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THE UNIVERSITY OF MANITOBA

VARIATIONS IN ABUNDANCE OF WALLEYES, STIZOSTEDION VITREUM VITREUM (MITCHILL), IN CEDAR AND MOOSE LAKES, MANITOBA

590

A Thesis

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ABSTRACT

During the summers of 1962 to 1964, experimental gill netting was conducted in Cedar and Moose Lakes, Manitoba. The age structure of walleyes caught in 9.5 and 10.8 cm experimental nets was examined to determine relative strengths of year classes in both populations. Age compositions of additional samples from the commercial fisheries on both lakes were also examined. Year classes were ranked in order of relative frequency of occurrence in the experimental catches.

Estimates of year class strength for each population were correlated with annual fluctuations in walleye catches of the commercial fisheries six years after hatching.

Strengths of year classes in Cedar and Moose Lakes were positively correlated with spring discharges from the Saskatchewan River during the first year of life of the year classes. This relationship was best for Cedar Lake walleyes in June and for Moose Lake walleyes in April. The manner in which high discharges may have promoted the success of walleye year classes is discussed.

The future abundance of Cedar and Moose Lakes walleyes might be predicted on the basis of observations of spring discharges from the Saskatchewan River. Such information would permit effective management of the commercial walleye fisheries on these lakes.

INTRODUCTION

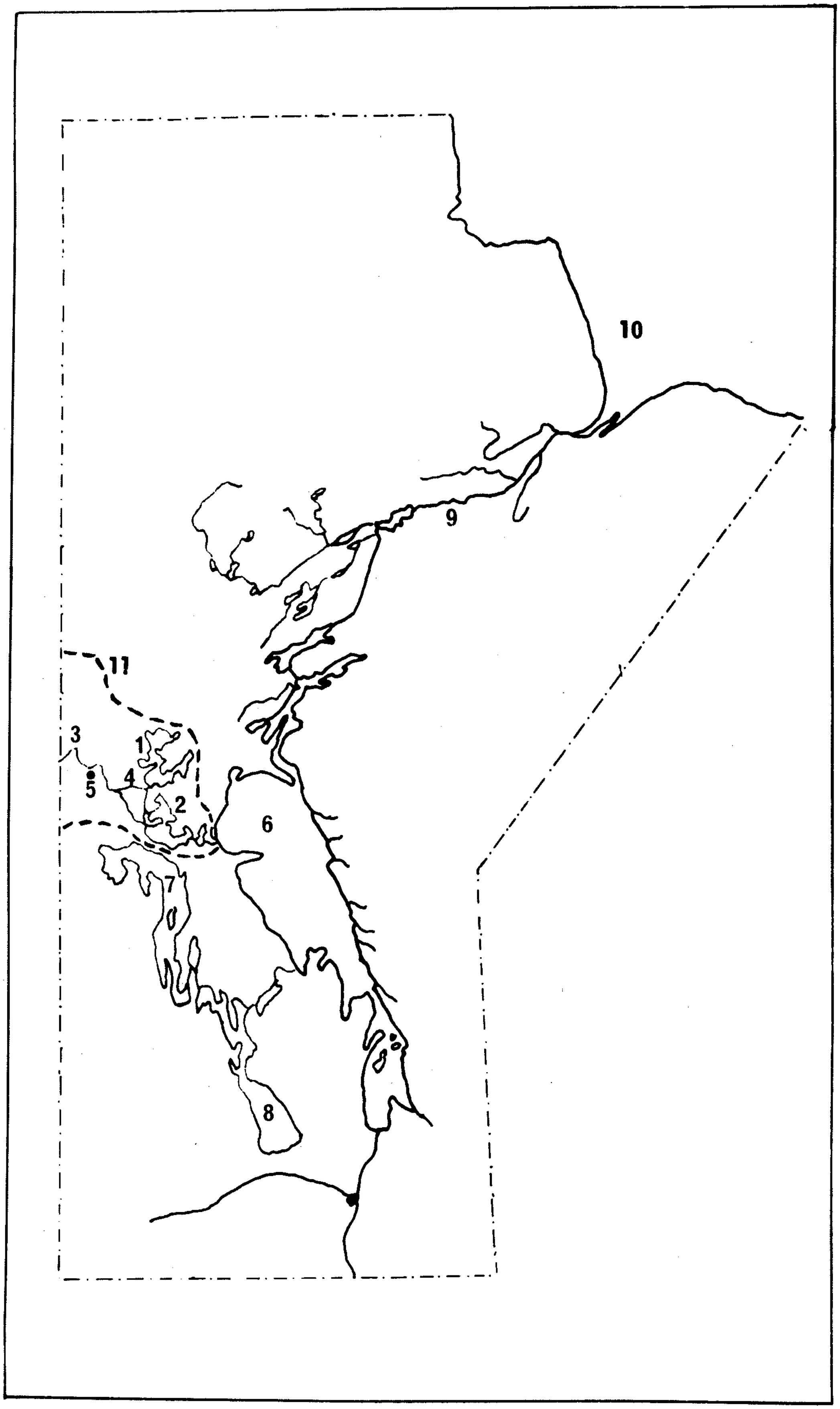
Cedar Lake and Moose Lake are located in west-central Manitoba (see Fig. 1). Each support a major commercial gill net fishery during the summer and winter seasons. The walleye (Stizostedion vitreum vitreum (Mitchill)) constitutes approximately 50 percent of the cash value of commercial catches and is the most important commercial species in each fishery (Anon., 1961). Some other species contributing to the fishery and of secondary importance are sauger (S. canadense), lake whitefish (Coregonus clupeaformis), pike (Esox lucius), goldeye (Hiodon alosoides), ciscoes (Coregonus spp), and some suckers (Catostomus and Moxostoma spp).

A biological survey was made in the summer months of 1962 to 1964 inclusive with the intent of assessing the productive capacity of the two lakes prior to their inundation caused by the construction of a hydro-electric power dam at Grand Rapids, Manitoba. As part of the general survey, experimental gill net catches of the above species and others were made. Data regarding walleyes in these experimental catches were employed in the present study.

Pronounced variations in catches of various fish species are common for freshwater commercial fisheries (Hile, 1937; Hile et al, 1953; Smith and Krefting, 1954; and Pycha, 1961). Frequently such variations are caused by fluctuations in the strength of individual year classes of fish recruited into the fishery during a given year. Consequently, annual fluctuations in the magnitude of commercial

FIGURE 1. Map of the province of Manitoba showing Cedar and Moose Lakes, the Saskatchewan River Drainage Basin and other associated drainage systems.

1. Moose Lake
2. Cedar Lake
3. Saskatchewan River
4. Summerberry River
5. The Pas
6. Lake Winnipeg
7. Lake Winnipegosis
8. Lake Manitoba
9. Nelson River
10. Hudson Bay
11. Eastern end of Saskatchewan River Drainage Basin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catches may depend upon factors other than exploitation. In some cases, however, intense exploitation may sufficiently deplete spawning stocks and thereby reduce the abundance of subsequent progeny entering a fishery. Most previous investigations into conditions affecting the strength of year classes in fish populations have emphasized environmental factors prevalent during the spawning, incubation and fry stages (Hile, 1941; Miller, 1952; Smith and Pycha, 1960; Johnson, 1961; Franklin and Smith, 1963; Lawler, 1965; Forney, 1966; and others).

In this study, fluctuations in year class strengths of walleyes in Cedar and Moose Lakes will be described. Although data on year class strengths and environmental conditions were insufficient to consider all factors which may have been related to fluctuations in walleye abundance, the relationship of discharge from the Saskatchewan River (which is connected to both lakes) to year class strengths will be considered. Finally, results will be related to the success of commercial fishing on each lake.

Growth data on the walleyes in both lakes were also examined. Information obtained from this examination, however, was not directly pertinent to the principal objective of the study which was the description of fluctuations in walleye abundance in Cedar and Moose Lakes and the relationship of these fluctuations to discharge. Since growth data were examined to contrast growth rates of walleyes in both populations, analyses of growth rates have been presented in Appendix B.

LITERATURE REVIEW

The effective management of any commercial or game fish species depends upon a thorough knowledge of its life history. Because of its abundance and importance both as a commercial and game species, most aspects of the walleye's life history have been studied and documented in the literature. A survey of some of this literature is presented below.

The walleye, a spring spawner, usually spawns in April and early May or when water temperatures have risen above 4.5 C. There is considerable evidence suggesting that walleyes exhibit a homing tendency during the spawning season and that there is little intermingling of these spawning populations. That walleyes will seek out previously used spawning areas in preference to other suitable areas has been noted by such North American investigators as Stoudt and Eddy (1939), Eschmeyer (1950), Smith et al (1952), Rawson 1957a) and Forney (1963). This homing behaviour and the lack of intermingling of spawning stocks has also been observed for a similar European species of percid (*Lucioperca* sp) in Lake Vänern, Sweden, by Puke (1951). Crowe (1962) examined and found a similar behaviour in spawning walleyes of northern Green Bay, Lake Michigan. Olson and Scidmore (1962), conducting a more intensive investigation on Many Point Lake, Minnesota, concluded "... that the return of some walleyes to the same spawning site is of a non-random nature" and "... that this return is most likely a homing behavior". Extensive intermingling of walleyes on spawning areas has been observed by Whitney, cited by Olson and

Scidmore (1962), in Clear Lake, Iowa. Here, however, it is important to point out that spawning areas were separated by less than 2 miles, whereas in other studies they were separated by greater distances.

Male walleyes are first to arrive on the spawning grounds, and even after the females arrive, predominate in the spawning run. Spawning occurs in streams, along wave - washed shores of lakes, or over shoals, and generally in water less than one meter deep. The variety of substrates over which a number of investigators have observed walleye spawning is listed by Eschmeyer (1950). It would appear from this review that the preferred substrate is a gravel-rubble bottom with a good flow or circulation of water. Eschmeyer also made observations on the nocturnal spawning behaviour of walleyes. A more detailed study of the walleye's spawning behaviour has been made by Ellis and Giles (1965). Eschmeyer (1950) further determined egg production in walleyes and discussed the mortality of spawned eggs. Other studies regarding mortality in walleye eggs are those by Johnson (1961), who examined the survival of naturally spawned eggs on five different substrates, and Smith and Kramer (1963), who determined the effects of pulp mill effluents on walleye eggs.

According to Eschmeyer (1950) and Rawson (1957a), males are last to leave the spawning sites. Rawson (1957a) observed that in the post-spawning movement, walleyes moved back into Lac la Ronge, but they concentrated inshore near the stream in which they had spawned. In July, he found they were moving into deeper waters and scattering, thus intermingling with fish from other spawning runs. By August a 1:1 sex ratio was restored in the lake. The wide dispersion and intermingling of runs following spawning has also been observed in walleye populations studied by Stoudt and Eddy (1939), Eschmeyer (1950), Smith et al (1952), Crowe (1962), Olson and Scidmore (1962), and Crowe et al (1963). Forney (1963) closely examined the dispersion of three spawning runs of Oneida Lake walleyes and from his study concluded that no random mixing of these spawning populations occurred in late summer.

The above tagging studies among others have shown that walleyes will move extensively and are capable of migrating great distances. Doan (1942) found that one tagged walleye in Lake Erie had travelled about 200 miles before being recaptured. Wolfert (1963), studying the movement of walleyes tagged as yearlings in the same lake, noted that 10 fish (2 percent of the total recaptures in 3 years) had travelled over 110 miles. One of these fish was recaptured in Saginaw Bay, Lake Huron, 236 miles from its point of release. Tagged walleyes released above dams will frequently be recaptured below them (Eschmeyer, 1950 and Desrochers, 1953). Migrations over great distances are exceptions, however, since only a few such "wandering" walleyes are captured. Average distances travelled by walleyes appears to be less than 50 miles.

With regard to the bathymetric distribution of walleyes, Deason (1933) stated that they were infrequently taken in appreciable numbers from water deeper than 8 fathoms (15 m). Hile and Juday (1941), in an investigation of the depth distribution for fishes in northeastern Wisconsin lakes, found walleyes to be abundant at 7 m in one thermally stratified lake. In another lake, they captured walleyes at all depths at which ciscoes occurred. The ciscoes were gill netted in water as shallow as 8 m, but were most prevalent below the thermocline at depths between 15 and 25 m. Rawson (1957a) observed that the average depth at which most Lac la Ronge walleyes were captured during the whole summer was less than 15 m. In August, however, the fish had moved into water 15 to 20 m deep. He attributed this movement to the walleye's pursuit of its "favorite" food item, ciscoes, which, during August, were abundant at similar depths. During the winter, Rawson further noted that walleyes inhabited the shallow bay areas of the lake. As to the daily activity patterns of walleyes, they are known to be most active during dusk and dawn when they are feeding inshore (Carlander and Cleary, 1949).

Upon hatching, walleye fry leave the spawning grounds for open water where they lead a pelagic existence until about mid-summer (Eschmeyer, 1950; Forney, 1966; and Houde, 1967). By mid-summer, when they have reached a length of approximately 30 mm (about 1 to 2 inches), the fry begin moving inshore and may be found in areas less than one meter deep. Both Raney and Lachner (1942) and Eschmeyer (1950) have observed that young walleyes school in shallow weedy areas in July and as summer progresses move gradually into deeper water. By September, young walleyes are no longer inshore.

The food habits of walleyes have received attention from numerous researchers. Most authors concerned with first-year growth made quantitative studies on the feeding habits of walleye fry. Another investigation pertaining to food of first-year walleyes is that by

Wolfert (1964). A recent study by Houde (1967) examines feeding and food selection of larval walleyes during their first six weeks of life. Results obtained by these studies illustrate the diversity of animal species which constitute the diet of young walleyes. In general, however, walleyes in the early stages of life tend to feed mostly on crustacean plankton and convert later to a diet of insects and finally fish, although variability occurs in the time at which fish become predominant in the diet.

Quantitative observations on feeding habits of sub-adult and adult walleyes have been made by Eschmeyer (1950), Rawson (1957b), Priegal (1963), Fedoruk (1966), and others. Other workers have given descriptive accounts of the walleye's feeding habits (Clemens et al, 1923 and 1924; Doan, 1942; Mendis, 1956; Rawson and Atton, 1953; Rawson, 1957a, 1959, 1960; Niemuth et al, 1962; and Reed, 1962). Seaburg and Moyle (1964) briefly mention digestive rates in walleyes. A review of the variety of organisms which were found to be utilized as food by walleyes is given by Eschmeyer (1950).

Of the many studies which have been conducted on the biology of the walleye, a large number have considered the growth of the fish. Although earlier biologists had made brief observations on walleye growth, it appears that the more intensive growth studies, i.e. those employing the scales to determine age, were first done on Great Lakes' walleyes (Adamstone, 1922; Hart, 1928; and Deason, 1933). Most investigations concerning growth in walleye populations have been in the USA (Schloemer and Lorch, 1942; Carlander, 1945 and 1948; Cleary, 1949;

Stroud, 1949; Eschmeyer, 1950; Patterson, 1953; Hile, 1954; Carlander and Whitney, 1961; Smith and Pycha, 1961; and Forney, 1965). In central Canada, very few detailed works have been done on the walleye's growth. One of the more noteworthy studies on growth of walleyes in central Canada was that made by Rawson (1957a) on walleyes of Lac la Ronge, Saskatchewan. Some surveys of commercially exploited lakes in northern Saskatchewan have included observations on walleye growth (Rawson and Atton, 1953; Mendis, 1956; and Rawson, 1957b, 1959, and 1960). Reed (1962) recorded some growth data for walleyes in the Saskatchewan River in Saskatchewan. Bajkov (1930) listed data which he states were representative of the average growth of walleyes in the prairie provinces. Kennedy (1948 and 1949) examined the growth of walleyes in Lake Manitoba. Two other studies, by Newton (1935) and Fedoruk (1961), have been conducted on walleyes occurring in Manitoba. Findings of the above authors, among other, point to the tremendous variability in growth rates for walleyes of different populations. This population variability is extensively documented by Carlander (1948) and Eschmeyer (1950). In general, growth rates of walleyes decreased as populations occurred farther northward. Deviations from this trend were noted and were probably caused by variations in habitat, food, and inter-relationships of the walleye with other fish species. It has also been observed that commercial exploitation can influence walleye growth (Kennedy, 1948).

