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An investigation of the goldeye
Amphiodon alosoides in

Manitoba waters

Author

W. M. Sprules

Central Fisheries Research Station

INTRODUCTION

The goldeye fishery is of considerable local importance in Manitoba as the smoked product is highly reputed and in constant demand by householders and restaurateurs in the province. Its reputation as a table delicacy has spread across the Dominion, in recent years, as a result of its use in the diners of the Canadian National and Canadian Pacific Railway. Goldeye may be ranked among the game fishes also since it rises readily to the fly during the late spring and summer months and provides considerable sport for anglers.

The production of goldeye in Canada comes almost entirely from Manitoba although a few hundred-weight are obtained annually from Alberta, Saskatchewan and Ontario. Since 1900 the peak production period occurred between 1926 and 1929 inclusive when more than 1,000,000 pounds were caught and landed annually in the Dominion. Since that time there has been a gradual decline in production until at present only $\frac{1}{4}$ of a million pounds is taken each year. This decrease can not be accounted for by a decrease in effort on the part of fishermen as the price they obtain for this species is one of the highest obtained for any of the fishes caught in this area. Further, since goldeye frequent the shallow bays in the fishing grounds they can be procured with smaller, less expensive equipment, by the individual fisherman, than can such species as whitefish which are found in the deep waters of the open lakes.

There is a paucity of literature on the early life history, spawning habits and general requirements of goldeye. The commercial

fishermen are well versed in the habits of most species taken in their nets but question of how, when and where goldeye spawn are answered with confusion and considerable contradiction. Some work on the biology of the goldeye has been conducted by the staff of the Game and Fisheries Branch of the Department of Mines and Natural Resources in Manitoba but much of this has remained unpublished. Recently, in 1938 and 1939, an extensive survey was undertaken by Mr. D. Hinks, working for the department mentioned above but this work was not completed, unfortunately, because of his enlistment and subsequent death in the recent world war.

The present investigation was started during the summer of 1945 as part of the field programme of the Central Fisheries Research Station of the Fisheries Research Board of Canada, to obtain more data on the spawning habits and early life history of goldeye and to apply these, wherever possible, to an improvement of the local fishery and conservation of the species.

METHODS

From June 17 to July 24 fishing was carried on in the Red Deer River, which flows into Dawson Bay at the north-west corner of Lake Winnipegosis, and in Dawson Bay proper within a 2 mile radius of the river's mouth. From July 24 to August 5 goldeye were taken in Red Deer Lake, which is an expansion of the river 10 miles from its mouth, and in the Steeprock and Shoal Rivers which flow into the south-east corner of Dawson Bay. During the latter part of August a trip was made along

100 miles of the Saskatchewan River and fishing was carried on in the main river and larger tributaries from 25 miles north-west of The Pas to 75 miles south-east of the town.

A total of 1880 goldeye were collected from these scattered localities. Most of the fish were caught in gill nets of $1\frac{1}{2}$ to $1\frac{1}{2}$ " stretched mesh with the largest number coming from $2\frac{1}{2}$ - and 3-inch mesh. Hoop nets were used for a short time in the Red Deer River but no goldeye were taken in these nets although gill nets set in the same vicinity proved the presence of large numbers of these fish. Goldeye of the year were taken in seine hauls made in tributaries of the Saskatchewan River.

HABITAT

In Dawson Bay goldeye were found most abundantly in shallow, sheltered bays and shore regions from 5 to 10 feet deep with soft mud bottoms. Of these areas, the shallow mud flats at the mouths of the larger rivers such as the Red Deer, Steeprock and Shoal Rivers proved to be the best fishing grounds. These rivers along with the Saskatchewan and its tributaries all contained goldeye and were characterized by rapid flow and muddy bottoms for the most part, although occasional pools and rapids occurred in all the rivers. Small, shallow lakes connected with these rivers also contained goldeye during the summer months.

From these data it is apparent that goldeye prefer shallow mud bottom areas in lakes and large, fast flowing streams with predominantly mud bottoms. The waters were all acid in reaction and brown in colour. The river waters carried considerable

quantities of mud at all seasons and the bottom was not visible at a depth of more than one foot on the average. Turbidity values ranged from 5, in areas of still water where the suspended material settled to the bottom, to 100 in Red Deer Lake, (Table 1). This latter value was obtained following a period of strong east winds which riled the bottom considerably.

