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RECRUITMENT, GROWTH, EXPLOITATION AND MANAGEMENT OF WALLEYES IN A SOUTHEASTERN WISCONSIN LAKE

By

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ABSTRACT

A population study of walleyes in 522-acre Pike Lake in southern Wisconsin was undertaken from 1959–62. Fyke nets were fished to obtain samples for growth and exploitation data while electrofishing gear was used to obtain fish for population estimates of young-of-the-year and yearlings. Petersen and Schnabel estimating methods suggested a reasonably stable recruitment of 5 to 10 young-of-the-year fish per acre in Pike Lake during the study period. Although estimates of both young-of-the-year and yearling walleyes showed a substantial mortality the second year, fluctuation in strength of the individual year classes and the variation in mortality tended to balance each other resulting in consistent recruitment of new fish to the population.

The stocking of 4 to 5 thousand fingerling fish per year contributed little to the walleye population in Pike Lake. Presence of native fish was more than 50 times that of stocked fish in subsequent samples.

Average length of samples of spawning run fish varied only 0.9 inch for males and only 0.7 inch for females over the four years, but the ranges of lengths within each age group were broad and considerably greater than the annual increments of growth. A high percentage of the male walleyes reached sexual maturity at age group III, while most females matured at age group IV. Only 4 percent of 1,994 mature males were less than 13 inches long, and only 6 percent of 840 females were mature below 16 inches in length.

Male and female walleyes grew at much the same rate the first two years; annual increments for the females then exceeded those of the males by 0.5 to 0.9 inch for the next four years, and females were larger by 2.8 inches at the end of six years. Only 3 percent of 1,994 males were over 18 inches long while 20 percent of 840 females were over 20 inches and 2 percent over 25 inches long. No male aged was over 6 years, but females were aged to age group X.

Fin clipping had no significant effect on growth, but tagging by placing aluminum strap tags on the upper jaw retarded annual growth by about 50 percent.

Walleyes in Pike Lake were exploited by anglers at the consistent annual minimum rate of 20 percent, but probably actually closer to 25 percent, while annual natural mortality did not exceed 5–10 percent.

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INTRODUCTION

Fishing survey reports point out that the walleye, *Stizostedion vitreum vitreum* (Mitchill), is the most popular large game fish in Wisconsin. It is also one of the more intensively managed warm-water species in the state.

Extensive continuing studies on the walleye have been carried on at the Northern Highland Research Station in northern Wisconsin and on Lake Winnebago and connecting lakes of the Wolf River system in east central Wisconsin. To provide comparative information for management purposes, a research program was initiated in 1957 on the walleye in southern Wisconsin waters. A portion of the program was conducted at Pike Lake, Washington County, from the spring of 1959 through the fall of 1962. This report presents the data collected at Pike Lake and their application to a walleye management program.

Primary interest at the beginning of the study was centered on the rate at which southern Wisconsin anglers were exploiting walleyes. It then became apparent the lake was an excellent facility for evaluating the survival of stocked walleye fingerlings and their contribution to an existing population. To accomplish both objectives other life history information was gathered, including fall population estimates of young-of-the-year and yearling walleyes, structure of the spawning population, and intensive age, rate of growth and maturity determinations.

STUDY AREA

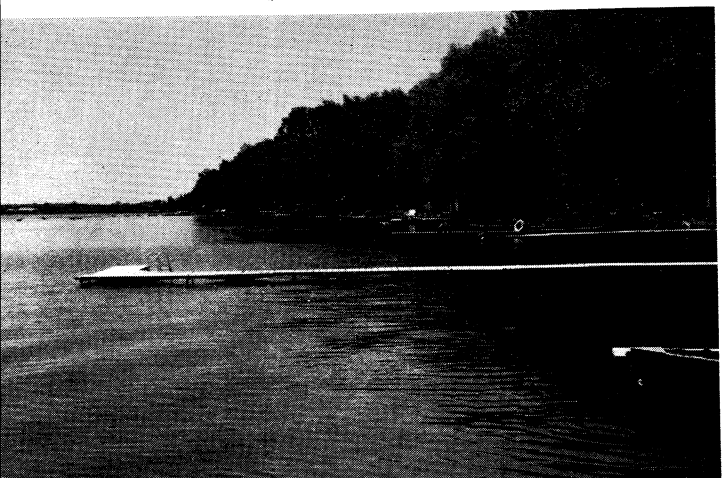
Pike Lake is situated in southeastern Wisconsin near the city of Hartford, Washington County. It was formed as a depression basin in the last drainage line of the Green Bay glacier, and covers 522 surface acres. The average depth is 13.5 feet and the maximum is 45 feet. About a third of the lake is less than 5 feet deep, and another third is over 20 feet deep.