Growth of young-of-the-year walleyes has been specifically examined by some authors. The first extensive study of this nature was done by Raney and Lachner (1942) on Oneida Lake. Eschmeyer (1950) also considered first-year growth in walleyes of Lake Gogebic, Michigan. Time of spawning and hatching, size of brood, water temperature, abundance of predators, and food organisms, particularly young yellow perch, all affect the first-year growth of walleyes (Dobie, 1956; Forney, 1966; Maloney and Johnson, 1957; Smith and Moyle, 1945; and Smith and Pycha, 1960).

Relatively little research on the biology of walleyes or other fish species occurring in Cedar Lake and Moose Lake has been done previous to the present study. In 1961, personnel from the Fisheries Branch, Department of Mines and Natural Resources, Province of Manitoba, conducted a tagging program on the more important commercial fish species in Cedar Lake and Moose Lake to determine rates of exploitation, and the degree of fish movement within and between the two lakes and adjacent waters. It was observed that walleyes in both lakes, in comparison to the other fish species, were subjected to the highest rate of commercial exploitation. Results of the study further indicated that Moose Lake walleyes remained in the lake, whereas recoveries of walleyes tagged in Cedar Lake shortly after the spawning season were made in both Lake Winnipeg and the Saskatchewan River (L.A. Sunde, personal communication). Walleyes in Cedar Lake therefore may not be a discrete population. Fisheries Branch personnel have also taken periodic samples of the commercial catches from both lakes.

Other biological investigations not specifically dealing with fish have been made on Cedar Lake and Moose Lake. In 1960, biologists from the U.S. Fish and Wildlife Service with assistance from provincial biologists briefly surveyed the fish resources, as well as wildlife resources, of the area (Anon., 1961). Webb (1965) studied limnology and benthic production of the southern basin of Cedar Lake in 1962.

DESCRIPTION OF THE AREA

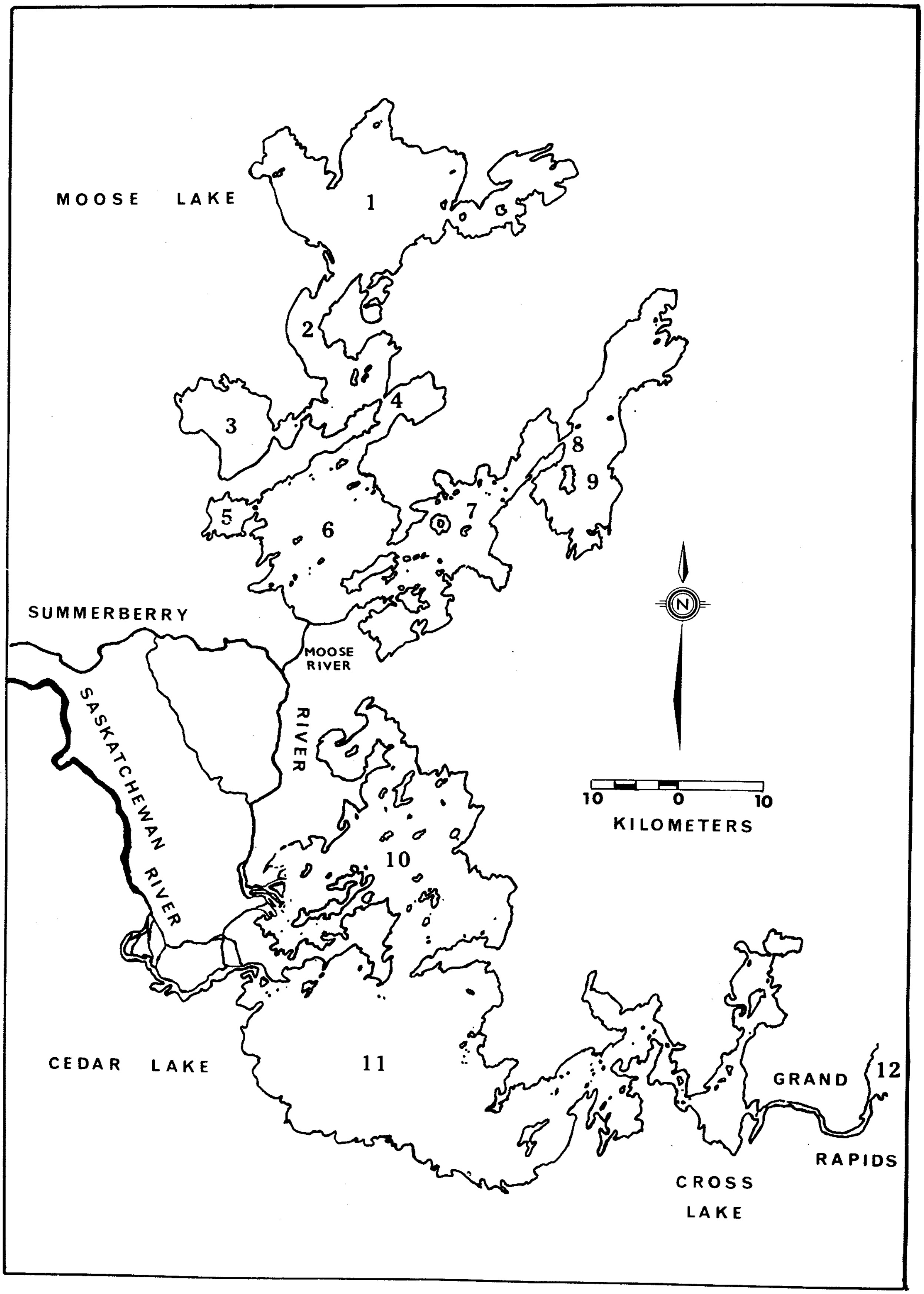
Cedar Lake and Moose Lake lie in the west-central part of Manitoba near the extreme eastern end of the Saskatchewan River Drainage Basin (Fig. 1). At The Pas, the Saskatchewan River breaks through a glacial end moraine, The Pas Moraine, and in the Summerberry Marsh gives off a major channel, the Summerberry River. These two rivers drain into Lake Winnipeg via Cedar Lake, Cross Lake, and the Grand Rapids. Both lakes border the eastern edge of the Summerberry Marsh.

Cedar Lake (53° 15'N, 100° 15'W) is located in the Interlake - Westlake Plain. This region consists of Silurian dolomite most of which is overlaid by calcareous glacial till. Most of Moose Lake (54° 00'N, 100° 10'W), north of Cedar Lake, lies within the Saskatchewan Delta. This is the largest lake in the area. The southwestern edge of the lake encroaches upon the Interlake-Westlake Plain. The Saskatchewan Delta contains alluvial clay deposits which cover Ordovician limestone. Relief of the terrain in both these regions is slight (Weir, 1960).

Cedar Lake has an area of 129,499 hectares (Anon., 1961) and is divided into two sections; a shallow north arm, and a deeper main basin (Fig. 2). Average depth of the north arm is about 3 m while its maximum depth is 5.5 m (Webb, 1965). It is shallowest at the outlet of the Summerberry River. The main basin has a mean depth of 5.8 m. At the shallow west end, the main basin of Cedar Lake receives the Saskatchewan River. From here the bottom slopes gradually to a maximum depth of 10 m near the west end of the basin (Webb, 1965). The main basin

FIGURE 2. Map of Cedar and Moose Lakes showing their general features.

1. North Arm of Moose Lake
2. Burntwood Channel
3. Opuskow Bay
4. North Arm Narrows
5. Crossing Bay
6. Big Wave Bay
7. Pickerel Channel
8. East Arm Narrows
9. East Arm of Moose Lake
10. North Cedar Lake
11. South Cedar Lake
12. Lake Winnipeg


MOOSE LAKE
1
2
3
4
5
6
7
8
9
SUMMERBERRY
MOOSE RIVER
RIVER
SASKATCHEWAN RIVER
N
10 0 10
KILOMETERS
10
CEDAR LAKE
11
GRAND
12
RAPIDS
CROSS LAKE

drains into a long arm which in turn discharges into Cross Lake.

Moose Lake, which has an area of 155,804 hectares (Anon., 1961), is broken up into a number of basins. It can be divided into three major units; the North Arm, Big Wave Bay, and the East Arm. These are each separated from one another by a channel and a narrows (Fig. 2). Two larger bays are Opuskow Bay off the south-west end of Burntwood Channel and Crossing Bay off the western edge of Big Wave Bay. Moose River links the Summerberry River to the southwest corner of Big Wave Bay. Direction of flow in Moose River varies in accordance with water levels in the lake and the Summerberry River. A number of smaller streams, which drain surrounding marshes, flow into Moose Lake, The East Arm, which is the deepest part of the lake, has a maximum depth of 19.8 m. Big Wave Bay has a fairly uniform depth of 6.1 m, but is shallow near the mouth of Moose River. Pickerel Channel, joining Big Wave Bay to the East Arm, has a maximum depth of 12 m midway between the two basins. The North Arm, Burntwood Channel, and Opuskow Bay are very shallow. Maximum depth of the North Arm is 4.3 m. Average depth of the Opuskow Bay - Burntwood Channel area is approximately 2 m.

The ice-free period for both lakes generally extends from mid-May to November. From the time of break-up on Cedar Lake in 1962, surface water temperatures rose to a high of about 21 C by July 31 (Webb, 1965). Surface water temperatures of Moose Lake in 1960 were very similar to those of Cedar Lake (Anon., 1961). Dissolved oxygen concentrations in both lakes are high during the summer. Webb (1965) found that the mid-summer oxygen concentration of Cedar Lake in 1962 was about 90 percent of the air saturation value. No summer stratification of temperature or oxygen content occurs in either lake because of thorough mixing brought about by the wind. Rooted aquatic vegetation is abundant in sheltered areas, particularly in the shallow northern portions of each lake. Exposed shorelines of both lakes are subject to severe wave action and consequently each lake has beaches of coarse gravel, limestone slabs, and boulders.

Webb (1965) classified Cedar Lake as a eutrophic lake. Since the topography surrounding Cedar Lake and Moose Lake is similar, it is expected that both lakes would have a similar trophic nature; however, parts of Moose Lake, i.e. the northern end of Pickerel Channel and the East Arm, have been classed as oligotrophic (Anon., 1961).

COLLECTION OF DATA AND METHODS

The biological survey conducted during the summers of 1962 to 1964 consisted of two phases; a systematic study of the limnology of each lake, and a program of experimental gill net fishing. In 1962, the survey was concentrated on Cedar Lake, while in 1963, it was moved to Moose Lake. During the summer of 1964, each lake was surveyed for alternating bi-weekly periods. The data utilized for the age and growth study of walleyes were extracted from these annual surveys.

Experimental Gill Netting

Gill nets employed in the survey were constructed of white woven-nylon webbing. Mesh sizes ranging from 3.8 to 13.3 cm (stretched measure) were used in the experimental gangs. Composition of the gangs varied with respect to the number, length and mesh size of the nets. Most nets were 45.7 m in length. Nets were joined, in order of increasing mesh size, by a sideline in a bridle or halter-like arrangement. This method of joining left a space of about 5 m between nets. Often additional sections of net (91.4 m) were set nearby the experimental gang. Catches from these additional nets were added to the catch from the same mesh size nets included in the experimental gang. In 1964, some of the sets were made up of only one mesh size. All sets were made on the bottom. Inshore sets were made at right angles to the shoreline with the smallest mesh on the inshore end. The duration of most sets was somewhat less than a day (18 to 20 hr). On occasions nets remained in the water longer. In two instances in

Cedar Lake they were lifted after two days. In one of these two day sets, the additional nets were removed after one day while the experimental gang was left for two days. The nets could not be lifted after a specific length of time because bad weather often hampered lifting the nets. No record was kept of the exact time each set lasted. Details of each net set are given in Tables A-I and A-II of Appendix A.

Twenty-five net sets were made in Cedar Lake of which four were made in 1963. Thirty-six sets were made in Moose Lake and three of these sets were made in 1962. Most sets in both lakes were made in areas open to commercial fishing. In 1963 and 1964, a total of fifteen sets were made in the East Arm of Moose Lake, which was then closed to summer fishing. No experimental netting was done in the area north of the North Arm Narrows of Moose Lake, and only four sets were made in the northern section of Cedar Lake.

A total of 1279 walleyes was captured in experimental gill nets; 764 were taken from Cedar Lake and 515 from Moose Lake (see Tables A-III and A-IV). The length-frequency distribution of walleyes captured in each mesh are presented for each lake in Tables A-V and A-VI. Gill nets which most effectively captured walleyes were of mesh sizes 5.1 to 10.8 cm (stretched measure).

Commercial Catch Samples

During the study period, commercial catches of walleyes from both lakes were poorly sampled. In June, 1962, 198 walleyes were sampled from the catches of two commercial fishermen on Cedar Lake.

Mesh size of the gill nets with which these catches were made was not checked; it was assumed the fishermen were using legal nets. The distribution of fork lengths for walleyes in this sample is given in Table A-VII.

Collection and Preparation of Scales

A scale sample for age determination was taken from each walleye captured in the experimental nets. Scales were removed from the region below the origin of the first dorsal fin and above the lateral line. Scales were placed in marked envelopes and stored for later use.

Impressions were made on cellulose acetate slides of the best four or five scales from each envelope. Scales were usually soaked in water for two or three minutes and then rubbed between the fingers to remove any skin which might have remained on the scales. Cleaned scales were allowed to dry before impressions were made. A roller press similar to the one described by Smith (1954) was used.

Determination of Age

Ages were determined from scale impressions with the aid of a Bausch and Lomb Tri-Simplex micro-projector. The entire scale image of larger scales could be viewed with a 10x objective. A higher objective was used to examine the finer detail of the scale impressions. All scale impressions were aged without reference to the sizes of the fish. More than one scale impression per slide was examined.

The main criterion for identifying true year marks or annuli was the extensive anastomosis of circuli extending into the postero-lateral field (Hile, 1954). Peripheral annuli were hard to recognize as were the first annulus and outer annuli on some scales from older fish. The first annulus was frequently represented by one or two imcomplete circuli. The position of the first annulus on scales of older fish was located by referring to other scales in which it was more distinct. Outer annuli on older scales were close together and could only be separated by close scrutiny of the circuli. In some scales, resorption had occurred along the lateral scale margins and with such scales it was difficult and frequently impossible to locate the outer annuli.