Early in the investigation it was deemed advisable to determine the salt content of the waters since local fishermen spoke consistently of catching the largest number of goldeye at the "salt flats" or off "salt points". A few standard solutions were prepared to test the chloride and sulphate content of the waters. The tests disclosed no direct correlation between goldeye distribution and the concentration of these ions and in every instance these ions were present only in small quantities. The waters of the Red Deer system contained 100 parts per million of the sulphate ion while the remaining waters tested showed only a trace or absence of the ion, (Table 1). The Steeprock, Bell Carrot, and Fasquia Rivers contained 50 parts per million of the chloride ion and the remaining waters showed a trace or absence of the ion, (Table 1).

A record of the maximum and minimum water temperature of the Red Deer River was obtained from June 23 to July 22. During this period the minimum temperature was 48.0 degrees Fahrenheit on July 1 and the maximum, 74.0 degrees Fahrenheit recorded on July 22. Goldeye were present in the river throughout this period.

SPAWNING

The investigation was started too late in the season to determine the earliest date at which spawning occurred. By June 19 when the first goldeye were taken in the Red Deer River both ripe and spent individuals were obtained in approximately equal numbers. However, ripe females were taken regularly until July 5 at which time they disappeared from the collections and no ripe females were taken at any locality after this date. An occasional female was caught throughout the late summer period in which the eggs were large but disintegrating, indicating that although ripe during the spawning period the eggs had not been expelled. Since the testes of the males did not change visually during the spawning season it was almost impossible to determine whether or not these individuals were spent so that they cannot be used to determine the length of the spawning period.

From this information it is apparent that goldeye spawn during early spring, evidently moving into turbid streams at or near break-up and spawning throughout June and early July. The spawning act was not observed at any time and eggs were not obtained from the streams so that it is impossible to make a definite statement of the exact nature of the spawning grounds. One ripe female with the eggs partially expelled was captured in a gill net placed in a sandy-bottomed stretch of the Red Deer River immediately below a rapids.

Further light was thrown on the spawning areas utilized by goldeye through the capture of fish of the year

along the Saskatchewan River. At Baptizing, McKenzie and Big Bend Creeks goldeye of the year were taken in seine hauls behind dams, placed at the outlets of the streams into the Saskatchewan River, which were erected to maintain water levels for muskrat ranching in the Saskatchewan drainage. Since these dams were not opened during the year, the young goldeye could not have gained access to the streams from the Saskatchewan River. Thus the parent stock must have spawned either in the streams proper or in the shallow lakes at the heads of these streams. Other gold-eye of the year were taken in 4 feet of water on sand bottoms in Reader's Cutoff, which is a tributary of the Saskatchewan River not obstructed by a dam, and in a sandy-bottomed eddy in the Saskatchewan River proper.

These fish were all obtained between August 14 and 23, approximately 2 months after the spawning period, and it is improbable that they had travelled far from the spawning beds during this interval.

GONADS AND SEX

Goldeye exhibit sexual demorphism when mature and at this period in the life cycle the male possesses a distinct lobe on the anterior part of the anal fin while the female retains a straight anal fin which is also found in all immature fish of this species. The testes are narrow paired organs, light red in colour and convoluted when mature and do not change appreciably when ripe. Only a small drop of milt can be expressed even when

considerable pressure is applied to an apparently ripe individual. In ripe females the ovaries fill most of the body cavity and the egg colour changes from a dull gray to a bright steel-blue. These can be expressed fairly readily when ripe but not nearly so readily as in many other species such as suckers, jackfish and pickerel. Immediately after spawning the female gonad takes on a typical spent appearance of reddish, ruptured tissue in which small white eggs can be seen. Within a month after spawning, the eggs rapidly increase in size and the gonad becomes turgid and gray in colour but much smaller than just prior to spawning. This rapid increase in egg size doubtlessly accounts for the confusion existing among fishermen regarding the spawning time of goldeye since throughout the summer fishing period the gonads are full of large eggs and thus have led to the belief in a fall spawning period.