Although the lake is only 25 miles from Lake Michigan, glaciation of the area causes drainage to the west by the small Rubicon River, which both enters and leaves the lake on the shallow north end, empties into the Rock River, and eventually drains to the Mississippi River.

Pike Lake is nearly round—1.2 miles long and 1.1 miles wide. About 40 percent of the 3.8 miles of shoreline is marshy with the remainder sand and gravel. A large portion of the lake bottom is covered by marl and is very soft in the shallow areas. Excellent spawning conditions exist for most warm-water fish species.

PIKE LAKE

Marshy shoreline.



Developed shoreline.

Because of the marshlands and the existence of two operating farms which take up the majority of the east shore, the shoreline is not highly developed. All of the presently available and suitable land has been used for summer and year-round homes, resorts, and boat liveries.

The water has an average methyl-orange alkalinity of 186 ppm, which is considered hard, and an average specific conductance of 429 micromhos. Chemical analysis of water is presented in Table 1.

Pike Lake stratifies in the summer and oxygen becomes insufficient to support fish life at depths below 25 feet. Water temperatures during this period range from 80° F. at the surface to 60° F. at 35 feet and deeper. The lake freezes over between mid-November and mid-December.

It is not known for certain that the walleye is native to the lake. Residents claim it was introduced years ago and the northern pike (*Esox lucius* Linnaeus) is the lake's namesake. In any event, the present fish population is dominated by the walleye and yellow perch (*Perca flavescens* Mitchill). Management has mainly been directed toward the walleye by extensive stockings of both fry and fingerlings. From 1933–44, over 33 million fry were stocked, an average of 2.7 million per year (Table 2). No walleye stocking was done in 1955–58, the 4 years prior to this study.

Other predator game fish are the northern pike, largemouth bass (*Micropterus salmoides* Lacepede), and an occasional smallmouth bass (*Micropterus dolomieui* Lacepede). Among the several panfish species other than the dominant yellow perch, the bluegill (*Lepomis macrochirus* Rafinesque) is most abundant. The population of the white sucker (*Catastomus commersoni* Lacepede) is large and the variety of minnows is wide.

Rough fish such as carp (*Cyprinus carpio* Linnaeus), bowfin (*Amia calva* Linnaeus), and longnose gar (*Lepisosteus osseus* Linnaeus) are common. A total of 37 fish species were identified from Pike Lake during the study period.

Despite its shallowness, Pike Lake does not have abundant aquatic vegetation. Emergent types such as cattail (*Typha* sp.) and bulrush (*Scirpus* sp.) are found along with a wide variety of other species including water lily (*Nymphea* sp.), wild celery (*Vallisneria americana*), water milfoil (*Myriophyllum* sp.), horned pondweed (*Zannechellia palustris*), bushy pondweed (*Najas flexilis*), the broadleaf pondweeds (*Potamogeton amplifolius, P. natans, P. crispus*), and the fineleaf pondweeds, (*P. gramineus, P. pectinatus,* and *P. foliosus*). Muskgrass (*Chara vulgaris*) is abundant in many areas. Blooms of filamentous algae occur during the summer.

TABLE 1

Chemical Analysis of Water from Pike Lake*

Sample Date	Specific Conductance (Mmhos)	pH	MOA (Total)	PO_4 (Total)	PO_4 (Dissolved)	NH_3-N	K-N	NO_3-N	Cl	SO_4	Ca	Mg	Na	K	Fe
May 20, 1960	422	8.3	181	0.15	0.01	0.6	0.75	0.8	6.1	12.0	29.0	26.5	3.25	1.6	0.05
June 28, 1960	408	8.2	192	0.32	0.04	0.17	0.89	0.4	6.5	25.5	25.7	31.0	3.5	1.9	0.04
July 13, 1961	473	8.2	193	0.05	0.007	0.11	----	0.2	8.2	----	----	----	----	---	----
Mean analysis	429	8.2	186	0.17	0.02	0.35	0.81	0.6	6.7	17.2	27.9	28.0	3.3	1.7	0.05

*All units other than specific conductance and pH expressed in parts per million. Data from Poff and Threinen (1962).