Accessory checks or false annuli were prevalent in most larger scales examined. Recognition of false annuli was based on observations listed for bluegill scales by Sprugel (1954). It is possible that some checks recorded as true annuli in the present study could have been accessory checks. Von Limbach (Bennett, 1948) observed in bluegills the occurrence of accessory checks which did not differ in appearance from typical annual checks. In contrast to this, Buchholz and Carlander (1963) noted in scales of slow growing yellow bass, true annuli with no crossing-over. Therefore, some annuli could have been missed on scales examined in the present study. Another anomaly occurring in ctenoid scales is the failure to form annuli in some years (Bennett, 1948; Regier, 1962; and Buchholz and Carlander, 1963). Forney (1965) observed that a high proportion of walleyes age group V and older, particularly males, did not form annuli in some years. The degree to which the above abnormalities occur will vary among different populations. They did not, however, appear to be a significant source of error in the age determinations of this study as there was good agreement in the calculated lengths of fish within year classes (see Appendix B).

Of the scale impressions from 1279 walleyes caught by experimental netting in Cedar and Moose Lakes, 27 were of regenerated scales and consequently unreadable. No decision concerning age was reached on the first reading of some scales. In other cases conclusions were doubtful and along with the apparently unreadable scales, these were set aside for a second reading. From a total of 343 scales read a second time, no ages were assigned to 34 from each lake. Scale samples of 16 walleyes from Moose Lake were lost.

In this study, the age assigned to a fish was determined by the number of scale annuli. It has been the convention of some authors (Hile, 1954; and Smith and Pycha, 1961) to credit an extra or virtual annulus to the edge of scales from walleyes caught in early spring. At this time scales of most fish would have the broad growth band of the previous year, but they would not as yet have formed a new annulus. Smith and Pycha (1961) have examined the time of annulus formation in walleye scales from Red Lakes, Minnesota, and found that it varied with age and with years of good and poor growth. Failure to recognize the occurrence of late annulus formation, especially on scales from fish caught in spring, can introduce serious errors into age assessments and consequently into estimates of year class strengths and growth rates. Time of annulus formation was therefore examined to determine if the initial method of age determination was correct.

To obtain an estimate of the time of annulus formation, the average calculated increments in fork length attained by each age group during 2-week intervals were determined for the 1962 experimental catch sample of walleyes from Cedar Lake (Table I). Although a similar analysis was made on the 1963 Moose Lake sample, only the data for Cedar Lake have been presented. Some age groups in the Moose Lake population were inadequately represented when data were arranged in the above manner. The method used to determine the calculated fork lengths from which calculated increments were derived is outlined in Appendix B.

TABLE I. The average increase in fork length (in mm) attained during 2-week intervals by 485 Cedar Lake walleyes for the period June 1 - Sept. 6, 1962. The number of fish is given in parentheses.

Period	Age group							
	II	III	IV	V	VI	VII	VIII	IX
June 1 - 14	-	26(1)	23(8)	23(11)	17(23)	14(15)	18(5)	16(2)
June 15 - 28	-	25(1)	38(1)	25(5)	23(20)	16(15)	15(3)	12(2)
June 29 - July 12	-	17(5)	22(3)	24(2)	28(5)	12(4)	8(1)	-
July 13 - 26	23(2)	22(14)	19(6)	12(3)	21(7)	16(10)	9(2)	-
July 27 - Aug. 9	24(3)	23(4)	30(7)	18(6)	23(15)	13(13)	17(2)	-
Aug. 10 - 23	45(9)	36(8)	37(3)	27(15)	22(29)	19(66)	15(19)	17(1)
Aug. 24 - Sept. 6	53(1)	42(2)	41(4)	31(10)	24(32)	21(45)	17(13)	18(2)

Results obtained for Cedar Lake walleyes (Table I) indicate that the new annulus had already formed on scales by the time experimental netting began on June 11, 1962. If the new annulus had not formed, increments for each age group in the period, June 1-14, would have included the previous year's growth and consequently would have been much higher than the increments for the next period, June 15-28. Despite variations in data in Table I, each age group exhibited an increasing trend in the size of increments throughout the summer. These results suggest that annulus formation occurred in most walleyes before the first week of June. Late annulus formation was noted in some cases. Eight walleyes captured from Cedar Lake in 1962 had a newly formed annulus at the scale edge and all but two of these fish were captured after June 30. Although the occurrence of late annulus formation may not have been recognized in some scales, most of the 1962 sample of Cedar Lake walleyes probably had undergone annulus formation before June 1 and gross errors were probably not made in the assignment of ages. It is assumed that time of annulus formation in the Moose Lake walleyes during 1962-1964 and in Cedar Lake walleyes in the two other sample years was the same. Therefore, the ages assigned to all walleyes caught in June and the early part of July were accepted and used in the analyses of year class strength and growth.

Finally, to check the consistency in aging, a random sample of 100 aged scales was chosen. This sample was reread without reference to previously assigned ages. There was no difference between first and second readings of 65 scales in the sample of 100.

In five of the remaining scales, the difference was in the assignment or non-assignment of an annulus near the scale margin. Thirty of the second readings differed in other ways; 26 differed by plus or minus one year, and 4 differed by plus or minus two years. The oldest scale in the sample was nine years old and the two readings for this scale were the same. Results of this test were similar to the findings Carlander (1961) obtained in rereading walleye scales. It was therefore concluded that consistency in aging scales was high enough to accept the assigned ages with confidence.

Age compositions of the walleye catches in each experimental net fished in Cedar and Moose Lakes from 1962 to 1964 inclusive are given in Table A-VIII and Table A-IX. The age composition of the commercial catch sample of walleyes taken from Cedar Lake on June 22 and 23, 1962 is shown in Table A-X. Scale samples were not taken from 26 walleyes in this sample and 12 fish could not be aged.

RELATIVE YEAR CLASS STRENGTHS

Variations in abundance of fish belonging to year classes in a population may have important effects on the success of a fishery. Failure of a year class early in life can result in a subsequent decrease in catch. The strengths of year classes may be determined by comparing the numbers of fish of given ages captured from a population over a series of years. These relative year class strengths then give an indication of the size of year classes in any given year.

Determination of year class strengths of walleyes in Cedar and Moose Lakes was based on the relative strengths of year classes represented in the experimental catches. Estimates of the actual abundance of each age group in the populations could not be made from available data. Examination of relative year class strength was further restricted to fish representative of the commercially exploitable segment of the two populations. Estimates of relative year class strengths were based on catches in two meshes; 9.5 cm and 10.8 cm (stretched measure). These meshes most effectively sampled walleyes representative of commercial catches from both lakes. Catches in these two meshes were also adjusted to a standard catch per unit effort. The unit of effort used was 45.7 m of net fished for one day.

One reason for including catches of the 9.5 cm mesh was that the size range of walleyes captured by this net was very similar to the size range in the 10.8 cm net. Neglecting the few very large and very small walleyes caught in the 10.8 cm nets (see Tables A-V and

A-VI), the range in fork length of walleyes captured by the 9.5 and 10.8 cm nets was approximately 300 to 500 mm. The modal frequency of catches in the 10.8 cm mesh occurred at a larger length and the mean fork length was greater than in the 9.5 cm mesh. Another reason for including catches of the 9.5 cm net was that there was evidence suggesting that gill nets of a smaller than legal mesh size were extensively used in both fisheries. Legal mesh size for both fisheries is 10.8 cm (stretched measure). Judging from the mean fork lengths and distribution of fork lengths in samples taken by L. A. Sunde (unpublished data) from commercial walleye catches for both lakes, the most commonly used illegal mesh appeared to be that of 9.5 cm. The degree to which these illegal nets were used in the commercial fisheries, however, is not known. The age compositions of the combined walleye catches in the 9.5 and 10.8 cm mesh nets were compared with commercial samples. Further details concerning the nature of the commercial catch samples of walleyes will be presented below (see also Tables A-XI to A-XVII, Appendix A).

Percentage age compositions of Cedar Lake walleyes in the combined catches of the 9.5 and 10.8 cm experimental gill nets (adjusted to the standard catch per unit of effort) were determined for the three summer sampling periods, 1962 to 1964 (Table II). Ages of four walleyes were not included in the tabulation of percentage age compositions; these were the two age I fish captured in 1962 and 1964 in the 10.8 cm net, the age XII walleye captured in 1963 in the 9.5 cm net and the single age III walleye taken in 1964 by the 9.5 cm net (Table A-VIII). The age I fish are obviously not representative of the exploitable-sized walleyes, and further, give no indication of the sizes of the year classes from which they came. The one age XII fish provided no information regarding the relative strength of the 1951 year class since no other fish of that brood were taken. The one walleye of age III was omitted since it was the only fish caught in the 9.5 cm net in 1964.

TABLE II. Percentage age composition of Cedar Lake walleyes captured in experimental gill nets with meshes of 9.5 and 10.8 cm (stretched measure) for 1962-1964. Age groups are given in parentheses.

Year Class	Year of capture		
	1962	1963	1964
1952	0.87 (X)	-	-
1953	2.60 (IX)	-	-
1954	13.87 (VIII)	11.11 (IX)	-
1955	49.42 (VII)	30.56 (VIII)	13.89 (IX)
1956	25.72 (VI)	30.56 (VII)	19.41 (VIII)
1957	3.76 (V)	8.33 (VI)	27.78 (VII)
1958	3.18 (IV)	11.11 (V)	27.78 (VI)
1959	0.58 (III)	5.56 (IV)	11.11 (V)
1960	-	2.78 (III)	-
No. of fish examined	194	36	36

The strongest year class of the 9 years represented in experimental catches from Cedar Lake during the three year period was the 1955 year class (Table II). This year class at age VII constituted almost 50 percent of the catch in 9.5 and 10.8 cm nets. (Evidence that the 1955 class was stronger than those of 1956 and 1957 is its percentage contribution to the 1962 experimental catch. Age VII fish in 1962 were relatively more abundant than age VII fish in 1963 (1956 year class) and 1964 (1957 year class).) The 1956 year class was considered to be second in numerical strength since the percentage of fish from this year class at age VIII in 1964 was higher than the 1954 year class at age VIII in 1962. The 1956 year class as age VII fish constituted 30.56 percent of the 1963 catch which was higher than the 1957 year class' contribution of 27.78 percent to the 1964 catch.

The third strongest year class appears to have been the 1954 class. In 1962, this year class as age VIII fish contributed 13.87 percent of the experimental catch. This was about 6 percent below the contribution made by the 1956 year class at the same age to the 1964 catch. At age IX, in 1963, the 1954 class was slightly less abundant than the 1955 year class in 1964. This would suggest that 1954 year class was stronger than the 1956 year class. The possibility that this was the case seems remote, since the percentage representation of the 1956 year class at age VII was almost as large as the 1955 year class at the same age.

The 1958 year class was ranked fourth in relative abundance. Percentages of age VI fish in the experimental catches of 1962 and 1964 at first suggested that the 1958 year class was stronger than the 1956 year class; the age VI fish of the 1958 year class made up 27.78 percent of the 1964 catch, whereas the same age group made up only 25.72 percent of the 1962 catch. It would therefore appear that the 1958 year class was the more abundant in Cedar Lake and should therefore have been ranked as second in size. There were no available data for the 1958 year class at age VII that would clarify its rank with respect to the 1956 year class. The conclusion that it was weaker than the 1956 year class was accepted because the 1956 class was strongly represented by older walleyes (ages VII and VIII). Further, according to the experimental catches, the 1956 year class was apparently stronger than the 1954 year class, which at age IX was nearly as well represented in the 1963 catch as the 1955 year class was in 1964.

The 1957 year class was given a rank of five since its percentage contributions to the 1962 and 1963 catches as age V and VI fish, respectively, were less than those observed for the 1958 year class in 1963 and 1964. A rank of six was given to the 1960 year class because of its greater representation at age III in 1963. The seventh position was assigned to the 1959 year class and the 1953 and 1952 year classes were given the ranks 8 and 9, respectively. Designation of rank to the 1952 and 1953 year classes was arbitrary.

Relative strengths as determined for the various year classes represented in the 9.5 and 10.8 cm experimental nets were nearly identical to results obtained from three different samples of the commercial walleye catches from Cedar Lake. Two of the three commercial catch samples were collected prior to the present study (L. A. Sunde, unpublished data). The first sample, numbering 295 fish, was taken in June and July, 1961. In February, 1962, a total sample of 426 walleyes was taken directly from catches of the commercial fishermen. The third sample of 198 walleyes, which has already been mentioned, was taken on June 22 and 23,1962. Effort used to catch the fish in the samples was unknown; therefore standard catch per unit of effort could not be calculated.

Mean fork lengths of walleyes in the 1961 and 1962 summer samples were 386 mm and 393 mm, respectively. These mean lengths agree more closely to the average fork length of 400 mm noted for the experimental 9.5 cm mesh net than to the average length of walleyes (425 mm) captured by the 10.8 cm mesh gill net. Modal lengths for the two samples were both in the 380 - 400 mm size class. This was approximately the size class interval in which the modal frequency was observed for the distribution of lengths for Cedar Lake walleyes captured by the 9.5 cm mesh net (Table A-V). The distribution of lengths and the average fork length (422 mm) of walleyes in the February sample agreed with the sizes of walleye retained by the experimental 10.8 cm mesh. This indicates that this sample was taken from nets of legal mesh size. However, the differences between commercial and experimental sizes indicate that illegal nets were used during the summer. This suspicion was confirmed by N. Scribe (personal communication) who stated that gill nets with 9.5 cm mesh and smaller are extensively used in the Cedar Lake fishery to pursue the goldeye during the summer season. Use of illegal nets during the summer accounts for the greater frequency of younger walleyes in samples taken in June and July, 1961, and June, 1962.

Percentage age composition of the samples from the commercial walleye catches is presented in Table III. Ages in the three samples were determined by the author. Sub-samples of 120 fish from the June and July, 1961, and February, 1962, samples were randomly chosen for aging. One walleye in each of the two sub-samples was greater than age X. These two fish were omitted from the consideration of age composition. In the June, 1962 sample, scales were collected from only 172 fish and ages were not assigned to 12 of these. Determination of relative year class strength was made in the same fashion as described previously for the experimental gill net catches.

Ranks determined for the 8 year classes represented in the commercial catch samples were as follows:

Year class	1952	1953	1954	1955	1956	1957	1958	1959
Rank	7	8	3	1	2	5	4	6

The two independent estimates of year class strengths were almost identical (note that the 1960 year class was absent in the commercial samples). The only difference between the two estimates was the ranks of the 1952 and 1953 year classes. In the estimate based on experimental catches, the 1952 year class was believed to be weaker than the 1953 year class; the 1952 and 1953 year classes in the experimental catches were assigned the ranks of 9 and 8, respectively. Age compositions of the commercial catch samples suggested that the position of these year classes was the reverse; the 1952 class appeared to be stronger than the 1953 year class since at age group X the percentage representation of the 1952 year class in February, 1962 was greater than that of the 1953 year class as IX-group fish in June, 1962. The 1952 year class was therefore estimated to be stronger than the 1953 class. Relative year class strengths of Cedar Lake walleyes based on consideration of experimental samples and commercial samples were as follows:

Year class	1952	1953	1954	1955	1956	1957	1958	1959	1960
Rank	8	9	3	1	2	5	4	7	6

TABLE III. Percentage age compositions of three samples of Cedar Lake walleyes taken from the commercial fishery. Age groups are given in parentheses.

