesh decreased abruptly.

Sex Ratio

Out of 889 goldeye collected in 1949, 641 (72.1 per cent) were females, while only 248 (27.9 per cent) were males. In every age-group in which enough fish were checked to draw conclusions there was a lack of balance between the sexes (Table II).

Geiser (10, 11) cited many references indicating that the mortality of male animals is unusually high when there are adverse environmental conditions. The steadily increasing percentage of females in age-group III, IV, and V (Table II) supports this hypothesis.

TABLE II

Sex Ratio Within Each Age-group of Lake Texoma Goldeye Collected in 1949.

Age-group	Number of females	Number of males	Per cent of females	Percent of males
I	4	0	100	0
II	117	19	86	14
III	148	95	61	39
IV	292	99	75	25
V	47	11	81	19
VI	2	0	100	0

Body Length-Scale Length Relationship and the Calculation of Growth

Different authorities have used various methods for measurement of the radius and diameter of scales. Van Oosten (23) found the anterio-posterior diameter measurement to give a more accurate expression of the relationship between scale length and body length for the lake herring than the radius measurement. Spoor (21) working with the white sucker (*Catostomus commersonii*) found the dorso-ventral diameter of the scale to be the most satisfactory measurement. Jenkins (14) found the dorso-lateral radius of the scale of the river carpsucker to be most accurate. Everhart (9) established that the anterior measurement was better than the lateral one for smallmouth black bass.

In view of these differences in the findings of various fishery biologists the writer took both anterior and dorso-lateral measurements from the focus to the margin of the scale. The anterior measurements were made along a central anterior radius. The dorso-lateral measurements were made from the focus perpendicular to the central anterior radius.

In spite of the wavy anterior margin of the scale (Figure 3) the anterior measurement proved to be more accurate than the dorso-lateral measurement. The anterior measurements gave a higher coefficient of correlation than did the lateral ones (.74 for the former as compared with .66 for the latter).

The data were grouped in ten-millimeter intervals of total fish length and ten-millimeter intervals of total scale length (X 43.0). The calculated means were plotted on a graph (Fig. 2). When the data are thus grouped two regression lines may be drawn.