TABLE 2

Record of Walleyes Stocked in Pike Lake from 1933–61

Year	Size	Number
1933–44	Fry	33,391,185
1945	Fry	400,000
	Fingerling	2,000
1946	Fry	1,600,000
	Fingerling	2,080
1947	Fry	415,000
1948	Fry	415,000
1949	Fingerling	3,450
1950	Fingerling	2,356
1951		0
1952	Fingerling	16,300
1953		0
1954	Fingerling	4,100
1955–58		0
1959	Fingerling (fin-clipped)	4,909
1960	Fingerling (fin-clipped)	5,900
1961	Fingerling (fin-clipped)	4,380

Mayflys (Ephemeroptera) are extremely abundant and hatch in large numbers during June and July. Walleyes can be caught by fishing dry flies during these hatches.

The angling seasons on walleyes during the study period varied slightly but approximated May 1 to February 15. There was no minimum size limit, but a daily bag limit of 5 fish per angler was in effect.

REPRODUCTION AND RECRUITMENT

Population Estimates of Young-of-the-Year Walleyes

A 230-volt 3 phase A.C. boom shocker unit was used to collect young-of-the-year and yearling walleyes during the fall of the years 1959–62. All fishing was at night, starting at dusk and continuing until a complete tour of the lake was made. Four 150-watt flood lamps operating off a 120-volt D.C. circuit provided light. The rig was fished near the shore in water 2- to 4-feet-deep in all types of habitat, over hard bottom, soft muddy bottom, and in the weeds. The conductivity of the water was good (429 micromhos) and an effective electrical field approximately 22 feet wide required two men in the bow to dip stunned fish. Success was good even in dense stands of *Chara* sp. Fish were marked by removal of a pectoral fin (the same fin in a given year), measured to the nearest 0.1 inch, and released in deep water.

Estimates of the population were based upon marked and unmarked fish taken in subsequent sampling. Electrofishing data for the 4 years

TABLE 3

Estimates of the Population of Young-of-the-Year Walleyes

Year and Time Interval	Fish Caught (A)	Marks at Large (B)	Number Recaptures (C)	AB	Petersen Estimate (AB/C)	Cumulative AB	Cumulative C	Schnable Estimate (AB/C)
1959								
1	145							
2	99	145	15	14,355	957	14,355	15	957
3	145	229	9	33,205	3,689	47,560	24	1,982
4	155	365	10	56,575	5,657	104,135	34	3,063
5	177	510	40	90,270	2,257	194,405	74	2,627
6	38	647	4	24,586	6,146	218,991	78	2,807
7	308	681	64	209,748	3,277	428,739	142	3,019
8	179	925	41	165,575	4,038	594,314	183	3,248
9	290	1,063	68	308,270	4,533	902,584	251	3,596
10	179	1,285	54	230,015	4,259	1,132,599	305	3,713
11	248	1,410	68	349,680	5,142	1,482,279	373	3,973
1960								
1	141							
2	110	141	6	15,510	2,585	15,510	6	2,585
3	88	245	8	21,560	2,695	37,070	14	2,648
4	97	325	13	31,525	2,425	68,595	27	2,540
5	55	409	11	22,495	2,045	91,090	38	2,397
6	105	453	32	47,565	1,486	138,655	70	1,980
7	19	526	7	9,994	1,428	148,649	77	1,930
8	163	538	44	87,694	1,993	236,343	121	1,953
9	143	657	47	93,951	1,999	330,294	168	1,966
10	106	753	30	79,818	2,661	410,112	198	2,071
1961								
1	352							
2	291	352	31	102,432	3,304	102,432	31	3,304
3	548	612	87	335,376	3,854	437,808	118	3,710
4	372	1,073	96	399,156	4,158	836,964	214	3,911
5	380	1,349	95	512,620	5,396	1,349,584	309	4,367
6	260	1,634	109	424,840	3,898	1,774,424	418	4,245
7	335	1,785	135	597,975	4,429	2,372,399	553	4,290
1962								
1	321							
2	412	321	45	132,252	2,939	132,252	45	2,939
3	178	688	55	122,464	2,227	254,716	100	2,547
4	415	811	93	336,565	3,619	591,281	193	3,064
5	367	1,121	113	411,407	3,640	1,002,688	306	3,276

(1959–62) and the results of the Petersen (1896) and Schnabel (1938) estimates of the young-of-the-year walleye population are shown in Table 3.