Year class	Date of capture		
	June, July - 1961	February - 1962	June 22, 23 - 1962
1952	-	0.85 (X)	-
1953	2.52 (VIII)	2.52 (IX)	0.62 (IX)
1954	7.56 (VII)	23.53 (VIII)	1.88 (VIII)
1955	46.22 (VI)	59.66 (VII)	15.62 (VII)
1956	39.50 (V)	13.45 (VI)	34.38 (VI)
1957	3.36 (IV)	-	37.50 (V)
1958	0.84 (III)	-	9.38 (IV)
1959	-	-	0.62 (III)
No. of fish examined	119	119	160

The percentage age compositions of the 1962 to 1964 summer samples of Moose Lake walleyes caught by the 9.5 and 10.8 cm mesh nets (adjusted to the standard catch per unit of effort) are presented in Table IV. In determining these percentages, three age groups were not considered because of inadequate representation. These age groups were: age group I represented by one fish in 1962 and age groups II and III each represented by one fish in 1964 (Table A-IX). The same rationale that was applied in estimating the relative year class strengths for Cedar Lake walleyes was again used to estimate the relative positions with respect to numerical strength of year classes of Moose Lake walleyes. Because of the nature of the age distribution, little information concerning the strengths of the 1954, 1955 and 1957 year classes was provided by the 1962 sample; the above year classes each constituted 16.67 percent of the 1962 sample. The 1962 catch did, however, affirm the strength of the 1956 year class which as age VI fish contributed 50 percent of the catch. The estimation of relative year class strength of Moose Lake walleyes was based largely upon the experimental catches of the 9.5 and 10.8 cm mesh nets in 1963 and 1964.

The strongest year class of walleyes in Moose Lake was, as in Cedar Lake, the 1955 year class. Members of this brood at age VIII contributed 28.57 percent of the 1963 catch. This was considerably larger than the 0.61 percent contribution of the 1956 year class at the same age in 1964. The next strongest year class again appeared to be the 1956 class. Members of this year class at age VII made a larger contribution to the 1963 catch than did the 1957 class at the same age to the 1964 catch of the 9.5 and 10.8 cm nets. That a larger number of individuals were in the 1956 year class than in the 1958 class is indicated by the contributions of the members of these year classes as age VI fish to the 1962 (1956 year class) and 1964 (1958 year class) catches. The 1959 year class was ranked as third in strength. At age V, this year class made up 70.86 percent of the 1964 experimental catch. This contribution was considerably greater than the percentage contribution of age group V fish to the 1962 and 1963 catches. The 1960 class was ranked as fourth. Its contribution at age 4 to the 1964 experimental catch in the 9.5 and 10.8 cm meshes was nearly as large as the 1959 year class' contribution to the 1963 sample.

TABLE IV. Percentage age composition of Moose Lake walleyes captured in experimental gill nets with meshes of 9.5 and 10.8 cm (stretched measure) for 1962 - 1964. Age groups are given in parentheses.

Year class	Year of capture 1962	1963	1964
1953	-	1.79 (X)	-
1954	16.67 (VIII)	1.79 (IX)	-
1955	16.67 (VII)	28.57 (VIII)	-
1956	50.00 (VI)	41.07 (VII)	0.61 (VIII)
1957	16.67 (V)	16.07 (VI)	10.12 (VII)
1958	-	8.92 (V)	17.49 (VI)
1959	-	1.79 (IV)	70.86 (V)
1960	-	-	0.92 (IV)
No. of fish examined	20	56	41

Ranks of the 1957 and 1958 year class were difficult to assess from their representations in the 1963 and 1964 catches. The greater contribution at age VI of the 1958 year class in 1964 suggested this year class should be ranked as the fifth strongest brood present in the Moose Lake walleye fishery during the study period. The 1958 year class represented 17.49 percent of the catch in 1964. The 1957 year class at age VI made up on 16.07 percent of the 1963 sample. Referring to the 1962 sample, the percentage representation of the 1957 year class at age V (16.67 percent) indicated that it was stronger than the 1958 class. Using the rationale applied previously to the relative strengths of the 1956 and 1958 year classes in Cedar Lake (Table II), the 1958 year class was considered to be stronger than the 1957 year class of Moose Lake walleyes. Ranks of 8 and 7 were assigned to the 1953 and 1954 year classes, respectively. Ranks assigned to the eight year classes were as follows:

Year class	1953	1954	1955	1956	1957	1958	1959	1960
Rank	8	7	1	2	6	5	3	4

Two additional samples taken by L. A. Sunde (unpublished data) were referred to in determining relative year class strengths of Moose Lake walleyes. The first of these samples represented a portion (375 fish) of the walleyes captured by pound and trap nets set at the North Arm Narrows of Moose Lake during a tagging program in May, 1961. A sub-sample of 120 of these fish were randomly chosen for age determinations. The second sample consisting of 724 walleyes was taken from catches of the commercial fishery in August, 1961. A cursory examination of this sample suggested that gill nets with mesh dimensions less than the legal 10.8 cm mesh size were also utilized in the Moose Lake fishery. The mean fork length of walleyes in this sample (399 mm) almost coincided with that observed for Moose Lake walleyes retained by the 9.5 cm mesh net during the 1962-1964 study period. The mean fork length of Moose Lake walleyes captured by the 9.5 cm experimental nets was 401 mm. Scale samples from 342 fish in this second sample were collected, and of these scale samples, 85 were randomly chosen for the purpose of age determination.

Percentage age compositions of the two 1961 samples are given in Table V. The assigned ages of the two groups of scale samples examined were considered to be representative of the entire samples taken in May and August, 1961. In the May sample, the percentage age composition was calculated for only 114 fish. Six fish were 9 years old or older and no other members of these earlier year classes to which the age compositions could be compared were captured in the summers of 1962 to 1964.

TABLE V. Percentage age composition of two samples of walleyes taken from Moose Lake in 1961. Age groups are given in parentheses.

Year Class	Date of capture	
	May - 1961	August - 1961
1953	20.17 (VIII)	1.18 (VIII)
1954	21.05 (VII)	29.41 (VII)
1955	54.39 (VI)	67.06 (VI)
1956	4.39 (V)	2.35 (V)
No. of fish examined	114	85

Percentage age compositions of the 1961 samples provided little additional information concerning relative strengths of year classes among Moose Lake walleyes since only four year classes were considered. There was, however, good agreement between these two samples with respect to the percentage contributions made by the 1954, 1955 and 1956 year classes. The 1955 year class was again strongest and was evidently much stronger than the other three year classes. Members of the 1955 brood as age VI fish apparently constituted almost 70 percent of the commercial walleye catch in August. The strong representation of the 1955 brood in the 1961 commercial catch sample would indicate that it was much stronger in 1962 than the percentage value determined from the 1962 experimental catches.

According to the estimates of relative year class strengths derived from the walleye catches in the experimental 9.5 and 10.8 cm nets, the 1956 year class was the second strongest year class in Moose Lake at the time of this study. This year class in the 1961 samples appeared much weaker than the other year class, constituting only 4.39 and 2.35 percent of the May and August samples, respectively, Its poor representation in the May sample may possibly be accounted for by the fact that the sample was taken from a spawning run and that few walleyes in Moose Lake may reach sexual maturity before the age of six years. The poor representation of the 1956 year class in August may have been due to incomplete recruitment into the commercial fishery.

The two samples did not agree with respect to the percentage representations of the 1953 year class. The percentage contribution of the 1953 year class to the May sample was higher than to the sample collected in August. This discrepancy may have resulted through the removal of the 1953 brood walleyes from the lake by summer fishing and natural mortality. A similar decline was not observed for the 1954 year class. This would again provide evidence for the previous contention that the 1954 year class of Moose Lake walleyes was larger than the 1953 year class. Since these two additional samples furnished some proof of the relative year class strengths previously estimated for Moose Lake walleyes, the first estimates were considered to appropriately represent the order of year class strengths.

The above ranks assigned to year classes of Cedar Lake and Moose Lake walleyes are not intended to give any indication of the exact sizes of the year classes considered. The ranks are intended merely to state the order of decreasing magnitude of the year classes relative to the 1955 year class. Also, walleyes in the experimental catches which could not be aged were deleted from the analyses. In the Cedar Lake sample, 17 fish caught in the 10.8 cm and 16 fish caught in the 9.5 cm nets were not aged. From the Moose Lake sample, no ages were assigned to 11 fish from the 10.8 cm and 18 fish from the 9.5 cm nets. Most of these walleyes were from the larger size groups. Because there was considerable overlapping in the length distributions among the older age groups, it was thought best not to estimate the ages of these fish.

Sources of error inherent in these analyses of relative year class strengths have been documented by Hile (1936, 1954).

For example, the age composition of samples taken from a fish population may vary as a result of variations in the seasonal distribution of fish or in the distribution of fish of different size (or age) groups. Hile (1954) noted that the average age of walleye samples taken from Saginaw Bay, Lake Michigan, in the late spring varied from sample to sample and that there were shifts in the dominance of age groups within these samples. The use of a single though fairly large sample may thus result in erroneous conclusions regarding the age composition of the whole population. A difference in the distribution of walleyes of different sizes has been observed by Eschmeyer (1950) in Hardy Pond, Michigan. He noted that walleyes in this reservoir were consistently from younger age groups although their growth was normal and fishing pressure exerted upon them was light. He considered the most probable explanation for this to be the downstream movement of the larger walleyes. Smith _et al_ (1952) observed a similar situation for walleyes of the upper and lower Red Lakes, Minnesota. Walleyes in the upper lake tended to be from younger age groups and it was suggested that this arose through the continual drift of the larger walleyes to the lower lake. Other factors as well may cause variations in the age composition of samples from a fish population. Forney (1961) stated that seasonal variation in the depth distribution of walleyes necessitated the use of several types of sampling gear and that there were differences in the age distributions available to each type of gear. The selective action of a particular type of gear on various age groups will also vary depending upon the rate of growth (Smith and Pycha, 1961). Consequently, estimates of age compositions determined for samples from a fish population, and particularly samples taken by gill nets, are perhaps representative of the samples themselves rather than of the whole population. As will be shown, however, estimates of year class strengths agreed closely with variations in commercial catches of walleyes from Cedar and Moose Lakes.

COMMERCIAL CATCH STATISTICS

As stated previously, variations in year class strength within a fish population may be reflected by the catches of a superimposed fishery. Commercial catch statistics for walleyes of Cedar and Moose Lakes were examined to determine the relationship of the estimated year class strengths to the commercial catches.

Records of the annual walleye catches from Cedar and Moose Lakes by commercial fishing in the period 1940 - 1964 are presented in Fig. 3. Annual catches were determined by adding the winter catch to the previous summer catch since conditions in the populations during the winter would depend on growth and fishing rates affecting the populations in the preceding summer. Weights of the catches are expressed in pounds of dressed weight. (The dressed weight of a fish is the weight after the head and entrails have been removed.)

Commercial production of walleyes is considerably higher for Moose Lake; the mean annual catch of walleyes for the period 1940 - 1964 was 151,920 pounds from Moose Lake and 99,569 pounds from Cedar Lake. Greater fishing pressure is apparently exerted upon Moose Lake walleyes. The only available date on the amount of fishing effort exerted in either lake were the number of fishermen licensed in each fishing season of each year. The annual number of fishermen licenced was determined in the same way as the total annual catch. An annual average of 91.8 fishermen was licensed to fish in Moose Lake over the period 1940 - 1964. The maximum and minimum numbers of

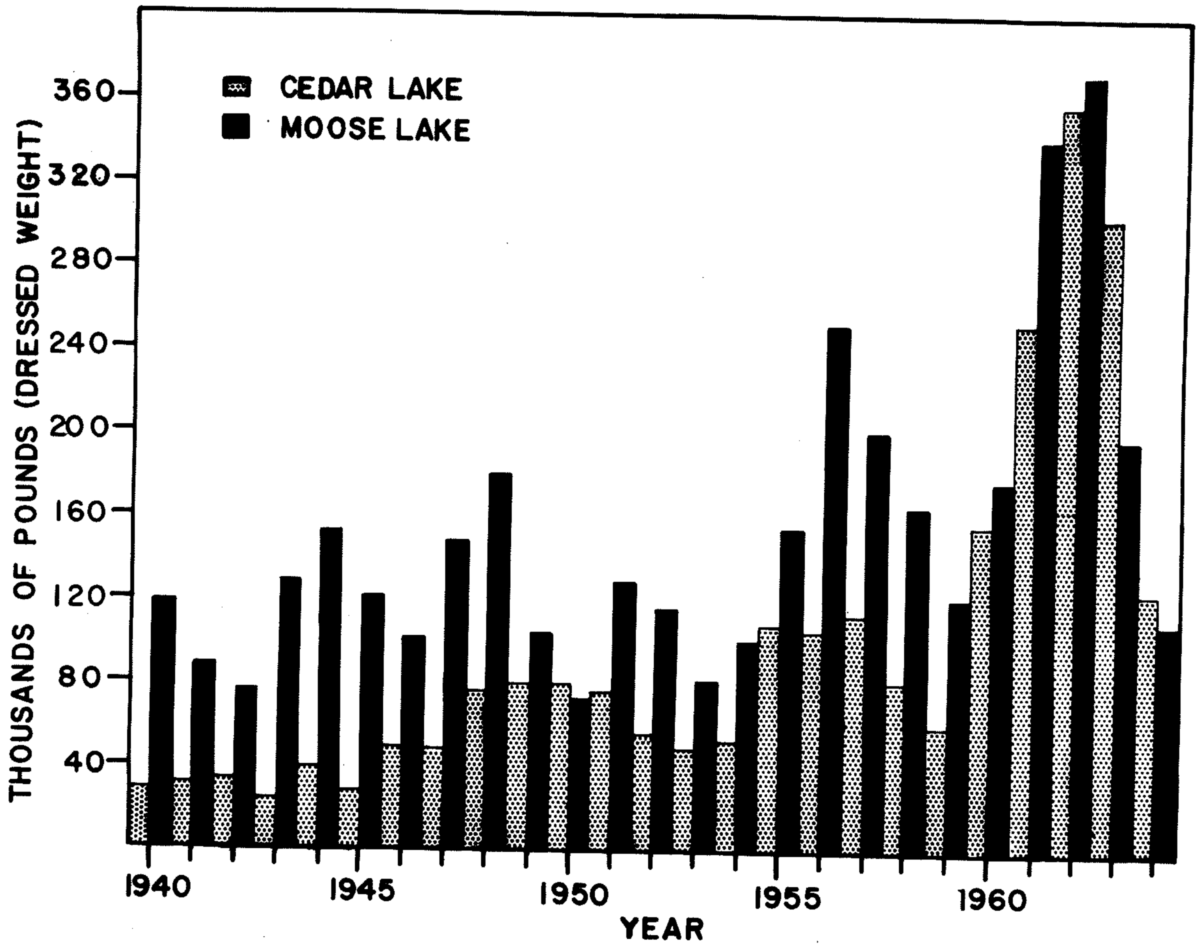


Figure 3. The annual commercial production (in pounds of dressed weight) of walleyes from Cedar and Moose Lakes for the years 1940 - 1964.

licensed fishermen on the lake were 150 in 1948 and 15 in 1940. The average number of fishermen licensed on Cedar Lake during the 25-year period was 52.6. The highest and lowest numbers were 90 in 1963 and 23 in 1940.