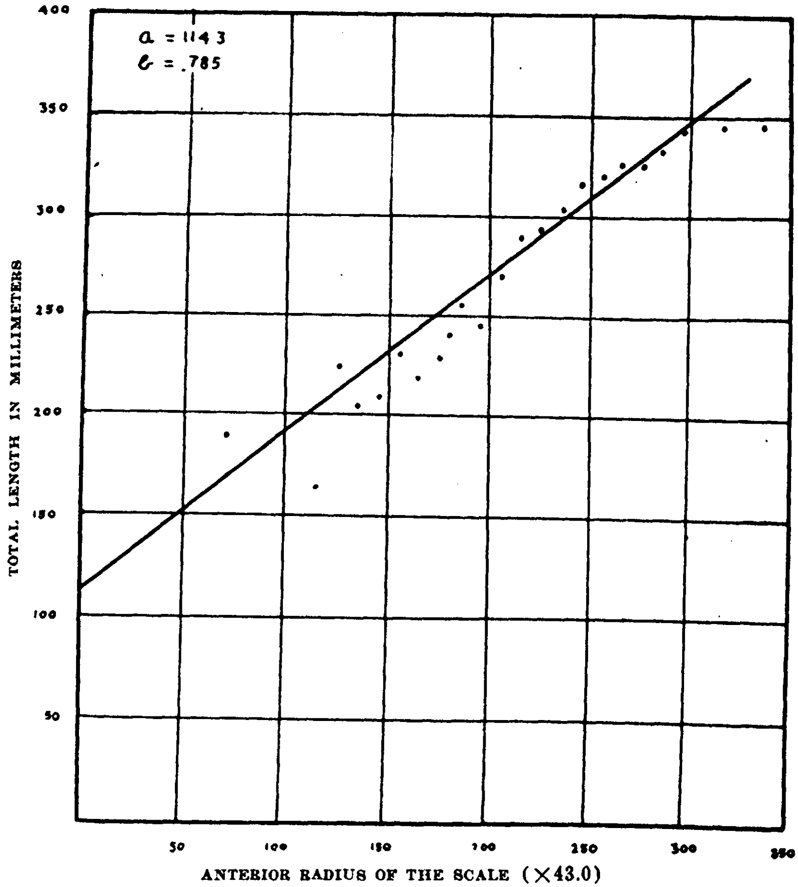

FIGURE 2. Body Length-scale Length Relationship of 954 Lake Texoma Goldeye Collected in 1948 and 1949. Dots Represent the Mean Body Length Corresponding to Each Ten-millimeter Interval of Scale Length.

Wilson (27) indicated that there has been some disagreement among fishery investigators as to which regression should be used. Winsor (28) stated, "Our general principle, it appears, should be . . . (to) arrange the experiment so that the desired regression can be determined directly. That is, the variable from which prediction is to be made should be taken as the independent variable."

Since the calculation of fish length (y) from known scale length (x) is desired, it is the regression of y on x which should be used in the determination of the intercept (a) and the slope of the regression line (b) as shown in Figure 2.

Correlation tables were made by a method described by Wilson (27), for both anterior and lateral scale measurements for use in computing the body length-scale length relationship and the coefficient of correlation. The regression equation $y = a + bx$ was used in fitting the regression line to the data, where y = total-length; a = a constant; b = a constant; x = scale radius. The calculated value of the intercept for the anterior measurement of the scale radius was (a) = 114.3 and the slope was (b) = 0.785.

Weese (26) found that the intercept value for white bass increased with age while the coefficient expressing the slope of the regression line decreased. This is probably true of the goldeye too, since 82 per cent of the 1949 goldeye were in age-groups III, IV, and V. Weese (26) also found that the coefficient of correlation decreased as the white bass became older.

Determination of Age

A review of the literature did not reveal that any previous investigator had presented evidence substantiating the validity of the scale method for determining the age of goldeye. In order to establish that the annuli were true year marks, the data were checked in several ways. First, the modes of the length-frequency distribution correspond with the modal lengths of age-groups, especially for the younger age-groups (Table III).

TABLE III

Length Frequencies at Each Age-group of Lake Texoma Goldeye (Sexes Combined) Collected in 1948 and 1949.

Ten-mm. intervals of total-length	Age-group							
	I	II	III	IV	V	VI	No. of fish	Per cent
160-169	1						1	.108
170-179	2						2	.216
180-189								
190-199	1						1	.108
200-209		1					1	.108
210-219		19					19	2.056
220-229		13					13	1.406
230-239		8					8	.865
240-249		27					27	2.922
250-259		22	1	1			24	2.597
260-269		25	1				26	2.813
270-279		17	3				20	2.164
280-289		7	12	3			22	2.38
290-299		4	57	3			64	6.926
300-309		3	85	21	2		111	12.012
310-319		1	49	39	3		92	9.956
320-329		1	40	80	4		125	13.528
330-339			16	143	10		169	18.29
340-349			3	98	23		124	13.419
350-359			2	38	16	1	57	6.168
360-369				7	8		15	1.623
370-379				1	1	1	3	.324
Total and grand total	4	148	269	434	67	2	924	

There is no overlap between age-groups I and II, and little overlap between age-groups II and III, while age-groups III and IV have different modes. Second; a comparison of the calculated lengths at the end of various years of life with empirical lengths at the time of capture shows that the former concur with the latter (Table VIII).

Calculated lengths do not exactly agree with empirical lengths (Table 8) since most of the fish were taken during the growing season; therefore, the empirical lengths fall between two calculated lengths. Thus, the average calculated length to the third annulus of fish in age-group III exceeds the actual measured length of fish in age-group II. Likewise, the calculated lengths of age-groups IV and V at the fourth and fifth annuli exceed the empirical lengths of fish in age-groups III and IV.