The estimates by the two methods agree well. The differences between estimates based on the last sample in three of the years ranged from 139 to 590 fish. The difference was 1,169 fish in 1959. The Schnabel estimate was the lower every year. The final Petersen

Walleye spawning grounds at Pike Lake.

estimate for each year is used as the estimate of the population in subsequent references as it involved the greatest number of marked fish at large and because there was good indication the population was being underestimated by the Schnabel method.

The highest estimated population of young-of-the-year was 5,142 fish in 1959 and the lowest was 2,661 fish in 1960. The 1961 and 1962 estimates were 4,429 and 3,640, respectively. The number of fish per acre was 9.9 in 1959; 5.1 in 1960; 8.5 in 1961; and 7.0 in 1962.

Validation of the Estimates of Young-of-the-Year Walleyes

After the estimates of the population of young-of-the-year walleyes had been made, it was desirable to validate them to determine the accuracy of the method used.

If the estimates were exact determinations of the population, the ratio of marked to unmarked fish at the end of the sampling period should have been maintained in all subsequent collections. Since electrofishing was done each fall for four years and the marked year classes fyke netted in subsequent years, several samples of each year class marked were available for comparison. Unmarked fish that could no longer be positively aged by length were aged by the scale method.

During the first fall that a group was marked, the percentages of marked fish were generally higher than in samples of the same group taken in subsequent years (Table 4). The only exception to the trend was the 40 percent for the 1961 sample of the 1960 year class (31.2

TABLE 4

Percentage of Marked Walleyes Present in the Estimated Population of Young-of-the-Year and Subsequent Samples

Year Class	Year and Time of Sample	Method of Capture	Estimate or Sample Size	Number of Marked Fish	Percentage of Marked Fish
1959	1959 Fall	Shocker	5,142	1,590	30.9
	1960 July	Shocker	219	65	29.7
	1960 Fall	Shocker	891	215	24.1
	1961 Spring	Fyke Net	663	116	17.5
	1962 Spring	Fyke Net	258	62	24.0
1960	1960 Fall	Shocker	2,661	829	31.2
	1961 Fall	Shocker	185	74	40.0
	1962 Spring	Fyke Net	304	48	15.8
1961	1961 Fall	Shocker	4,429	1,985	44.8
	1962 Fall	Shocker	625	213	34.1

percent marked as young-of-the-year). The closest agreement was with the 1959 year class; the July 1960 percentage was 29.7 compared to the assumed percentage of 30.9.

Fyke netting of the 1959 year class in 1961 showed only 17.5 percent of the sample to be marked—13.4 percent less than the assumed percentage of 30.9. Netting the following year, however, yielded 24 percent.

Similarly, the 1962 netting of the 1960 year class showed a difference of 15.4 percent (15.8 as compared to an assumed 31.2 percent). No further data were available for this group. Why these two largest discrepancies should occur the first time the fish were netted is puzzling.

The chi-square test of the marked-unmarked ratio of young-of-the-year walleyes and the marked-unmarked ratio in succeeding catches of the same year class indicated that these ratios differed significantly at the 5 percent level for all succeeding catches but the July 1960 sample of the 1959 year class.

The lesser percentages of marked fish, with one exception, in later samples suggest possible explanations. First, all of the estimates of the young-of-the-year populations may have been slightly low. Second, it is possible that long-term survival is slightly less for marked than unmarked fish. Third, errors in estimating the age of unmarked fish in each sample may be responsible for bias in the ratios. None of these explanations alter the fact that the estimates established excellent ranges of reproductive success over the 4-year period and enabled year-to-year comparisons not available by other methods of sampling.

Estimates of the Yearling Population

Yearling populations of walleyes in 1960–62 were also sampled through electrofishing. The procedure was the same as with young-of-the-year except that yearling fish received a temporary caudal fin clip. At least 30 percent of the estimated population of yearlings were marked, with the exception of the 1962 sampling of the 1961 year class when 22.8 percent of the estimated population was caught.

The estimates from individual samples of the yearling walleyes are given in Table 5. Differences between the Petersen and Schnabel estimates of yearlings did not follow the same trend as with young-of-the-year fish where the Petersen estimate was the higher all 4 years. The final Schnabel estimate for yearlings was the higher in 2 of 3 years.

The estimates of both the young-of-the-year and yearling walleyes show a substantial loss of fish between the end of the first and the end of the second growing season. Because of the difference in results by the Schnabel and Petersen methods, both are given in Table 6 along with percentage survival from one year to the next.