For the years 1940 to 1954, annual walleye catches by each fishery were frequently lower than the 1940 - 1964 mean annual catch from the lake. In 1955 a sharp increase in annual catches occurred and thereafter the catches were frequently above average in each fishery. This shift to higher annual catches is believed to be due in part to the change-over from cotton to nylon gill nets in 1954 or 1955. The fisheries on Lake Winnipeg and Lake Manitoba began using nylon nets in 1950 and the gradual change-over to the new more efficient gear probably spread to other northern fisheries several years later (personal communication from K. H. Doan). The largest annual catch of walleyes from each lake occurred in the first year of the present study (1962) when catches from Cedar Lake and Moose Lake were 357,200 pounds and 373,200 pounds, respectively. In the case of Cedar Lake, the 1962 walleye catch was 3.6 times greater than the 1940 - 1964 mean annual catch. The 1962 catch from Moose Lake was 2.5 times greater than the mean annual catch from that lake. These peaks in production were apparently due largely to the contributions made by the strong 1955 year classes in each population. The relationship between the estimated year class strengths and the magnitude of the commercial catches from each lake was examined in greater detail using the available catch statistics. Analyses of walleye abundance in Cedar and

Moose Lakes were limited to catch data for the period 1955 - 1964 (Table VI). The 1955 season was selected as the initial year of the period because it was believed that the majority of fishermen in both lakes had converted to nylon gill nets by this time.

As mentioned above, catch of a species by a fishery may be used directly in some cases to describe fluctuations in the species abundance. The essential condition for estimating changes in abundance in this manner is that the fishing effort exerted upon the population has remained relatively constant over a period of years. The number of fishermen in the Cedar Lake fishery gradually increased over the period 1955 - 1964, while in the Moose Lake fishery the number varied. Large walleye catches from both lakes may have been the result of greater fishing effort rather than a higher level of abundance. Estimates of abundance using catches alone are also invalid for fisheries such as those on Cedar and Moose Lakes where a quota is imposed upon catch in each fishing season.

Variations in levels of abundance are more accurately reflected by changes in the catch per unit of effort of a particular fish species. Hile (1937) and Hile et al (1953) have used the catch per unit effort of various types of gear employed in the Great Lakes to calculate indices of abundance for walleyes. Smith and Krefting (1954) used the catch per unit effort made exclusively by gill nets to estimate changes in abundance of walleyes in Red Lakes, Minnesota. Using this method, they found that changes in the abundance of walleyes were independent of changes in the level of fishing effort and reflected

TABLE VI. The summer and winter seasons' commercial catches of walleyes from Cedar and Moose Lakes from 1955 to 1964. Catches are expressed in thousands of pounds of dressed weights. The number of licensed fishermen is given in parentheses.

Lake	Season	Catch in year -									
		1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Cedar Lake	Summer	64.6 (19)	67.6 (22)	65.2 (25)	55.7 (33)	37.3 (33)	67.1 (32)	118.3 (37)	186.9 (41)	189.7 (51)	97.7 (35)
	Winter	43.4 (16)	39.2 (15)	48.2 (26)	25.7 (21)	23.0 (21)	88.9 (25)	135.1 (27)	170.3 (39)	113.5 (39)	26.6 (38)
Total		108.0 (35)	106.8 (37)	113.4 (51)	81.4 (54)	60.3 (54)	156.0 (57)	253.4 (64)	357.2 (80)	303.2 (90)	124.3 (73)
Moose Lake	Summer	97.8 (29)	179.4 (54)	141.6 (75)	145.6 (62)	105.0 (80)	117.9 (63)	131.3 (54)	197.7 (68)	175.5 (55)	92.6 (69)
	Winter	57.0 (26)	74.1 (34)	59.9 (53)	19.9 (48)	17.6 (25)	60.6 (27)	173.3 (52)	175.5 (64)	22.5 (45)	16.7 (55)
Total		154.8 (55)	253.5 (88)	201.5 (128)	165.5 (110)	122.6 (105)	178.5 (90)	304.6 (106)	373.2 (132)	198.0 (100)	109.3 (124)

the strengths of individual year classes within the fishery. This method was used in the present study.

Since no records regarding the exact amount of effort expended in Cedar and Moose Lakes were available, estimates of the catch per unit of effort in each year during the period 1955 - 1964 were obtained by dividing the annual number of licensed fishermen into the annual walleye catch. The number of gill nets licensed was not used since the number permitted per license remained constant over the 10-year period. Each license holder was allowed to operate fifteen 91.4 m sections of gill net with a mesh size not less than 10.8 cm (stretched measure). Although they varied somewhat during the 10-year period, the lengths of the fishing seasons were not considered since it was not known if fishing effort was distributed uniformly in each season nor was it known if each person purchasing a commercial fishing license fished in each season. The catch per license provided only an approximation of the catch per unit of effort. It was assumed that fishing effort in each lake from 1955 to 1964 increased in some proportion with an increase in the number of fishermen licensed.

To obtain an estimate of fluctuations in the abundance of walleyes in Cedar and Moose Lakes, the catch per license in each year was expressed as a percentage of the mean catch per license for each lake over the 10-year period (Fig. 4). The mean catch per license for Cedar Lake from 1955 to 1964 was 2797 lb. per license as compared to 1986 lb. for Moose Lake. Even though the 1955 - 1964

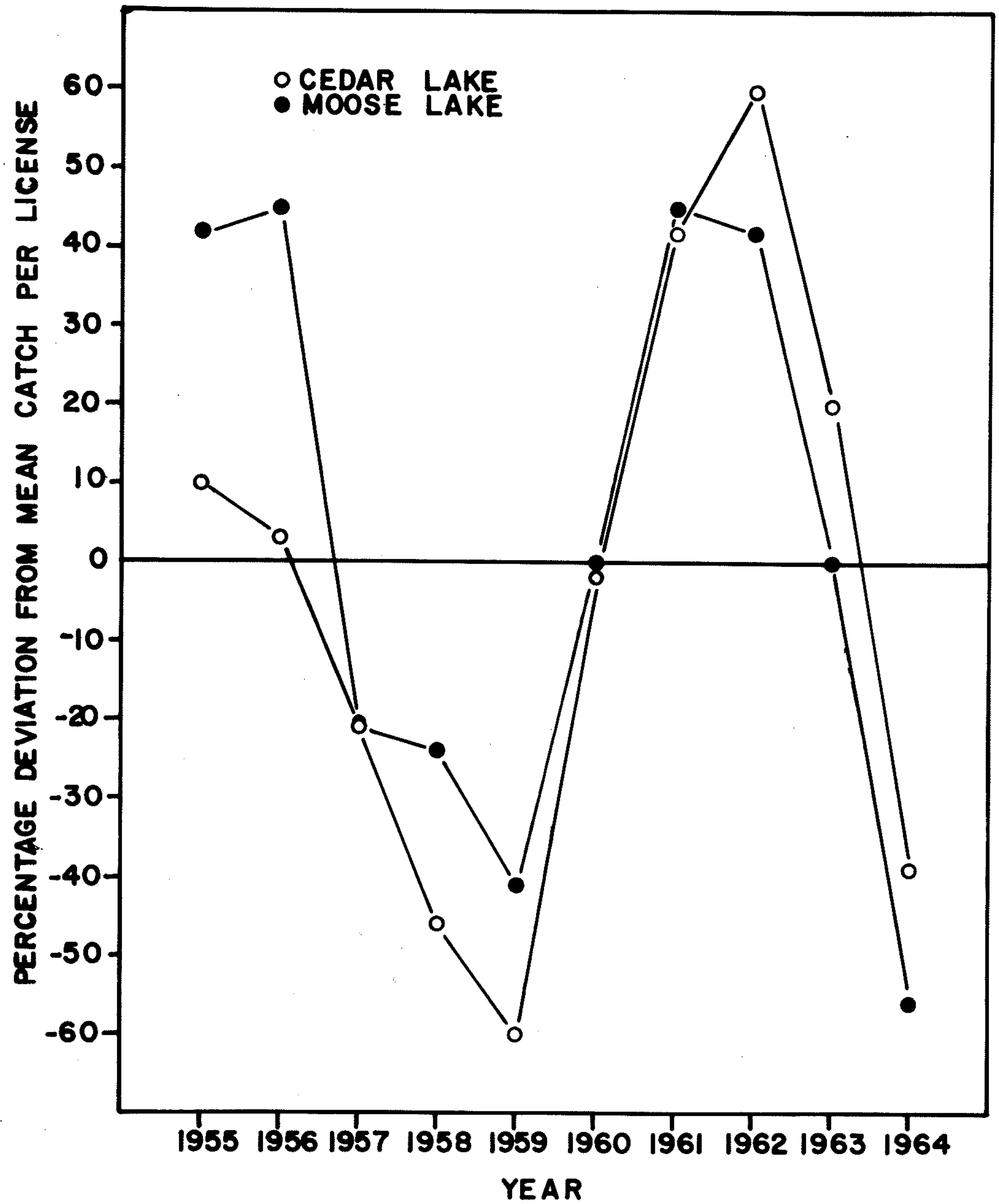


Figure 4. Annual fluctuations in the walleye catch per license for the Cedar and Moose Lakes fisheries expressed as percentage deviations from the respective 1955 - 1964 catch per license means.

mean catch per license was higher for the Cedar Lake fishery, the percentage deviations of the annual catch per license from the 10-year means are very similar for each lake. The seasonal quotas established for each fishery may have had some effect on the size of walleye catches and hence on the estimates of variations in abundance. The data shown in Fig. 4 are, nevertheless, believed to represent the general pattern of population fluctuations in both lakes since low catches were made even though the quotas increased throughout the 10-year period. The percentage values in Fig. 4 provide only an approximation of fluctuation in abundance. They may not represent the actual size of variations in the catch per unit of effort.

In relating the estimates of relative year class strengths to the commercial catches of walleyes, it was assumed that, on the average, each year class made its maximum contribution to the commercial catch when its members were six years old. This assumption was based in part upon percentage age compositions observed in commercial catch samples of walleyes taken in 1961 and 1962. In the June and July, 1961 sample from Cedar Lake (Table III), the age VI fish of the 1955 year class was the strongest age group represented. During the winter fishing season of 1962, the 1955 year class at age VII made up 59.66 percent of the February commercial catch sample from Cedar Lake. Age VI walleyes of the 1955 year class in Moose Lake constituted 67.06 percent of the commercial catch sample taken in August, 1961 (Table V). Smith and Pycha (1961) found that age VI walleyes were the most predominant in the commercial gill net catches from Red

Lakes, Minnesota, over a 9-year period. The gear used (8.9 cm mesh) and the growth rate of walleyes in the Red Lakes were similar to the conditions in Cedar and Moose Lakes.

Ranked estimates of year class strength when plotted against the annual catches per license six years later indicated that the strongest year classes of walleyes in both lakes contributed most on the average to high catch per unit of effort (Fig. 5). This relationship, in the case of Cedar Lake, is shown for seven year classes and annual catches; six year classes and annual catches were considered from the Moose Lake population. Lack of data regarding earlier year classes prevented consideration of the 1955 to 1957 catches from Cedar Lake and the 1955 to 1958 catches from Moose Lake. In both cases, the distribution of points could be fitted with a straight line having a negative slope. (Lines shown in Fig. 5 were fitted by regression.) Although the assumption that maximum recruitment occurred at age VI may not have applied to each year class, the plots do indicate that the stronger year classes of walleyes in each lake were associated with higher annual catches.

Estimates of year class strengths in each population also coincided with the estimated fluctuations in abundance shown in Fig. 4. In the Cedar Lake fishery, the catch per unit of effort (catch per license) of walleyes dropped from 1955 to a low in 1959 of 60 percent below the 1955 - 1964 mean catch per unit of effort from that lake. Information on the age composition of Cedar Lake walleyes

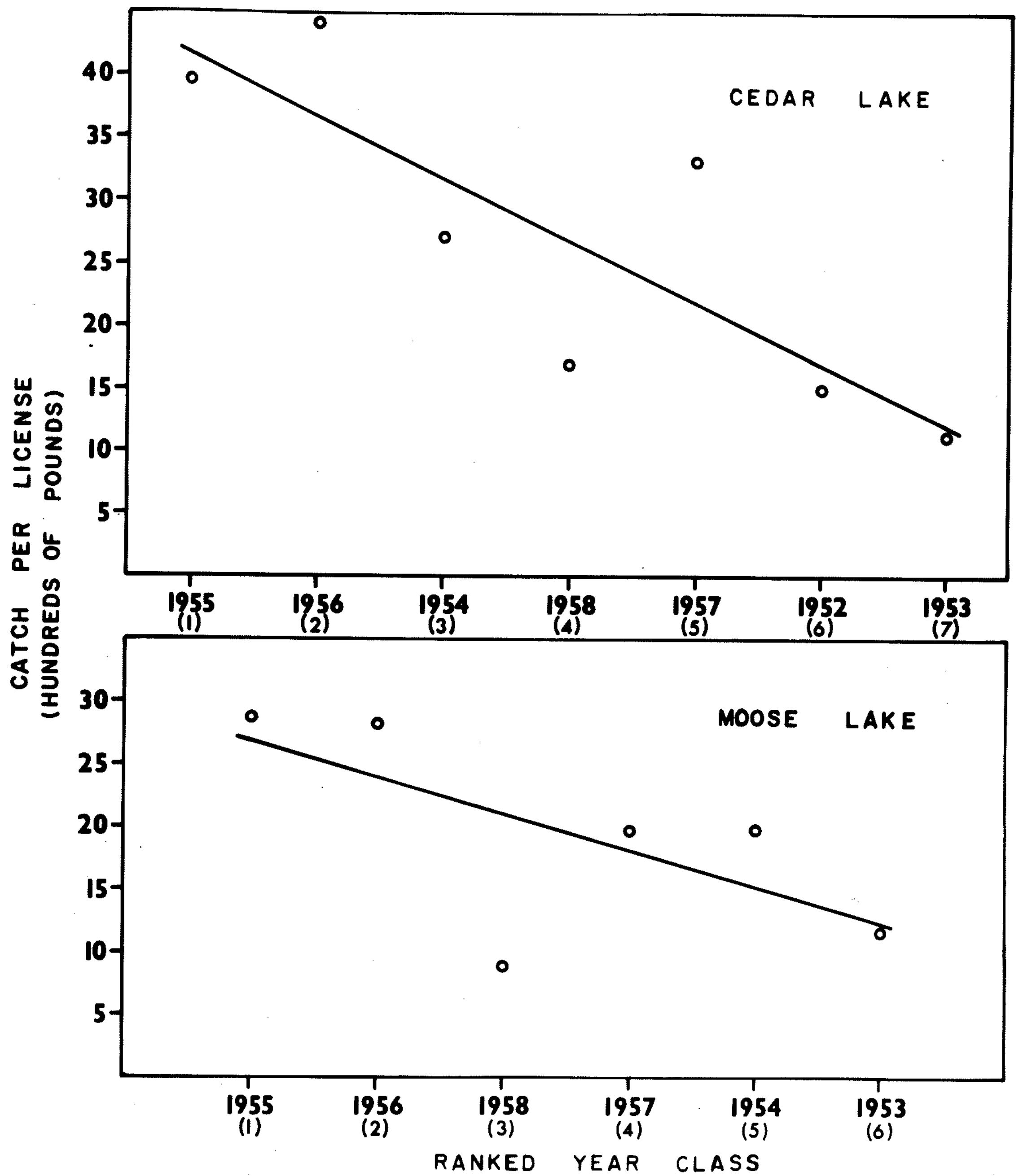


Figure 5. The relationship between the ranked estimates of year class strength and the annual catches per license six years later shown for Cedar Lake and Moose Lake walleyes.

was inadequate to determine if the decline in catch from 1955 to 1957 was due to progressively weaker year classes entering the fishery. The low catch in 1958 appears to have been caused by the poor contribution of the 1952 year class at age VI. Of the nine year classes considered from Cedar Lake, the 1953 year class was the weakest and was probably responsible for the extremely low catch per unit effort in 1959. The 1954, 1955 and 1956 year classes were respectively ranked as the third, first and second strongest year classes. Contributions by these appear to be associated with the rapid increase in 1962. The catch per unit effort declined after 1962. This decline may have been due to the recruitment of the weak 1957 and 1958 year classes into the fishery. The 1957 and 1958 year classes were assigned the ranks 5 and 4, respectively. The strengths of these year classes do not completely agree with the variations noted in the catch per unit of effort. Assuming each of these year classes made their maximum contribution to the commercial catch at age VI, the catch per unit of effort should have been higher in 1964 when the stronger 1958 year class was in the fishery. This discrepancy could have occurred through continued contributions from the previous strong year classes which may have masked the weak contribution of the 1957 year class. Similar agreement between the year class strengths and fluctuations in the catch per unit effort was noted for the population of Moose Lake walleyes. Fluctuations in the catch per unit of effort in the two lakes differed in that a peak in the catch per unit of effort from Moose Lake occurred in 1961. In Cedar Lake, it occurred in 1962.