Differences were noted in the nature of the immature gonads of all age classes from 1 year up. In the field these were broadly segregated into "striated" and "non-striated" and thence broken down into sizes such as $1/16$, $1/8$ and $1/4$ of an inch. When teased portions of these gonads were viewed with the aid of a microscope, it was found that all the striated gonads contained small eggs while no eggs were visible in the non-striated gonads. The size differences of each group of gonads was found to be closely related to the age and size of the specimens and probably represents the natural growth of the gonads with the growth of the fish. Thus it is possible to determine the sex of

goldeye of the year up to the present time. Rincks found evidence of a two-year spawning cycle in female goldeye. This has not been substantiated completely by the findings of this investigation, although females were captured during the spawning season in the Red Deer River, which were larger than many mature forms and yet contained small eggs and were definitely not going to spawn that season. Specimens will have to be taken during the fall and winter months in order to determine whether two types of gonads exist in the females of mature size groups before the existence of a two-year spawning cycle could be confirmed.

SEX RATIO

In all the localities where $1\frac{1}{2}$ - to $3\frac{3}{4}$ -inch gill nets were used it was found that males outnumbered females by more than 2 to 1 on the average. Conversely where $\frac{1}{2}$ -inch nets were used females outnumbered males in about the same ratio. This follows naturally from the rate of growth data since males of each year class were smaller than the corresponding females. The sex ratio of all goldeye caught, including immature individuals down to the first year class, was 1.06 to 1.00 as 726 males and 682 females were collected.

GOLDEYE OF THE YEAR

A total of 472 goldeye of the year was taken in seine hauls along the Saskatchewan River and in certain of its tributaries. The total lengths in millimeters of these specimens were obtained

but the weight was not recorded since a suitable balance was not available in the field.

The lengths ranged from 46 to 95 millimeters, (table 2) with a grand average of 66.99 millimeters for the total sample. These fish were taken between August 14 and 23 and represent the the growth acquired since the spawning period which probably ranged from late May to early July. The sample from Baptizing Creek had the smallest average length, 63.27 millimeters and a deviation of the mean of .311 followed by McKenzie Creek with an average of 68.53 mm. and deviation of .603, the Saskatchewan River at Big Eddy, 73.02 and 1.256 and Reader's Cutoff with an average of 73.19 and a deviation of 1.249. Only two fish were caught in Big Bend River, both of which were 85 mm. in length.

A significance test was applied to the average lengths of the samples obtained from these different localities and significant differences were proved, (table 3.). The sample from Baptizing Creek differed from that of McKenzie Creek, Reader's Cutoff and the Saskatchewan River at Big Eddy by more than seven times its standard error, while the sample from McKenzie Creek differed from Reader's Cutoff and Big Eddy by more than three times its standard error. Conversely there was no significant difference between the average lengths of the samples from Reader's Cutoff and Big Eddy as the difference between these was only .096 times its standard error.

Some of the difference between the average lengths of the samples from Baptizing Creek and McKenzie Creek when compared with Reader's Cutoff and Big Eddy may be accounted for by date

alone since the former samples were obtained 8 days before the latter. It is impossible at present to state what 8 days growth at this period of the life cycle would represent in millimeters, but it would undoubtedly account for some of the difference. However, the differences noted for Baptizing and McKenzie Creeks themselves cannot be accounted for in this manner and must represent a real difference which is probably related to parent stock, spawning date, available food, temperature and other factors influencing the early growth of the fish.

It is of interest to note that the populations at Baptizing Creek, McKenzie Creek and Big Bend River were isolated in that they were retained behind control dams which prevented their exit into the Saskatchewan River. The samples from these localities in turn showed the greatest differences in average lengths. On the other hand the population in Reader's Cutoff was free to move into the Saskatchewan River at all times as there was no dam in this stream. The sample from this stream and the Saskatchewan River proper at Big Eddy were found not to vary significantly.

RATE OF GROWTH

A total of 163 goldeye, excluding fish of the year, were obtained in the Saskatchewan River and its tributaries between August 11 and 23. Total length measurements from the tip of the snout to fork of the tail and weight of the specimens were recorded in the field. The scale samples were analyzed and the ages recorded in this report represent the number of completed annuli.