The best indicated survival was 81.4 percent from the Schnabel estimates for the 1959 year class. The poorest was 19.0 percent by the

TABLE 5

Estimates of the Population of Yearling Walleyes

Year and Sample Number	Petersen Estimate	Schnabel Estimate
1960		
2	2,706	2,706
3	7,056	4,447
4	7,848	5,580
5	4,640	5,311
6	8,495	5,924
7	2,380	5,451
8	2,428	3,591
9	2,894	3,379
10	2,505	3,235
1961		
2	1,312	1,312
3	1,008	1,069
4	1,033	1,056
5	681	895
6	546	818
7	506	730
1962		
2	1,840	1,840
3	1,374	1,560
4	2,556	1,962
5	2,736	2,199

TABLE 6

Population Estimates of Young-of-the-Year and Yearling Walleyes

Year Class	Petersen Estimates			Schnabel Estimates		
	Young-of-the-Year	Yearlings	Percentage Survival	Young-of-the-Year	Yearlings	Percentage Survival
1959	5,142	2,505	48.7	3,973	3,235	81.4
1960	2,661	506	19.0	2,071	730	35.2
1961	4,429	2,736	61.7	4,290	2,199	51.2

Petersen method for the 1960 year class. Unfortunately, the two methods did not give consistent results for the three years. Both indicate that the 1960 year class had the poorest survival (35.2% by the Schnabel method and 19.0% by the Petersen) but the Schnabel method indicates the best survival (81.4% for the 1959 year class) while the Petersen method indicates best survival for the 1961 year class (61.7%).

The data as a whole do suggest, however, that substantial mortality took place from one year to the next and also that there was a great variation in the extent of this mortality. The percentage survival for the three year classes varied from 81.4 to 35.2, or a range of 46.2 percent (Schnabel estimates) or 61.7 to 19.0, for a range of 42.7 percent (Petersen method).

Some of the mortality of these fish occurred as a result of angling. In an electrofishing survey on July 19 and 20, 1960, a sample of 219 yearling fish in the 7.8 to 11.2 inch range averaged 9.5 inches long. The average in the fall of 1960 was 11.6 inches. As there was no size limit on walleyes, they could be taken by anglers as soon as they reached a length considered desirable. Walleyes over 10 inches long appear to fall in that class for many anglers. Yearling fish were subjected to nearly 2 months of angling prior to the population estimates each fall.

Combined estimates for two consecutive years of young-of-the-year and yearling walleyes are shown in Table 7. The fluctuations in strength of the individual year classes and the variation in mortality between the first fall and the second tend to balance each other, resulting in exceptionally consistent recruitment of new fish to the population.

The substantial overlapping of length ranges of the various older age groups plus the differential growth by sex further tended to provide a pool of similar-sized fish for the angler during the four years of study despite variations in year class strength and second-year survival.

TABLE 7

Combined Estimates for Two Consecutive Years of Young-of-the-Year and Yearling Walleyes

Years	Schnabel Estimates		Petersen Estimates	
	Young-of-the-Year	Yearlings	Young-of-the-Year	Yearlings
1959–60	6,044	-----	7,803	-----
1960–61	6,361	3,965	7,090	3,011
1961–62	7,566	2,929	8,069	3,242

In summary, the actual strength of the four year classes varied most modestly. The greatest variation of young-of-the-year fish was 2-fold and of yearlings only 5.4-fold. Pycha (1961) reported fluctuations well over 50-fold in ten year classes (1943–1952) of walleyes in Green Bay waters of Lake Michigan.

EVALUATION OF STOCKING WALLEYE FINGERLINGS

Walleye fingerlings were stocked in Pike Lake in October 1959, 1960 and 1961 and an additional stocking was made in August 1960. All fish in each group were marked by removal of a fin so they could be identified in future samples. Stocked fish were "pond-run" from state-operated rearing ponds. Because they were harvested late in the growing season, they were much larger than the average walleye fingerlings distributed throughout the state. The average lengths varied from 3.5 to 4.2 inches and the fish were considered to be in good condition. Dispersal of the stocked fish was rapid. They were scattered about the entire shoreline and mixed with the native fingerlings (6.3–7.4 inches, average length) and yearlings within a few days.

Because of the extremely poor survival of stocked fish, it was not possible to obtain estimates of the numbers present as yearlings. The method used to evaluate the survival of stocked fish was to determine the number of recaptures in each sample per 1,000 fish marked. This was done for both stocked fish and native fish marked during population estimates conducted about the same time the fish were stocked each fall. Excluding the August 1960 stocking of 1,900 fish, the numbers stocked varied from 4,000 to 4,909 and were 2 to 5 times the number of native fish marked each year.