The successive occurrence of three strong year classes of walleyes in Cedar Lake as opposed to only two in Moose Lake may have accounted for the peak catch per unit of effort occurring in different years in the two lakes.

Although the estimates of relative year class strength and of the variations in catch per unit of effort did not precisely represent fluctuations in the abundance of walleyes, the two estimates for each population closely agreed with one another. This agreement strongly suggests that the annual fluctuations noted in the commercial walleye catches from Cedar and Moose Lakes over the period, 1955 - 1964 were largely caused by variations in the success of individual year classes in the two populations.

RELATIONSHIP OF YEAR CLASS STRENGTH TO DISCHARGE

Contributions of a year class of fish to commercial or sport fisheries may depend upon environmental conditions prevalent during the spawning, incubation and fry stages for that year class (Ricker, 1954). During these initial life phases a year class may be most vulnerable to adverse hydrological conditions. Hydrological conditions will include the various inter-related physical and chemical properties of natural waters which directly or indirectly affect fish populations.

Discharges from the Saskatchewan River were examined to determine whether or not they would indicate variations in the hydrological conditions of Cedar and Moose Lakes which might explain the differential survival of year classes in the two walleye populations. Variations in the discharges from this river would definitely affect Cedar Lake since most of the flow enters the southern basin of Cedar Lake (Anon., 1961). The discharges from the Saskatchewan River are also believed to affect Moose Lake although perhaps to a lesser degree. Moose Lake is joined to the Saskatchewan River via the Moose and Summerberry Rivers (see Fig. 2). Flow in Moose River, the outlet of Moose Lake, was observed to be toward the lake during periods of high water levels in the Saskatchewan and Summerberry Rivers. Variations in the hydrological conditions of the two lakes may also be indicated by the discharges. For example, years of high spring flows may be associated with early high temperatures, ice break-up, or other events. Mean monthly discharges in cubic feet per second were obtained for the months of April to and including September for the years 1952 - 1960 (Water Resources Paper, No. 113, 117, 121, 125, 127 and 132 - 1953, 1954, 1958, 1960 and 1961). Flow rates were measured at The Pas, Manitoba (see Fig. 1).

To determine if discharges from the Saskatchewan River had affected hydrological conditions enough to influence the strengths of the 1952 - 1960 and 1953- 1960 year classes of walleyes in Cedar Lake and Moose Lake, respectively, ranks were assigned to the discharge values corresponding to the first year of life of the year classes considered. A rank correlation test was then applied. Rank correlation coefficients were calculated for each month from April to September to ascertain whether discharge in some particular month was correlated with the survival of a year class. These coefficients along with statements of the probability that no correlation existed between the ranks of year classes and of discharges from the Saskatchewan River are given in Table VII for each population.

For Cedar Lake, the best positive correlation between the two factors was obtained for the months of May and June; the rank correlation coefficient was higher in June and was significant at the 20 percent, but not at the 10 percent level of probability. A positive but low coefficient was also obtained in April. Positive correlation between discharge and year class ranks of Moose Lake walleyes was obtained in April and May. The coefficient in May was low. The rank correlation coefficient for April in the case of Moose Lake was the

the only coefficient obtained that was statistically significant at a probability level of 5 percent. Coefficients obtained for the months of July to September in Cedar Lake and June to September in Moose Lake indicated that no direct relationship existed between discharge and year class strengths in these months.

TABLE VII. Rank correlation coefficients (r_s) showing the degree of correlation between ranks for mean monthly discharges from the Saskatchewan River in each month April to September and the ranks determined for year classes in each population of walleyes.

Month	Cedar Lake		Moose Lake	
	r_s	$P(\rho = o)$ 7df	r_s	$P(\rho = o)$ 6df
April	+0.033	$P > 0.5$	+0.738	$0.05 > P > 0.02$
May	+0.383	$0.4 > P > 0.3$	+0.238	$P > 0.5$
June	+0.567	$0.2 > P > 0.1$	-0.071	$P > 0.5$
July	-0.050	$P > 0.5$	-0.167	$P > 0.5$
August	-0.050	$P > 0.5$	-0.167	$P > 0.5$
September	-0.004	$P > 0.5$	-0.351	$0.4 > P > 0.3$

The months in which a positive correlation coefficient was previously observed were studied in more detail. The flows in these months in various combinations were summed and then ranked. Three combinations of monthly discharges were considered in the case of Cedar Lake data. They were April-May, May-June, and April-May-June. Only one combination, that of April-May, was considered in the case of Moose Lake data. Rank correlation coefficients were calculated to determine if the rank correlation could be improved by considering the combined discharges of two or more months. Results of these tests (Table VIII) indicated that the correlation did not improve. This suggests that hydrological conditions as indicated by discharges in time periods of a month or less in the spring or early summer may be crucial to the survival of walleye year classes in each lake. The rank correlation coefficients could perhaps have been improved if discharges in periods of less than a month had been considered.

TABLE VIII. Rank correlation coefficients (r_s) showing the degree of correlation between the summed and ranked mean monthly discharges from the Saskatchewan River for combinations of months which previously showed positive correlation coefficients and the ranks determined for year classes in each population of walleyes.

Months	Cedar Lake		Moose Lake	
	r_s	$P(\rho=0)$ 7df	r_s	$P(\rho=0)$ 6df
April - May	+0.216	$P > 0.5$	+0.643	$0.1 > P > 0.05$
May - June	+0.510	$0.2 > P > 0.1$	---	---
April - May - June	+0.540	$0.2 > P > 0.1$	---	---

DISCUSSION

Considerable fluctuations occurred in the commercial walleye catches from Cedar and Moose Lakes (Fig. 3). They were most pronounced during the period 1955 - 1964. Analyses of the age structure in experimental walleye catches from each lake (Tables II and IV) and in additional samples indicated that variations had occurred in year class abundance. Fluctuations in commercial catches as revealed by variations in the catch per unit of effort (Fig. 4) were shown to be related to the variations in the estimated strengths of year classes (Fig. 5). The large 1955 and 1956 year classes within each lake resulted in a high catch per unit of effort six years after hatching (Fig. 4). Similarly, the poor catch per unit of effort in 1959 (Fig. 4) resulted from the recruitment of the weak 1953 year class. Although catch quotas established for each fishery may have had some effect on the size of annual catches, it was apparent that variations in walleye catches between 1955 and 1964 were largely due to differences in the size of year classes recruited into each fishery.

Positive coefficients of correlation indicating a direct relationship between the survival of walleye year classes in Cedar and Moose Lakes and discharges from the Saskatchewan River occurred in the first three months of the six considered in the rank correlation analyses (Table VII). Since the discharges involved in the analyses applied to the first year of the year classes considered, these results suggest that the survival of each brood during its early stages in both lakes was influenced by discharges from the Saskatchewan River. The correlation of year class strength to discharge does not imply a direct causal relationship between discharges and the success of year classes in each lake. Rather, it is believed that discharges from the river caused or were related to variations in the hydrological conditions of both lakes which were either deleterious or advantageous to the early survival of walleye year classes in each lake.

Since conditions during spawning and early life history of walleyes in Cedar and Moose Lakes is unknown, the biological significance of the correlations is also unknown. However, other studies have investigated the affects of a variety of environmental factors upon fish populations. Results of these other studies suggest some of the possible ways in which discharges may have affected the survival of walleyes in Cedar and Moose Lakes. Water levels will affect the availability of spawning areas and thereby affect spawning success (Eschmeyer, 1950). Johnson (1961) observed that the weak 1958 year class of walleyes in Lake Winnibigoshish, Minnesota, may have resulted from low water levels in the spring of that year. Stable water levels in nursery areas during the incubation and fry periods are important for optimum survival of pike (Franklin and Smith, 1963). Yields of trout fry from streams in the arid interior areas of British Columbia are dependent upon the wetness of spring and early summer (Larkin, 1954). High water levels may be beneficial to the survival of fish by dispersing juveniles, thus preventing over-crowding and severe competition for food (Webster, 1954). Water levels may also moderate or be associated with temperature regimes of the water. The length of the incubation period is a factor in egg survival (Johnson, 1961; Christie, 1963; and Lawler, 1965). Inclement water temperatures may in some years completely curtail spawning (Derback, 1947). First-year growth may also determine the survival of a year class. Forney (1966) noted that year classes of walleyes in Oneida Lake, New York, which experienced good growth in their first year would suffer a lower mortality in the first winter. Water temperatures, particularly in May and June, and very early or late spawning are known to affect the amount of first-year growth attained by walleyes (Smith and Pycha, 1960 and Forney, 1966). Smith and Pycha (1960) also observed that the total first-year growth of walleyes may be determined before fish become a predominant part of their diet. This suggests that factors conducive to the early and sustained production of zooplankters, which larval walleye feed on, may favour the survival of a year class. Hile (1941) obtained a positive correlation between heavy early-season rainfall and the first-year growth of rock bass in Nebish Lake, Wisconsin. He suggested that the manner in which heavy rainfall promoted good first-year growth was by washing in organic materials and nutrient salts and causing a significant enrichment of the lake. The significance of high fertility in producing an early crop of zooplankton and thereby increasing the yield of walleye fry has been demonstrated for pond-reared walleyes by Smith and Moyle (1945). All the environmental conditions which are known to enhance or retard the successful development of fish year classes could be caused by varying discharges from the Saskatchewan River.

The investigations into factors affecting the abundance of fish populations have stressed the importance of conditions during the early life history of year classes. The correlations obtained between discharge and year class strength of walleyes in Cedar Lake and Moose Lake are in agreement with the results obtained in other investigations and, in particular, with those dealing with spring spawning fish. This agreement suggests that variations in discharges from the Saskatchewan River were either responsible for or in some way related to variations in the hydrological conditions of both lakes which were significant enough to cause fluctuations in the success of walleye year classes. Although discharges may have affected each lake differently, the effect on walleye abundance in both populations was similar. The estimated fluctuations in abundance (Fig. 4) were almost identical for both populations.

The fluctuations in walleye year class strengths caused by unidentified factors related to variations in discharge were of sufficient magnitude to be reflected in the success of the commercial fisheries on Cedar and Moose Lakes. The good survival of year classes early in life was apparently associated with years in which high discharges occurred in the spring months. These strong year classes of walleyes were subsequently responsible for highly successful catches by the commercial fisheries. This relationship has implications regarding possible management of the walleye fisheries on the two lakes. The best means of obtaining estimates of fluctuations in the abundance of a fish population prior to recruitment would be by experimental fishing for pre-recruits over a series of years. To obtain this information for walleyes in Cedar and Moose Lakes would often be difficult and entail considerable expense. In lieu of such data, measurements of discharges from the Saskatchewan River in the spring and early summer in each year could be used to estimate whether the survival of each walleye year class was good or poor. This information could in turn be used to predict the future success or failure of the fisheries and management regulations could be adjusted accordingly. Since the data on which this study was based were collected over a relatively short term, further and more detailed investigations would be required to establish the reliability of discharges as an indicator of year class abundance. The situation in Cedar and Moose Lakes may also have been altered by the inundation of the area and the operation of the hydro-electric dam. Additional studies will therefore be necessary to determine how these changes have affected the walleye populations in Cedar and Moose Lakes.

SUMMARY

During the summer months of 1962 to 1964 inclusive, a biological survey was made of Cedar and Moose Lakes. A total of 1279 walleyes were captured by experimental gill netting in both lakes.

The age of each fish was determined by the number of scale annuli. The examination of the time of annulus formation in Cedar Lake walleyes in 1962 indicated that it probably occurred before June 1. It was assumed that the time of annulus formation in Moose Lake walleyes in 1962 to 1964 and in Cedar Lake walleyes in the two other sample years occurred at a similar time.

The relative year class strengths of Cedar Lake and Moose Lake walleyes were estimated from the percentage age compositions of catches in the experimental 9.5 and 10.8 cm mesh gill nets and of additional samples taken from the commercial fisheries. Percentage age compositions in the experimental samples were determined after the catches by the two nets had been adjusted to a standard catch per unit of effort. Relative year class strengths were expressed as ranks.

Ranks were assigned to nine and eight year classes of walleyes from Cedar Lake and Moose Lake, respectively. The 1955 year class was the strongest in Cedar Lake and was followed by the 1956, 1954, 1958, 1957, 1960, 1959, 1952 and 1953 year classes in the order of decreasing size. The 1955 year class was also the strongest in Moose Lake and was followed by the 1956, 1959, 1960, 1958, 1957, 1954, and 1953 year classes.

The commercial production of walleyes from Moose Lake was higher than that from Cedar Lake. The mean annual catch of walleyes from Cedar and Moose Lakes for the period 1940 - 1964 was 99,569 pounds and 151,920 pounds, respectively. The rate of exploitation, as suggested by the mean annual number of licensed fishermen was higher in Moose Lake. An average of 91.8 fishermen were licensed to fish in Moose Lake in each year during the 25 year period. The average annual number of fishermen on Cedar Lake for the same period was 52.6 fishermen.

The annual production of walleyes increased in 1955 and thereafter catches were generally above average. This was believed to have been caused by the change-over in the commercial fisheries from cotton to nylon gill nets. Unprecedented peaks in the production of walleyes from both lakes were realized in 1962. These large catches were caused largely by the entry of the strong 1955 and 1956 year classes into the commercial fisheries.

Fluctuations in the abundance of walleyes in each lake were estimated by the percentage deviations in the annual catch per unit of effort (catch per license) in the years 1955 to 1964. The fluctuations in abundance appeared to be almost identical in both populations. Assuming that each year class made its maximum contribution to the commercial catch at age VI, a comparison of ranked year class strength to catch per unit of effort indicated that large year classes were associated with large catches. The estimates of year class strength of walleyes in Cedar and Moose Lakes also coincided with the estimated fluctuations in abundance. This relationship suggested that variations in the annual walleye catches from both lakes were primarily due to variations in the success of individual year classes in the two populations.

The relationship between year class strengths of walleyes in Cedar and Moose Lakes and discharges from the Saskatchewan River was examined using the rank correlation test. Variations in year class abundance were positively correlated with variations in discharges. This relationship in both lakes occurred during the period April to June encompassing the spawning, incubation and early juvenile stages. High discharges could have, according to other workers, increased the success of spawning, provided optimum conditions during incubation or promoted first-year growth. High discharges alone may not have been responsible for the success of year classes but may have been associated with other unidentified favourable factors.