The rate of growth data are summarized in table 4.

This sample ranged in age from 1 year, with an average length of 6.28 inches and weight of 1.74 ounces, to 7 years, with a length of 14.50 inches and weight of 23.00 ounces. The length increases rapidly up to the end of the third year, when an average length of 10.58 inches is attained, and thence increases more slowly. The weight also increases rapidly up to the end of the third year, when an average weight of 8.86 ounces is reached and continues to increase at about the same rate in the older year classes. Male individuals are shorter and weigh less than females in every age class.

The number of fish, 1 year old or older, obtained from the separate localities in the Saskatchewan River drainage was small and have not been considered separately in connection with the respective rates of growth. However, the same trend was indicated in every instance as was found in analysis of the populations of goldeye of the year. Thus, the Baptizing Creek fish were shorter and lighter for each year class than those from McKenzie Creek and both of these samples were smaller and lighter than corresponding age classes from Reader's Cutoff and the Saskatchewan River proper.

It has not been possible, up to the present time, to determine the ages of the specimens from other localities, because of the lack of optical equipment. The length and weight-frequency distribution of goldeye from these localities are summarized in tables 5 and 6.

AGE AT MATURITY

It is difficult to state the age at which maturity is reached at present since so few adult fish were taken in the Saskatchewan River and age determinations have not been made of the remaining specimens. Further, a certain amount of indecision still remains regarding the nature of the mature female gonad. However, all the males belonging to the two-year class were immature while 4 of the 15 three-year-males and all the four-year olds were mature. The mature three-year olds averaged 11.12 inches and 10.50 ounces while the immature males of the same year class averaged 10.48 inches and 8.45 ounces. The four-year old males averaged 11.50 inches and 12.30 ounces. From these data it would appear that some males mature during their third year and the remainder during their fourth year. No statement of the age at which females become mature can be made at this time, but the data seem to indicate later maturity for females than males.

FOOD

The stomach contents of approximately 300 goldeye, of various sizes and from scattered localities, were preserved and will be analyzed when optical equipment is available. From casual observation in the field, it was apparent that invertebrates form the bulk of the food consumed although fish were eaten on occasion. Goldeye are bottom and surface feeders. During July and August, the water surface broke constantly in the early evening as the fish rose to the surface to take ovipositing aquatic insects. The

stomachs at this time were packed with adults of mayflies, mostly of the genus Hexagenia.

PREDATORS

Analyses of the stomach contents of jackfish, pickerel, sauger and perch were made at intervals from June 19 to July 10 at the Red Deer River to determine if any of these species were preying on goldeye. Although fish constituted the most important food item, from the standpoint of percentage volume, in all these species, no recognizable remains of goldeye were found, (table 7).

Goldeye of the year were found in the stomachs of 4 jackfish out of 60 examined from Baptizing and McKenzie Creeks. Behind the control dams in these streams the water boiled with the activity of jackfish and groups of small goldeye would leap clear of the water as the jackfish struck. One 23 inch jackfish was caught in a 1½-inch mesh gill net, with a 7½-inch goldeye in its mouth. It appeared that the goldeye had been gilled in the net and that the jackfish became entangled when trying to remove the goldeye. One sauger stomach out of 25 examined contained goldeye of the year.

Although no cormorants were obtained to study for gold-eye predation it was learned from a local trapper of the McKenzie Creek area, that these birds often regurgitate young goldeye when shot. Pelicans were actively feeding in the vicinity of the nets set in the Red Deer River but it is not known whether they were taking goldeye or other species as food.

FURTHER WORK

Several samples of goldeye should be procured during the winter months of 1945-46, from the vicinity of the Red Deer River where the most extensive netting programme was carried on during the summer, in order to compare the nature of the female gonads with those already observed. If gonads, of what appear to be mature fish, can be separated into two groups on the basis of egg size throughout this period, some light will be thrown on the possibility of the existence of a two-year spawning cycle.

It is planned to visit the spawning grounds in the Saskatchewan River drainage at break-up, during the spring of 1946, to determine the exact spawning period, nature of the spawning grounds and to learn something of the spawning act itself, if possible. Continued netting and seining in the area will be carried on to increase the data on hand related to the early life history and general ecological requirements of goldeye.