Differences in the amount of effort expended either by electrofishing or fyke netting to obtain samples of native or stocked fish from previous years contributed to considerable variation in the recapture figures, but both groups received the same treatment.

The greatest number of recaptures per 1,000 stocked fish was 8.5 in the fall of 1961 from the group of 4,000 fish stocked in 1960. The other 8 samples yielded rates from zero to 1.5 recaptures per 1,000 fish stocked (Table 8). The unweighted average of all 9 samples was 1.5 recaptures per 1,000 fish stocked.

The number of recaptures per 1,000 native fish marked ranged from 38.9 to 135.2. The unweighted average of all 7 samples was 77.5 recaptures per 1,000 fish marked, better than 50 times the average of 1.5 for stocked fish.

It is obvious that fingerling stocking contributed little to the walleye population in Pike Lake. The best success attained in the three years was the fall stocking of 4,000 fingerlings in 1960. The 1961 sampling produced 34 of these fish or 8.5 recaptured per 1,000 stocked. The comparable sample of native fish produced 74 of 829 marked, or a rate of 89.3 recaptures per 1,000 marked—a return of better than 10 times that for stocked fish. Comparisons of the other groups are overwhelmingly in favor of native fish to stocked fish.

The 1960 stocking, which produced the best results, was made in the year that population estimates showed the smallest year class of native young-of-the-year walleyes for any of the four years of the study. It was also the year that survival of native fish from young-of-the-year to yearlings was the poorest of the three years for which data are available.

AGE AND GROWTH

Fyke nets of 2-inch stretched mesh, hung on 5-foot frames and with 50- to 75-foot leads, were set prior to and during the spring spawning period during each year of the study (1959–62). They were fished until desired numbers of fish were caught or the daily catches dropped to small numbers. The total catch exceeded 4,000 walleyes for various phases of the study. Total length of each fish was measured to the nearest 0.1 inch. Sex and maturity were determined by pressing on the fish's abdomen to cause it to exude either milt or eggs. Fish were designated male, female or sex unknown. The "unknowns" were assumed to be immature. As all samples were taken before growth began and under closely similar conditions, measurement of total lengths should have provided an excellent basis for comparison of the length distribution of walleyes captured at the same time but in different years.

One troublesome problem arose in the treatment of the data. All fish caught in 1959 and the majority from 1960 were tagged and were not considered a portion of the population in the samples of subsequent seasons. This exclusion was necessary because of the differ-

TABLE 8

Recaptures of Stocked and Native Walleyes

	Stocked Fish				Native Fish			
Year of Release	Number Stocked	Sampling Period	Number of Recaptures	Recaptures Per 1,000 Marked	Number Marked	Sampling Period	Number of Recaptures	Recaptures Per 1,000 Marked
1959	4,909	1960 July*	0	0.0	1,590	1960 July	65	40.9
		1960 Fall*	5	1.0		1960 Fall	215	135.2
		1961 Spring†	2	0.4		1961 Spring	116	72.9
		1962 Spring	2	0.4		1962 Spring	62	38.9
1960	1,900	1961 Fall	0	0.0	829	1961 Fall	74	89.3
		1962 Spring	2	1.1		1962 Spring	48	57.9
1960	4,000	1961 Fall	34	8.5				
		1962 Spring	6	1.5				
1961	4,380	1962 Fall	2	0.5	1,985	1962 Fall	213	107.3
			Average	1.5			Average	77.5

*The July and all fall samples taken by electrofishing.
†The spring samples taken by fyke nets.

ence in growth of tagged and untagged fish (detailed in a later section). To illustrate the consequence of this procedure, it is obvious that if all fish in a size interval were tagged in a given year, a gap in the length distribution (at a greater length) will occur the following year. The 1960 distribution would have included 368 more fish (tagged in 1959 and recaught in 1960)—an increase of 24 percent. The 1961 distribution would have been increased by 404 fish or 26

As no way could be devised to place recaught tagged fish properly percent, and the 1962 distribution by 90 fish or 13 percent.
in subsequent length distributions, they were excluded completely despite the realization that larger fish should have been represented better and average lengths in the last three samples in Table 9 should have been slightly higher.