The effect of discharges on year class strength of walleyes was related to the success of the commercial fisheries on both lakes. The results of this study implicate the use of spring and early summer discharges from the Saskatchewan River to predict the success of walleye year classes and future commercial catches from Cedar and Moose Lakes. Recent changes in both lakes brought about by the construction of a hydro-electric power dam downstream from these lakes would warrant additional studies to determine what effect they have had on the walleye populations. Further study would also be desirable to confirm the reliability of discharges as an index of year class abundance among the walleyes of Cedar and Moose Lakes.

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APPENDIX A. Included in this section are descriptions of experimental gill net sets made in Cedar and Moose Lakes, data on the experimental walleye catches from both lakes in 1962 to 1964, and other samples of walleyes from the two lakes.

Table A-I. Details of the experimental gill net sets made in Cedar Lake during the summers of 1962 - 1964.

Date	Effort (Days)	Depth (Meters)	Type of set	Meshes (cm-stretched measure) and length (meters) of sections set							
				3.8	5.1	7.6	9.5	10.8	12.1	12.7	13.3
11/6/62	One	1.5-4.6	Shore	-	-	45.7	45.7	45.7	45.7	45.7	-
13/6/62	"	1.5-3.0	" "	-	-	45.7	45.7	45.7	45.7	45.7	-
15/6/62	"	1.2-2.4	" "	-	-	45.7	45.7	137.1	45.7	45.7	-
20/6/62	"	1.5-2.4	" "	-	-	45.7	45.7	137.1	45.7	45.7	-
24/6/62	"	6.1	Off-shore	-	-	45.7	45.7	137.1	45.7	45.7	-
9/7/62	"	6.1	"	-	45.7	45.7	45.7	137.1	45.7	137.1	-
12/7/62	"	3.0-3.7	Shore	-	45.7	45.7	45.7	137.1	45.7	137.1	-
14/7/62	"	1.5-4.6	"	-	45.7	45.7	45.7	137.1	45.7	137.1	-
22/7/62	"	1.5-4.6	"	-	45.7	45.7	45.7	45.7	45.7	45.7	-
30/7/62	"	4.6-6.1	Off-shore	-	-	-	-	91.4	-	91.4	-
31/7/62	Two	4.6-6.1	"	-	45.7	45.7	45.7	45.7	45.7	45.7	-
11/8/62	One	3.7-4.6	"	-	45.7	45.7	45.7	137.1	45.7	137.1	-
21/8/62	"	6.1	"	-	45.7	45.7	45.7	45.7	45.7	45.7	-
24/8/62	"	6.1	"	-	-	45.7	45.7	45.7	-	-	-
3/9/62	Two	3.0-4.6	Shore	-	-	45.7	45.7	45.7	45.7	45.7	-
5/8/63	One	3.0	Off-shore	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
7/8/63	"	4.6	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
8/8/63	"	1.5	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
10/8/63	"	3.7	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
23/6/64	"	9.1	"	-	32.9	45.7	-	45.7	45.7	45.7	-
25/6/64	"	6.1	Shore	-	32.9	45.7	-	45.7	45.7	45.7	-
28/6/64	"	3.7	Off-shore	-	32.9	45.7	-	45.7	45.7	45.7	-
22/7/64	"	6.1	"	-	32.9	45.7	-	45.7	45.7	45.7	-
26/7/64	"	5.5	"	-	-	-	-	457.0	-	-	-
19/8/64	"	9.1	"	91.4	45.7	45.7	45.7	45.7	-	45.7	-
22/8/64	"	9.1	"	91.4	45.7	45.7	-	-	-	-	-
27/8/64	"	7.6	"	-	-	-	-	182.8	-	-	-

Table A-II. Details of the experimental gill net sets made in Moose Lake during the summers of 1962 - 1964.

Date	Effort (Days)	Depth (Meters)	Type of set	Meshes (cm-stretched measure) and length (m) of sections set							
				3.8	5.1	7.6	9.5	10.8	12.1	12.7	13.3
30/6/62	One	1.5-4.5	Shore	-	-	45.7	45.7	137.1	45.7	45.7	-
2/7/62	"	15.2-18.3	Off-shore	-	-	45.7	45.7	137.1	45.7	45.7	-
3/7/62	"	15.2	"	-	-	45.7	45.7	137.1	45.7	45.7	-
1/6/63	"	6.1	"	-	45.7	45.7	45.7	45.7	45.7	-	45.7
3/6/63	"	4.6-6.1	"	-	45.7	45.7	45.7	45.7	45.7	-	45.7
4/6/63	"	4.0	"	-	45.7	45.7	45.7	45.7	45.7	-	45.7
9/6/63	"	5.6	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
12/6/63	"	4.6-5.5	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
14/6/63	"	3.0	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
16/6/63	"	6.1	"	45.7	-	45.7	45.7	45.7	45.7	45.7	45.7
22/6/63	"	9.1	"	45.7	-	45.7	45.7	45.7	45.7	45.7	45.7
25/6/63	"	9.1	"	45.7	-	45.7	45.7	45.7	45.7	45.7	45.7
26/6/63	"	9.1	"	45.7	-	45.7	45.7	45.7	45.7	45.7	45.7
29/6/63	"	12.2	"	45.7	-	45.7	45.7	45.7	45.7	45.7	45.7
30/6/63	"	13.7	"	-	-	45.7	45.7	45.7	45.7	45.7	45.7
9/7/63	"	16.8	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
20/7/63	"	15.2	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
27/7/63	"	1.6-1.4	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
31/7/63	"	1.8-2.4	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
1/8/63	"	15.2	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
13/8/63	"	4.6	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
14/8/63	"	6.1	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
15/8/63	"	4.6	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
22/8/63	"	15.2	"	-	45.7	45.7	45.7	45.7	45.7	45.7	45.7
2/6/64	"	4.6	"	-	32.9	45.7	-	45.7	45.7	45.7	-
10/6/64	"	4.6	"	-	32.9	45.7	-	45.7	45.7	45.7	-
6/7/64	"	15.2	"	-	32.9	45.7	-	45.7	45.7	45.7	-
7/7/64	"	15.2	"	-	32.9	45.7	-	45.7	45.7	45.7	-
12/7/64	"	10.7	"	-	32.9	45.7	-	45.7	45.7	45.7	-

Table A-II. (cont'd)

Date	Effort (Days)	Depth (Meters)	Type of set	Meshes (cm-stretched measure) and length (m) of sections set							
				3.8	5.1	7.6	9.5	10.8	12.1	12.7	13.3
13/7/64	One	12.2	Off-shore	-	32.9	45.7	-	45.7	45.7	45.7	-
14/7/64	"	16.8	"	-	-	45.7	-	45.7	45.7	45.7	-
3/8/64	"	9.1-10.7	"	-	-	-	-	457.0	-	-	-
8/8/64	"	3.0	"	45.7	45.7	45.7	45.7	45.7	-	45.7	-
12/8/64	"	6.1	"	45.7	45.7	45.7	45.7	45.7	-	45.7	-
13/8/64	"	15.2	"	-	-	-	-	457.0	-	-	-
4/9/64	"	3.0	"	45.7	45.7	45.7	-	45.7	45.7	45.7	-

TABLE A-III. The number of walleyes captured from Cedar Lake in each year by gill nets of the various mesh sizes used. N.F. indicates nets that were not fished during the year given.

Year	Mesh size (Stretched measure in cm)								Total
	3.8	5.1	7.6	9.5	10.8	12.1	12.7	13.3	
1962	N.F.	66	231	161	46	12	5	N.F.	521
1963	N.F.	32	16	38	6	-	1	-	93
1964	16	59	22	1	49	1	2	N.F.	150
Total	16	157	269	200	101	13	8	-	764

TABLE A-IV. The number of walleyes captured from Moose Lake in each year by gill nets of the various mesh sizes used. N.F. indicates nets that were not fished during the year given.

Year	Mesh size (Stretched measure in cm)								Total
	3.8	5.1	7.6	9.5	10.8	12.1	12.7	13.3	
1962	N.F.	N.F.	5	5	18	1	-	N.F.	29
1963	5	77	37	59	14	4	1	3	200
1964	45	78	108	22	31	1	1	N.F.	286
Total	50	155	150	86	63	6	2	3	515

TABLE A-V. The length-frequency distribution of 764 Cedar Lake walleyes captured in gill nets of the various mesh sizes used during the summers of 1962 - 1964. Fork lengths are expressed in millimeters.

Interval of fork length	Mesh size (Stretched measure in cm)							Total
	3.8	5.1	7.6	9.5	10.8	12.1	12.7	
620-659	-	-	-	1	1	-	-	2
580-619	-	-	-	-	-	1	-	1
540-579	-	-	-	-	1	-	-	1
500-539	-	-	-	2	2	-	-	4
460-499	-	-	5	4	14	1	3	27
420-459	-	4	18	28	47	6	-	103
380-419	-	5	87	128	30	4	3	257
340-379	1	5	102	33	2	1	1	145
300-399	1	15	55	3	2	-	1	77
260-299	1	22	2	-	-	-	-	25
220-259	2	80	-	1	-	-	-	83
180-219	3	22	-	-	-	-	-	25
140-179	6	1	-	-	1	-	-	8
100-139	-	1	-	-	1	-	-	2
60-99	2	2	-	-	-	-	-	4
No. of fish	16	157	269	200	101	13	8	
Average fork length	198	258	372	400	429	441	413	

TABLE A-VI. The length-frequency distribution of 515 Moose Lake walleyes captured in gill nets of the various mesh sizes during the summers of 1962 - 1964. Fork lengths are expressed in millimeters.

Interval of fork length	Mesh size (Stretched measure in cm)								Total
	3.8	5.1	7.6	9.5	10.8	12.1	12.7	13.3	
540-579	-	-	-	-	2	-	-	-	2
500-539	-	-	-	-	1	-	1	-	2
460-499	1	-	-	1	9	2	-	-	13
420-459	-	1	7	20	18	1	-	1	48
380-419	2	4	21	45	27	-	-	2	101
340-379	1	10	37	17	2	1	-	-	68
300-339	4	33	72	3	2	1	-	-	115
260-299	6	28	13	-	-	-	1	-	48
220-259	2	53	-	-	-	1	-	-	56
180-219	10	24	-	-	1	-	-	-	35
140-179	24	1	-	-	1	-	-	-	26
100-139	-	1	-	-	-	-	-	-	1
Average fork length	221	268	342	401	420	386	415	411	

TABLE A-VII. Frequency distribution of fork lengths (expressed in millimeters) for 198 Cedar Lake walleyes sampled from the commercial fishery on June 22 and 23, 1962.

Class interval of fork length	Frequency
320 - 329	1
330 - 339	4
340 - 349	4
350 - 359	7
360 - 369	16
370 - 379	24
380 - 389	36
390 - 399	29
400 - 409	34
410 - 419	16
420 - 429	12
430 - 439	6
440 - 449	5
450 - 459	2
460 - 469	1
. . .	-
530 - 539	1

Mean fork length 393 mm

TABLE A-VIII. The age distribution of walleyes in each mesh fished in Cedar Lake (1962 - 1964) and the number of walleyes to which ages were not assigned.

Mesh (cm - stretched measure)	Year of collection	Number of fish in age group -													Number not aged
		0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
13.3	1963	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.7	1962	-	-	-	-	-	2	1	1	1	-	-	-	-	-
	1963	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	1964	-	-	-	-	-	-	-	1	1	-	-	-	-	-
12.1	1962	-	-	-	-	-	1	2	6	3	-	-	-	-	-
	1963	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1964	-	-	-	-	-	-	-	-	-	-	-	-	-	1
10.8	1962	-	1	-	-	3	1	9	21	4	3	1	-	-	3
	1963	-	-	-	-	-	-	1	-	2	1	-	-	-	2
	1964	-	1	-	-	-	4	10	10	7	5	-	-	-	12
9.5	1962	-	-	-	1	4	6	40	73	22	3	1	-	-	11
	1963	-	-	-	1	2	4	2	11	9	3	-	-	1	5
	1964	-	-	-	1	-	-	-	-	-	-	-	-	-	-
7.6	1962	-	-	1	3	18	46	68	62	15	2	1	-	-	15
	1963	-	-	-	3	1	2	3	2	2	1	-	-	-	2
	1964	-	-	-	1	10	1	4	1	2	-	-	-	-	3
5.1	1962	1	-	14	31	7	2	6	4	-	-	-	-	-	1
	1963	3	-	8	12	5	2	-	2	-	-	-	-	-	-
	1964	-	1	13	37	4	2	1	-	-	-	-	-	-	1
3.8	1964	2	9	3	2	-	-	-	-	-	-	-	-	-	-

TABLE A-IX. The age distribution of walleyes in each mesh fished in Moose Lake (1962 - 1964) and the number of walleyes to which ages were not assigned.

Mesh (cm - stretched measure)	Year of collection	Number of fish in age group - 0	I	II	III	IV	V	VI	VII	VIII	IX	X	Number not aged
13.3	1963	-	-	-	-	-	-	-	3	-	-	-	-
12.7	1962	-	-	-	-	-	-	-	-	-	-	-	-
	1963	-	-	-	-	-	-	-	-	-	-	-	1
	1964	-	-	-	1	-	-	-	-	-	-	-	-
12.1	1962	-	-	-	-	-	-	1	-	-	-	-	-
	1963	-	-	1	-	-	1	1	-	-	-	-	1
	1964	-	-	-	1	-	-	-	-	-	-	-	-
10.8	1962	-	1	-	-	-	2	9	2	2	-	-	2
	1963	-	-	-	-	-	-	4	8	1	-	-	1
	1964	-	-	1	1	3	6	7	3	3	-	-	8
9.5	1962	-	-	-	-	-	1	2	1	1	-	-	-
	1963	-	-	-	-	1	5	5	15	15	1	1	16
	1964	-	-	-	-	-	15	3	2	-	-	-	2
7.6	1962	-	-	-	-	1	1	3	-	-	-	-	-
	1963	-	-	-	-	9	4	9	7	1	-	-	7
	1964	-	-	1	12	60	20	7	-	1	-	-	7
5.1	1963	-	1	24	31	7	8	-	2	-	-	-	4
	1964	-	6	19	21	24	3	-	-	1	-	-	4
3.8	1963	-	1	2	1	1	-	-	-	-	-	-	-
	1964	1	28	5	3	4	2	-	-	-	-	-	2

TABLE A-X. The age composition of 160 walleyes sampled from the commercial fishery on Cedar Lake on June 22 and 23, 1962, and the number of walleyes to which ages were not assigned.