Table 1. Summary of the physico-chemical characteristics of certain waters visited during the goldeye investigation of 1945.

Locality	Date	Bottom	Depth (ft.)	Time C.D.T.	Temp. °C.	Turb- idity	pH ²	SO ₄ P.P.M.	Cl. P.P.M.
¹ Red Deer River (mouth)	June 23	Muck	5	1400		15			
¹ Red Deer River (south)	July 19	Muck	5	1400	22.2	50	7.6	100	T ³
¹ Red Deer Lake (east end)	July 24	Muck	6	1600	22.7	100	7.6	100	T
¹ Red Deer Lake (west end)	July 27	Muck	4	1300	22.0	15	7.6	T	T
¹ Red Deer River (west of lake)	July 27	Muck	8	1200	21.7	5	7.6	100	T
¹ Steeprock River	Aug. 1	Gravel	3	0900	19.0	5	7.6	T	50
¹ Shoal River	Aug. 3	Sand	7	1700	20.9				
Bell River	Aug. 3	Gravel	3	2015	21.0	5	7.6	T	50
Overflowing River	Aug. 5	Gravel	4	1630		5	7.6	T	T
¹ McKenzie Creek	Aug. 18	Muck	10	1030	20.8	15	7.6	0	0
¹ Baptizing Creek	Aug. 18	Muck	8	0945	22.0	5	7.6	0	0
¹ Saskatchewan River (Pine Bluff)"	"	Sand	15	1040	22.0	50	7.6	0	0
¹ Reader's Cutoff	Aug. 23	Sand	7	1400	16.5	25	7.6	0	0
Carrot River	Aug. 24	Muck	8	1030	18.3	15	7.6	0	0
Pasquia River	Aug. 24	Muck	10	1130	17.0	15	7.6	50	50

¹ Indicates presence of goldeye.

² pH comparator only recorded to 7.16 and all samples, except that from the Pasquia River, had a pH value greater than this figure.

³ T represents Trace.

Table 2. The length range and average length of 472 goldeye of the year taken from August 14 to 23 in the Saskatchewan River and its tributaries.

Locality	Date	Number of fish	Minimum length	Maximum length	Average length	Deviation of mean
Baptizing Creek	Aug. 14 & 15	235	52 mm.	74 mm.	63.27	.311
McKenzie Creek	Aug. 15	131	53	82	68.53	.603
Big Eddy Saskatchewan River	Aug. 23	41	55	87	73.02	1.256
Render 's Cutoff	Aug. 23	63	46	95	73.19	1.256
Big Bend River	Aug. 23	2	85	85	85.00	--
TOTAL		472		Grand average	66.99	

Table 3. The significance of the comparisons of samples of goldeye of the year from scattered localities along the Saskatchewan River.

Baptizing vs. McKenzie	Difference is 7.74 times its standard error.
Baptizing vs. Reader's	Difference is 7.69 times its standard error.
Baptizing vs. Big Eddy	Difference is 7.50 times its standard error.
McKenzie vs. Reader's	Difference is 3.35 times its standard error.
McKenzie vs. Big Eddy	Difference is 3.23 times its standard error.
Reader's vs. Big Eddy	Difference is .096 times its standard error.

Big Bend is not used in the comparisons because of the smallness of the sample.

Table 4. The average total length and weight according to age of 163 goldeye taken from August 11 to 23, 1945, at scattered localities along the Saskatchewan River drainage.

Age	Number of specimens	Average length	Average weight
1	63	6.28	1.74
2	19	8.64	4.61
3	29	10.58	8.86
4	18	11.58	12.44
5	22	12.43	16.09
6	11	12.86	17.27
7	1	14.50	23.00

Table 5. Length-frequency distribution of goldeye taken between June 16 and August 5, 1945, in scattered localities of the Dawson Bay area of Lake Winnipegosis.
Number of specimens