Age and rate of growth were determined by the scale method for 646 adult walleyes for which sex data were available and 371 smaller fish for which the sex was unknown. Scales were removed from the third row above the lateral line and in the area directly below the anterior base of the dorsal fin. Impressions were made in cellulose acetate and read at a magnification X43. Measurements for the calculation of individual growth histories were made along the anterior radius most nearly collinear with the focus. The distances from the focus to each annulus and to the edge of the scale were recorded to the nearest 0.1 inch. Since all of the fish for the study of age and growth were collected during April, before annual growth had started, a virtual annulus was credited the edge of the scale. Age groups are designated in Roman numerals.

Length Distribution

The distributions of lengths for male and female fish showed the population to have a healthy length distribution in the period 1959–62 (Table 9). The annual average lengths of the males varied only 0.9-inch (from 14.8 to 15.7 inches) and those of the females only 0.7-inch (from 18.3 to 19.0 inches) over the 4 years. The average lengths of fish in the combined collections were 15.3 inches for 1,994 males and 18.6 inches for 840 females. Variation was considerably greater in the yearly average lengths of the immature fish, which ranged from 11.3 to 13.4 inches.

Only 62 of the 1,994 males (3%) were over 18 inches long and only 1 male was over 20 inches. The females grew larger; 20 percent (176 of 840 fish) were longer than 20 inches. Sixteen females, or 2 percent, were over 25 inches long.

TABLE 9 Total Length Distribution of Walleyes Caught on Spawning Runs, 1959–62

Length Interval (Inches)	Sex Unknown					Males					Females					Total
	1959	1960	1961	1962	Total	1959	1960	1961	1962	Total	1959	1960	1961	1962	Total	
9.0– 9.4	--	--	--	8	8	--	--	--	--	--	--	--	--	--	--	8
9.5– 9.9	--	--	--	40	40	--	--	--	--	--	--	--	--	--	--	40
10.0–10.4	--	--	9	76	85	--	--	--	--	--	--	--	--	--	--	85
10.5–10.9	1	--	44	84	129	--	--	1	--	1	--	--	--	--	--	130
11.0–11.4	12	1	85	56	154	1	--	--	--	1	--	--	--	--	--	155
11.5–11.9	13	1	168	26	208	1	1	4	1	7	--	--	--	--	--	215
12.0–12.4	25	2	173	22	222	5	7	15	4	31	--	--	--	--	--	253
12.5–12.9	16	5	86	12	119	14	4	17	5	40	--	--	--	--	--	159
13.0–13.4	3	5	43	12	63	39	18	15	24	96	--	--	--	--	--	159
13.5–13.9	13	3	5	8	29	74	19	9	39	141	--	--	--	--	--	170
14.0–14.4	11	--	1	14	26	101	35	15	43	194	1	--	--	--	1	221
14.5–14.9	8	1	1	17	27	107	80	35	35	257	6	--	--	--	6	290
15.0–15.4	3	1	--	11	15	78	127	38	30	273	7	6	2	1	16	304
15.5–15.9	1	3	1	5	10	91	118	48	24	281	15	6	5	3	29	320
16.0–16.4	--	--	1	1	2	60	121	40	13	234	22	23	3	2	50	286
16.5–16.9	--	--	--	1	1	49	83	35	16	183	28	35	16	6	85	269
17.0–17.4	--	--	--	--	--	25	56	28	7	116	27	56	14	5	102	218
17.5–17.9	--	--	--	--	--	22	34	16	5	77	24	52	18	8	102	179
18.0–18.4	--	--	--	--	--	8	12	11	3	34	15	58	16	4	93	127
18.5–18.9	--	--	--	--	--	8	6	4	2	20	11	30	20	10	71	91
19.0–19.4	--	--	--	--	--	3	2	--	1	6	11	30	15	7	63	69
19.5–19.9	--	--	--	--	--	1	--	--	--	1	7	24	14	1	46	47
20.0–20.4	--	--	--	--	--	1	--	--	--	1	2	16	10	8	36	37
20.5–20.9	--	--	--	--	--	--	--	--	--	--	7	7	7	1	22	22
21.0–21.4	--	--	--	--	--	--	--	--	--	--	6	9	7	1	23	23
21.5–21.9	--	--	--	--	--	--	--	--	--	--	3	12	2	4	21	21
22.0–22.4	--	--	--	--	--	--	--	--	--	--	2	9	4	1	16	16
22.5–22.9	--	--	--	--	--	--	--	--	--	--	3	5	2	4	14	14
23.0–23.4	--	--	--	--	--	--	--	--	--	--	5	1	--	--	6	6
23.5–23.9	--	--	--	--	--	--	--	--	--	--	1	2	1	--	4	4
24.0–24.4	--	--	--	--	--	--	--	--	--	--	6	5	--	2	13	13
24.5–24.9	--	--	--	--	--	--	--	--	--	--	4	1	--	--	5	5
25.0–25.4	--	--	--	--	--	--	--	--	--	--	1	4	2	--	7	7
25.5–25.9	--	--	--	--	--	--	--	--	--	--	1	3	1	1	6	6
26.0–26.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26.5–26.9	--	--	--	--	--	--	--	--	--	--	1	--	--	--	1	1
27.0–27.4	--	--	--	--	--	--	--	--	--	--	1	--	--	--	1	1
27.5–27.9	--	--	--	--	--	--	--	--	--	--	1	--	--	--	1	1
Number of fish	106	22	617	393	1,138	688	723	331	252	1,994	218	394	159	69	840	3,972
Average length	12.8	13.4	12.0	11.3	11.8	15.2	15.7	15.4	14.8	15.3	18.3	18.7	18.7	19.0	18.6	15.1