Number of fish in age group -							Number
III	IV	V	VI	VII	VIII	IX	not aged
1	15	60	55	25	3	1	38

TABLE A-XI. Frequency distribution of fork lengths (expressed in inches) for 295 Cedar Lake walleyes sampled from the commercial fishery in June and July, 1961. (Data from L. A. Sunde)

Class interval of fork length	Frequency
11.0 - 11.4	1
11.5 - 11.9	3
12.0 - 12.4	10
12.5 - 12.9	4
13.0 - 13.4	9
13.5 - 13.9	18
14.0 - 14.4	38
14.5 - 14.9	43
15.0 - 15.4	47
15.5 - 15.9	48
16.0 - 16.4	34
16.5 - 16.9	15
17.0 - 17.4	12
17.5 - 17.9	5
18.0 - 18.9	4
19.0 - 19.9	2
20.0 - 20.9	1
21.0 - 21.9	-
22.0 - 22.9	-
23.0 - 23.9	1
Mean fork length	15.2 inches (386 mm)

TABLE A-XII. Frequency distribution of fork lengths (expressed in inches) for 426 Cedar Lake walleyes sampled from the commercial fishery in February, 1962. (Data from L. A. Sunde)

Class interval of fork length	Frequency
13.0 - 13.4	1
13.5 - 13.9	-
14.0 - 14.4	1
14.5 - 14.9	11
15.0 - 15.4	20
15.5 - 15.9	57
16.0 - 16.4	86
16.5 - 16.9	127
17.0 - 17.4	70
17.5 - 17.9	28
18.0 - 18.9	22
19.0 - 19.9	1
20.0 - 20.9	2
Mean fork length	16.6 inches (422 mm)

TABLE A-XIII. Frequency distribution of fork lengths (expressed in inches) for 724 Moose Lake walleyes sampled from the commercial fishery in August, 1961 (Data from L. A. Sunde)

Class interval of fork length	Frequency
10.0 - 10.4	1
. . . .	
12.0 - 12.4	5
12.5 - 12.9	9
13.0 - 13.4	27
13.5 - 13.9	54
14.0 - 14.4	55
14.5 - 14.9	81
15.0 - 15.4	104
15.5 - 15.9	110
16.0 - 16.4	94
16.5 - 16.9	60
17.0 - 17.9	54
18.0 - 18.9	32
19.0 - 19.9	16
20.0 - 20.9	12
21.0 - 21.9	2
22.0 - 22.9	4
23.0 - 23.9	4
Mean fork length	15.7 inches (399 mm)

TABLE A-XIV. The age composition of a random subsample of 120 from 295 walleyes sampled from the Cedar Lake commercial fishery in June and July, 1961.

Number of fish in age group -						
III	IV	V	VI	VII	VIII	XI
1	4	47	55	9	3	1

TABLE A-XV. The age composition of a random subsample of 120 from 426 walleyes sampled from the Cedar Lake commercial fishery in February, 1962.

Number of fish in age group -					
VI	VII	VIII	IX	X	XIII
16	71	28	3	1	1

TABLE A-XVI. The age composition of a random subsample of 120 from 375 walleyes taken by pound and trap nets at the North Arm Narrows of Moose Lake in May, 1961.

Number of fish in age group -							
V	VI	VII	VIII	IX	X	XI	XII
5	62	24	23	2	1	1	2

TABLE A-XVII. The age composition of a random subsample of 85 from 724 walleyes sampled from the Moose Lake commercial fishery in August, 1961.

Number of fish in age group -			
V	VI	VII	VIII
2	57	25	1

APPENDIX B

GROWTH ANALYSES

COMPARISON OF GROWTH RATES

The determination of growth rates of walleyes from Cedar and Moose Lakes was based on those captured by experimental gill netting in 1962 to 1964. Scale measurements from 1163 walleyes from both lakes were used in calculating past fork lengths and growth rates. All scale measurements were taken from the scale image at 22.8 magnifications. Measurements were taken along the anterior scale radius on a vertical line relative to the focus (Hile, 1954) and were marked off on manila tagboard strips.

Past fork lengths were calculated from the scales using Fraser's modification of Lea's direct proportion equation (Fraser, 1920). The equation is:

$$l_n = s_n \left(\frac{L - C.F.}{S}\right) + C.F.,$$

where l_n = the calculated fork length in the n^{th} year, s_n = the magnified distance along the anterior radius from the scale focus to the n^{th} annulus, L = the fork length at capture, S = the magnified anterior scale radius and C.F. = the correction factor or the length of the fish at the time of scale formation. The correction factor, estimated in the manner outlined by Ricker (1942), was 52 mm for both Cedar and Moose Lakes walleyes. The back-calculation of fork lengths was done with a nomograph constructed of plexiglass which could be used with the paper strips bearing the scale measurements. A description of the device used is given by Shuck (1949).

Back-calculated lengths were used to determine the annual increments of fork length attained by walleyes in both lakes. The annual increments of males and females were examined using the method described by Smith and Pycha (1961) to ascertain whether both sexes grew at the same rate. Data for the three years were combined in this analysis. Results indicated that there was no sexual dimorphism in the growth rates of walleyes in either lake. The percentage increments attained by females at each age from ages II to IX corresponded with or differed only slightly from those attained by the males (Tables B-I and B-II). Since both sexes grew at similar rates in each lake, data for males and females were not treated separately in subsequent analyses.

The average calculated fork lengths (in mm) for each age group of individual year classes represented in experimental catches from both lakes are presented in Tables B-III and B-IV. The average calculated fork lengths of walleyes of the same year class at any given age but caught in different years varied. These differences, however, were less than the differences observed between year classes (see bottom of Tables B-III and B-IV). These results, according to Hile (1941) indicate that the scale annuli have been correctly identified. Lee's phenomenon, as defined by Ricker (1942), was not evident when the calculated fork lengths for a given year class were considered.

The comparison of the growth rates of walleyes from both lakes was made using the growth transformation method (Walford, 1946).

TABLE B-I. Grand average annual increments calculated for Cedar Lake walleyes (sexes separate) of ages 1 to 10. The year classes included are: females, 1952 - 1963; males, 1953 - 1963. The increments of fork length are expressed in millimeters.

	Females				Males			
Age	No.of fish	Mean increment	Sum of means	Percentage increment	No.of fish	Mean increment	Sum of means	Percentage increment
1	381	119	-	-	302	117	-	-
2	375	60	179	50.4	301	58	175	49.6
3	358	55	234	30.7	281	52	227	29.7
4	301	48	282	20.5	254	47	274	20.7
5	271	43	325	15.2	230	43	317	15.7
6	238	40	365	12.3	196	39	356	12.3
7	160	33	398	9.0	123	33	389	9.3
8	58	30	428	7.5	30	30	419	7.7
9	16	27	455	6.3	3	33	452	7.9
10	3	19	474	4.2	-	-	-	-

TABLE B-II. Grand average annual increments calculated for Moose Lake walleyes (sexes separate) of ages 1 to 10. The year classes included are: females, 1953 - 1963; males, 1954 - 1963. The increments of fork length are expressed in millimeters.

	Females				Males			
Age	No.of fish	Mean increment	Sum of means	Percentage increment	No.of fish	Mean increment	Sum of means	Percentage increment
1	261	117	-	-	190	122	-	-
2	247	60	177	51.3	169	61	183	50.0
3	212	53	230	29.9	153	52	235	28.4
4	164	51	281	22.2	131	51	286	21.7
5	98	46	327	16.4	89	52	338	18.2
6	77	49	376	15.0	42	46	384	13.6
7	50	38	414	10.1	19	32	416	8.3
8	20	28	442	6.8	7	26	442	6.2
9	2	26	468	5.9	1	14	456	3.2
10	1	26	494	5.6	-	-	-	-

TABLE B-III. Average calculated fork lengths in millimeters for Cedar Lake walleyes (sexes combined) at the end of each year of life for each age group and arranged by year class and year of capture. The number of fish and the average observed fork lengths for each age group in each year of capture are also presented.

Year class	Year of capture	Age group	No. of fish	Length at capture	Calculated length at end of year of life									
					1	2	3	4	5	6	7	8	9	10
1952	1962	X	3	434	116	178	230	268	303	329	358	384	406	425
1953	1962	IX	7	422	112	165	210	251	286	318	353	382	406	
1954	1962	VIII	45	417	106	164	214	260	302	337	374	402		
	1963	IX	5	479	115	172	214	269	308	355	393	430	464	
1955	1962	VII	168	399	114	171	223	267	309	349	381			
	1963	VIII	14	410	110	155	200	239	280	323	361	392		
	1964	IX	4	476	110	174	227	265	314	358	396	427	460	
1956	1962	VI	131	380	118	175	228	275	319	357				
	1963	VII	15	407	108	168	218	264	311	355	388			
	1964	VIII	10	448	122	182	240	291	332	370	402	435		
1957	1962	V	52	357	122	182	240	291	333					
	1963	VI	6	414	144	200	249	306	355	396				
	1964	VII	12	436	129	189	238	292	335	378	412			
1958	1962	IV	32	328	129	192	253	301						
	1963	V	8	392	143	206	262	314	360					
	1964	VI	15	416	133	196	252	301	347	393				
1959	1962	III	35	258	110	176	233							
	1963	IV	8	320	116	178	229	286						
	1964	V	7	381	118	191	248	298	356					
1960	1962	II	15	221	114	183								
	1963	III	16	255	112	169	217							
	1964	IV	15	335	122	187	242	308						
1961	1962	I	1	150	114									
	1963	II	8	216	119	170								
	1964	III	40	251	116	168	227							
1962	1964	II	16	239	140	212								
1963	1964	I	11	178	136									
Maximum difference between age groups					22	19	27	28	34	35	35	35		
Maximum difference between year classes					38	47	62	75	80	78	59	53	58	

TABLE B-IV. Average calculated fork lengths in millimeters for Moose Lake walleyes (sexes combined) at the end of each year of life for each age group and arranged by year class and year of capture. The number of fish and the average observed fork lengths for each age group in each year of capture are also presented.

Year class	Year of capture	Age group	No. of fish	Length at capture	Calculated length at end of year of life									
					1	2	3	4	5	6	7	8	9	10
1953	1963	X	1	455	119	172	219	243	284	331	368	391	415	441
1954	1962	VIII	3	463	109	161	239	283	339	373	408	437		
	1963	IX	1	419	111	183	215	258	307	348	366	395	409	
1955	1962	VII	3	417	118	191	233	283	325	371	412			
	1963	VIII	17	420	119	167	211	249	288	340	377	405		
	1964	IX	1	508	116	177	235	282	334	398	447	468	496	
1956	1962	VI	15	435	121	187	251	302	354	406				
	1963	VII	35	417	118	168	215	258	305	359	396			
	1964	VIII	4	443	128	180	234	280	324	366	400	430		
1957	1962	V	4	393	126	192	240	290	352					
	1963	VI	19	403	117	173	223	282	336	379				
	1964	VII	4	402	128	177	215	272	319	356	386			
1958	1962	IV	1	386	101	155	226	321						
	1963	V	18	360	118	168	221	282	328					
	1964	VI	16	405	129	182	244	296	342	383				
1959	1963	IV	18	316	104	180	236	283						
	1964	V	46	361	110	182	235	284	338					
1960	1963	III	32	249	111	168	214							
	1964	IV	90	317	116	176	225	280						
1961	1962	I	1	173	113									
	1963	II	27	223	123	179								
	1964	III	39	293	130	191	254							
1962	1963	I	2	148	112									
	1964	II	26	232	120	193								
1963	1964	I	34	181	139									
Maximum difference between age groups					11	24	36	44	49	47	35			
Maximum difference between year classes					35	32	43	53	66	66	35	32		

The fork lengths at each age used in this analysis were derived by the summation of average calculated increments. Data for the three years were combined for each lake. Results revealed that the growth rates of walleyes in Cedar Lake and Moose Lake were essentially the same (Fig. B-1). The parameters obtained for Cedar Lake and Moose Lake walleyes were: $k = 0.887$, $l_\infty = 652$ mm and $k = 0.883$, $l_\infty = 658$ mm, respectively.

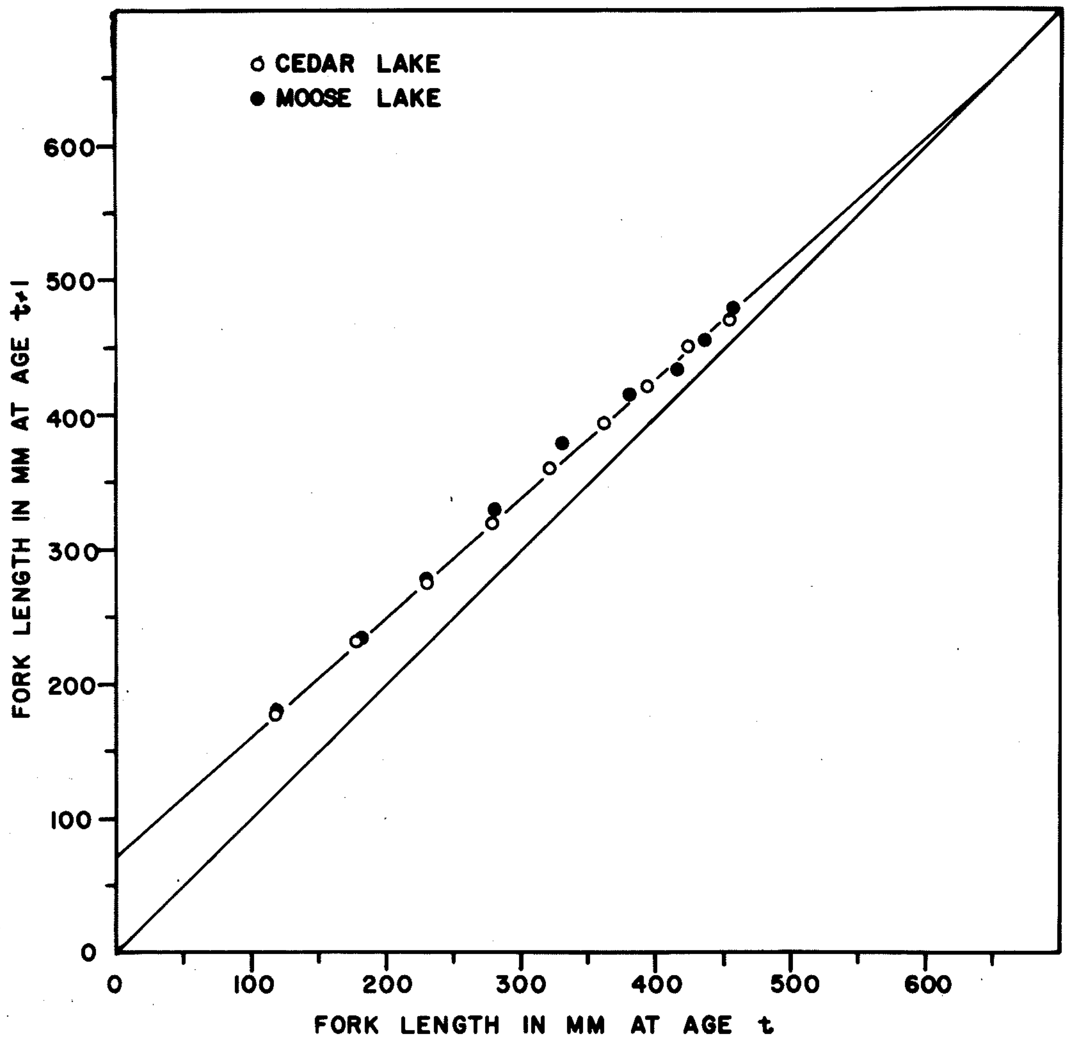

Figure B-1. The comparison of growth rates of walleyes in Cedar Lake and Moose Lake using Walford's growth transformation. The least squares regression equations for the two sets of data are: Cedar Lake, $l_{t+1} = 73.7 + 0.887\ l_t$ with $l_\infty = 652$ mm (line shown); Moose Lake, $l_{t+1} = 77.0 + 0.883\ l_t$ with $l_\infty = 658$ mm.

ANNOTATED BIBLIOGRAPHY

Included herein are the additional publications cited in Appendix B.

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