The third point substantiating the scale method for the aging of the goldeye is that the calculated growth histories of fish collected in 1948 and 1949 are in close agreement (Table IV), as well as averages of empirical total-length. It should be remembered that a standard conversion factor was used for converting 1948 standard-lengths to total-lengths. This probably explains the shorter lengths of the older 1948 fish in age-groups IV and V since their average empirical weight was greater than that of the 1949 fish.

TABLE IV

Comparisons of Averages of Empirical Total-lengths and Averages of Calculated Total-lengths for 1948 and 1949 Collections of Lake Texoma Goldeye

Averages of empirical total-lengths of fish of various age-groups at time of capture			Grand weighted averages of calculated total-lengths at ends of various years of life		
	Year of capture		Year of life	Year of capture	
Age-group	1948	1949		1948	1949
I		6.9 (4)*	1	7.6 (74)	7.5 (817)
II	11.0 (8)	9.8 (140)	2	8.9 (74)	8.8 (813)
III	12.2 (23)	12.0 (224)	3	10.9 (66)	11.2 (673)
IV	12.8 (36)	13.1 (387)	4	12.2 (23)	12.6 (449)
V	13.4 (7)	13.5 (60)	5	12.9 (7)	13.2 (62)
VI		14.3 (2)	6		14.2 (2)
Totals	(74)	(817)		(74)	(817)

*numbers of fish in parentheses.

Annuli on goldeye scales (Figure 3) can be recognized by the criteria that they usually cut over circuli (though this is sometimes extremely slight or even missing, especially at the first annulus), and by a difference in the distance between circuli immediately before and after the year-mark. Sometimes an annulus can be recognized by erosion or absorption of a strip of scale in the area where the annulus occurs. Accessory checks, or false annuli, were found consistently between the year-marks on the scales of larger fish. In some cases these checks made age determinations difficult and some scale samples were discarded. Fortunately, most of these checks were prominent in the anterior field only.

Rate of Growth

To calculate individual growth histories a direct proportion nomograph was used similar to that described by Carlander and Smith (3). The data were averaged to find the average growth for each year of life (Tables V and VI). Growth histories were also calculated for the sexes separately (Table VII, Figure 4). That calculated lengths were slightly inaccurate is indicated by the fact that the coefficient of correlation was somewhat low.