Total length (inches)	Dawson Bay	Red Deer River	Red Deer Lake	Steepprock Bay and River	Shoal River
4 - 4 $\frac{1}{2}$					
5 - 5 $\frac{1}{2}$	1	-	-	-	-
6 - 6 $\frac{1}{2}$	1	-	1	3	-
7 - 7 $\frac{1}{2}$	7	5	2	1	-
8 - 8 $\frac{1}{2}$	27	40	2	23	-
9 - 9 $\frac{1}{2}$	9	18	7	13	1
10 - 10 $\frac{1}{2}$	6	94	7	16	7
11 - 11 $\frac{1}{2}$	26	188	9	41	7
12 - 12 $\frac{1}{2}$	123	304	32	88	20
13 - 13 $\frac{1}{2}$	34	36	5	38	3
14 - 14 $\frac{1}{2}$					
TOTAL	234	685	65	223	38

Table 6. Weight frequency distribution of goldeye taken between June 16 and August 5, 1945, in scattered localities of the Dawson Bay area of Lake Winnipegosis.

Weight (ounces)	Number of specimens				
	Dawson Bay	Red Deer River	Red Deer Lake	Steepprock Bay and River	Shoal River
1	2	-	-	-	-
2	5	5	1	2	-
3	18	10	2	1	-
4	12	37	-	7	-
5	6	10	5	20	1
6	2	3	1	10	1
7	2	17	4	-	-
8	5	58	3	3	1
9	1	49	2	10	3
10	10	96	3	11	4
11	20	113	2	4	1
12	27	101	6	14	5
13	15	62	6	21	5
14	17	50	11	21	4
15	29	33	6	23	4
16	34	29	9	18	4
17	11	10	1	13	4
18	14	-	2	15	-
19	4	2	1	13	-
20				14	1
21				2	
22				1	
TOTAL	235	685	65	223	38

Table 7. Summary of the food of certain fishes from the Red Deer River taken between June 19 and July 10, 1945.

Species	Jackfish	Pickereel	Sauger	Perch
Number of stomachs examined	28	68	80	78
Number of stomachs with food	16	14	51	41
Percentage of stomachs void	42.9	79.4	36.3	47.4
Length range of fish examined	12½-20½	6½-21½	9-16½	5½-12½
Average length of fish examined	17.24	11.99	12.28	8.87
Weight range of fish examined, (ounces)	10-35	1-64	4-25	1-14
Average weight of fish examined	21.89	12.22	11.47	6.41

Food	No.	%	No.	%	No.	%	No.	%
	Stom.	Vol.	Stom.	Vol.	Stom.	Vol.	Stom.	Vol.
Spot-tail minnow	2	17.8	-	-	12	33.2	1	16.5
Perch	3	16.8	2	14.2	3	2.4	3	7.5
Log perch	2	26.2	-	-	12	23.9	-	-
9 spine stickleback	2	3.1	1	2.8	-	-	10	27.1
Sucker	2	8.8	1	45.6	1	3.6	-	-
Fish remains	10	21.0	8	36.2	27	36.9	6	15.8
Total fish	16	93.7	11	98.8	51	100.0	17	66.9
Mayfly nymphs	-	-	1	T	-	-	6	1.1
Damsel fly nymphs	-	-	2	0.6	-	-	-	-
Caddis fly larvae	-	-	-	-	-	-	11	8.8
Backswimmers (adult)	-	-	-	-	-	-	2	T
Total Insects	-	-	2	0.6	-	-	17	9.9
Scuds	-	-	1	0.6	-	-	13	6.0
Crayfish	-	-	-	-	-	-	3	17.0
Total Crustacea	-	-	1	0.6	-	-	16	23.0
Hydracarina	-	-	-	-	-	-	1	0.2
Eggs (fish?)	-	-	-	-	-	-	1	T
Debris	1	6.3	-	-	-	-	-	-
TOTAL		100.0		100.0		100.0		100.0

Figure 1. Map showing the localities in which goldeye were obtained from June 17 to August 23, 1945.

Saskatchewan River area

- (1) Reader's Cutoff
- (2) Big Eddy, Saskatchewan River
- (3) Pine Bluff, Saskatchewan River
- (4) Baptizing Creek
- (5) McKenzie Creek

Dawson Bay area

- (6) Red Deer River (west)
- (7) Red Deer Lake (west)
- (8) Red Deer Lake (east)
- (9) Red Deer River (mouth)
- (10) Steeprock River
- (11) Shoal River
- (12) Dawson Bay