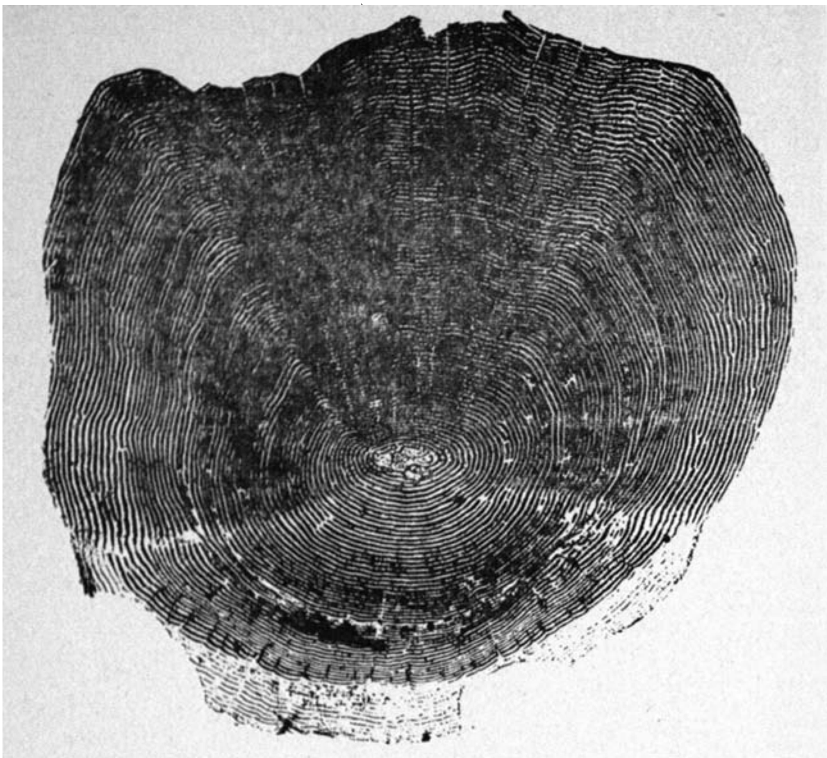

FIGURE 3. Goldeye Scale From an Age-group-I Fish.

TABLE V.

Average Calculated Total-lengths and Increments of Average Total-length for Each Age-group of Goldeye (Sexes Combined) Collected in Lake Texoma, 1948.

Age-group	Number of fish	Average empirical total-length MM.	Average empirical total-length IN.	Average empirical weight GMS.	Average empirical weight OZ.	Ave. calculated total-lengths (MM.) at end of year of life 1	2	3	4	5
II	8	279	11.0	206	7.3	192	238			
III	23	310	12.2	258	9.1	191	227	279		
IV	36	326	12.8	290	10.2	194	225	277	309	
V	7	340	13.4	367	12.9	198	228	274	307	327
Grand weighted average total-length (mm.)						193	227	277	309	327
Grand weighted average total-length (in.)						7.6	8.9	10.9	12.2	12.9
Increments of average total-length (mm.)						193	34	50	32	18
Increments of average total-length (in.)						7.6	1.3	2.0	1.3	.7
Equivalent standard-length (mm.)						157	185	226	252	264
Total number of fish				74		74	74	66	43	7

The mean total-length of 1032 goldeye captured in 1948 and 1949 was 313 millimeters or 12.3 inches. The mean weight for these fish was 277 grams (9.8 ounces). Bajkov (1) working in the prairie provinces of Canada, stated, "The average weight of the goldeye of the prairie lakes varies between one-half and three-quarter pounds." This indicates that the Lake Texoma goldeye do not differ greatly in weight from the goldeye in that region.

The largest fish (14.7 inches, total-length; 19.8 ounces) was a female from the 1949 collection belonging to age-group VI. The largest male goldeye captured at Lake Texoma was 13.9 inches in total-length and weighed 15.0 ounces. The largest female fish from Texoma was much smaller than the goldeye captured in the North Platte River, Wyoming (Simon, 19). This fish was 18 inches long and weighed 43 ounces. A large Iowa specimen was 18.0 inches long but weighed only 33 ounces (Carlander, 5).

TABLE VI

Average Calculated Total-lengths and Increments of Average Total-length for Each Age-group of Goldeye (Sexes Combined) Collected in Lake Texoma, 1949.

Age-group	Number of fish	Average empirical total-length MM.	Average empirical total-length IN.	Average empirical weight GMS.	Average empirical weight OZ.	Ave. calculated total-lengths (mm.) at end of year of life 1	2	3	4	5	6
I	4	175	6.9	38	1.3	146					
II	140	249	9.8	148	5.2	171	209				
III	224	305	12.0	258	9.1	192	226	287			
IV	387	334	13.1	313	11.0	198	227	283	320		
V	60	344	13.5	349	12.3	197	227	279	316	336	
VI	2	364	14.3	470	16.6	198	229	280	312	343	360
Grand weighted average total-length (mm.)						191	224	284	319	336	360
Grand weighted average total-length (in.)						7.5	8.8	11.2	12.6	13.2	14.2
Increments of average total-length (mm.)						191	33	60	33	17	24
Increments of average total-length (in.)						7.5	1.3	2.4	1.3	.7	.9
Calculated average increments (mm.)						191	33	57	37	20	17
Equivalent calculated standard-length (mm.)						156	183	232	260	274	294
Total number of fish	817					817	813	673	449	62	2

The growth of goldeye at Lake Texoma is similar to that of other species of fish at that Lake and other new impoundments (Table V and VI). The growth rate has declined as the lake has aged and the number of fish increased. The fish in older age-groups exhibit greater amounts of growth during the first two years of life than do younger fish, apparently a reversal of Lee's phenomenon. These data are in agreement with the findings of Sneed and Thompson (20), Stroud (22), Eschmeyer and Jones (8), and others who have observed that the growth of various species in newly created impoundments is extremely good immediately after impoundment. There is evidence that an increase in population is partially responsible for a slower growth rate of fish. Johnson (15) reviewed the literature regarding the effects of crowding upon fish and other aquatic animals and suggested that the slow growth of black and white crappie in Greenwood Lake, Indiana, may have been the result of the accumulation of metabolic wastes and of psychological effects.

The annual growth increment for 1949, obtained by comparing the mean lengths of each age-group, was respectively 7.5, 1.3, 2.4, 1.3, 0.7, and 0.9 inches. There was a tendency for the increment to decrease with increasing age, although there were alternately good and poor growing years. One possible explanation of this may be that slow growth in alternate years is correlated with spawning since it is reported that goldeye do not spawn every year after maturity (13). Clemens (6), working with Lake Erie burbot found that mature burbot had slower growth rates than immature ones.

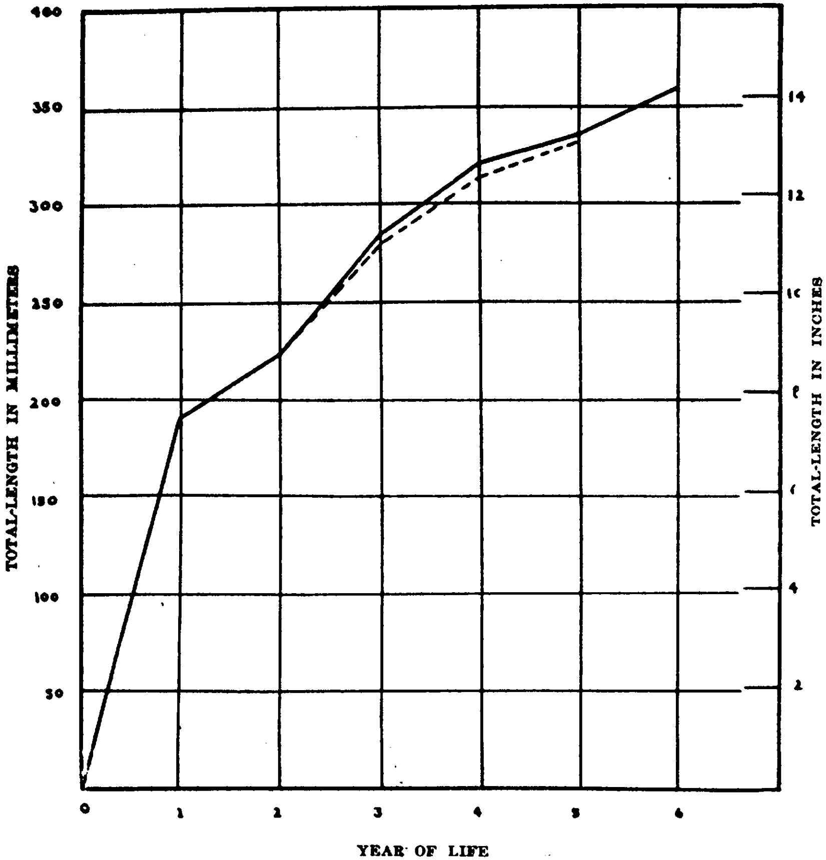

FIGURE 4. Weighted Average Calculated Total-lengths of 826 Goldeye. Solid Line Represents the Females. Broken Line represents the Males. 1948 and 1949 Collections.

The few goldeye sexed in 1948, together with those sexed in 1949, were combined to increase the size of the sample. There is a differential growth rate in length for the two sexes (Table VII, Figure 4). The females averaged longer in empirical length for every age-group. In calculated length the females averaged longer at the end of their third year of life and thereafter (Figure 4).

TABLE VII

Average Total-length at Capture of Male and Female Lake Texoma Goldeye and the Difference in Length of the Sexes.

	Number of fish		Mean total-length at capture		Length difference of the sexes in mm.	Length difference of the sexes in inches
Age-group	Males	Females	Males	Females		
II	18	117	232	251	19	0.7
III	87	127	302	308	6	0.2
IV	106	309	326	336	10	0.4
V	12	47	340	345	5	0.2

The growth in length of Lake Texoma goldeye is compared with the growth in other waters in Tables VIII and IX. It should be remembered that the Lake Texoma fish were grouped in ten-millimeter intervals according to scale lengths, then body lengths were calculated. Others have grouped their fish by body lengths to calculated growth. Lake Texoma goldeye grew much more rapidly the first year of life than goldeye in the northern lakes which have been studied (Tables VIII and IX). After the first year, the northern fish had greater increments of growth for every year (with one exception) so that they gradually overtook the Lake Texoma goldeye in length. The goldeye from Manitoba exhibited the same pattern of alternately good and poor growing years as shown for Lake Texoma fish (Table VIII).

TABLE VIII

Comparison of the Growth Rate of Lake Texoma Goldeye Collected in 1949 with that of Goldeye in Other Waters.

Body of water	Worker	Number of fish	Ave. calculated standard-length (mm.) at end of year of life						
			1	2	3	4	5	6	7
Lake Texoma (1949)	Martin*	817	156	183	232	260	274	294	
Red Lake, Minn. (1942)	Eddy and Carlander	625	60	137	202	237	268	291	
Manitoba (1930) (various lakes)	Bajkov	——	100	150	205	230	290	330	345

*Total-lengths were converted to standard-lengths.

TABLE IX

Comparison of the Growth Rate of Lake Texoma Goldeye Collected in 1949 With That of Goldeye in Lower Red Lake, Minnesota.

Body of water	Worker	Number of fish	Ave. calculated total-length (in.) at end of year of life					
			1	2	3	4	5	6
Lake Texoma (1949)	Martin	817	7.5	8.8	11.2	12.6	13.2	14.2
Lower Red Lake (1939)	Van Oosten and Deason	10	3.1	7.9	11.0	12.4	13.5	14.4

Length-Weight Relationship

The equation log (weight) = −4.54392 + 2.89078 log (length) was found to apply for calculating weights. (Table X presents the data for 996 fish in both years' collections.)

The bulk of the fish of potential commercial value, (*i.e.*, length intervals where more than 100 fish were taken with gill nets) have average total lengths between 11.8 inches and 13.6 inches and average empirical weights between 8.5 ounces and 12.5 ounces (Table X).

TABLE X

Length-weight Relationship of 996 Lake Texoma Goldeye (Sexes Combined) Collected in 1948 and 1949.

TOTAL-LENGTH (INCHES)	STANDARD-LENGTH (MM.)	EMPIRICAL WEIGHT (OZ.)	CALCULATED WEIGHT (OZ.)	CALCULATED WEIGHT (GRAMS
6.9	139	1.4	1.6	45
7.0	145	1.6	1.8	51
8.5	173	3.1	3.0	84
8.6	184	3.4	3.5	100
9.3	195	4.3	4.2	119
9.8	204	5.3	4.8	135
10.4	213	6.1	5.4	153
10.7	223	6.9	6.2	175
11.4	235	7.9	7.2	204
11.8	245	8.5	8.1	230
12.2	254	9.2	9.0	255
12.8	263	10.3	9.9	282
13.2	274	11.3	11.2	318
13.6	283	12.5	12.3	350
13.9	293	13.2	13.7	387
14.3	303	14.4	15.0	426
14.7	315	19.8	16.8	476
14.3	330	13.0	19.0	538

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