Length Distribution of the Age Groups

Data for the length-frequency distribution of the age groups of walleyes of known sex were obtained by combining the samples from 1959, 1960, and 1962. All of the fish of unknown sex and presumably immature were collected in 1962. As growth for the year had not started, lengths are actual measurements at time of capture.

The distribution of total lengths of walleyes in various age groups is shown in Table 10. The length ranges within each well-represented age group were broad (from 2.9–5.4 inches) and were considerably greater than the annual increments of growth. Also, distributions of adjacent age groups overlapped considerably for both sexes. At any 0.5-inch interval from 14.0 to 18.4 inches, a male could have been from 2, 3 and at one interval, 4 different age groups. Females from any 0.5-inch intervals from 15.5 to 22.4 inches could have been from either 2 or 3 age groups.

It was mentioned previously that few males were longer than 18 inches. No male aged was over 6 years old. Apparently this age represents the average life expectancy in these waters under current angling and natural mortality. Females were aged to age group X, although scales from fish older than age group VII were difficult to read and many were discarded.

Age and Size at Maturity

Samples taken during the spawning runs provided data on attainment of sexual maturity. These samples contained large numbers of immature fish in 1961 and 1962, but relatively few in 1959 and 1960. With no sex data from these fish, it is not possible to give precise information as to the percentages of mature and immature individuals at different sizes and ages by sex.

Generally, male walleyes mature at age group III (Table 10); however, the capture of some mature age group II males, among finclipped fish of known age, demonstrated exceptions.

An extremely high percentage of the male walleyes attained maturity in Pike Lake as age group III. The presence of only two immature age group IV fish in the collections and the recording of only 81 immature fish at lengths above 14 inches during the four spring samplings would indicate that nearly all males were mature at age group III.

Females were only rarely mature at age group III (only 1.9% of the sample of 203 mature females fell into this group), but 48 percent of the total females sampled were mature at age group IV. The lack of immature age group IV fish in the collection and the small

TABLE 10 Total Length Distribution of Walleyes in Age Groups Caught on Spawning Runs, 1959, 1960 and 1962

Length Interval (Inches)	Unknown			Males				Females							
	II	III	IV	III	IV	V	VI	III	IV	V	VI	VII	VIII	IX	X
9.0– 9.4	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9.5– 9.9	40	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10.0–10.4	75	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10.5–10.9	81	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11.0–11.4	54	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11.5–11.9	24	--	--	1	--	--	--	--	--	--	--	--	--	--	--
12.0–12.4	15	6	--	2	--	--	--	--	--	--	--	--	--	--	--
12.5–12.9	7	4	--	7	--	--	--	--	--	--	--	--	--	--	--
13.0–13.4	--	11	--	30	--	--	--	--	--	--	--	--	--	--	--
13.5–13.9	--	8	--	47	--	--	--	--	--	--	--	--	--	--	--
14.0–14.4	--	8	--	61	3	--	--	--	--	--	--	--	--	--	--
14.5–14.9	--	11	2	61	6	--	--	--	--	--	--	--	--	--	--
15.0–15.4	--	8	--	38	11	--	--	1	--	--	--	--	--	--	--
15.5–15.9	--	5	--	12	46	2	--	1	3	--	--	--	--	--	--
16.0–16.4	--	1	--	1	38	3	--	2	8	--	--	--	--	--	--
16.5–16.9	--	1	--	1	13	18	2	--	21	1	--	--	--	--	--
17.0–17.4	--	--	--	--	6	11	--	--	20	2	--	--	--	--	--
17.5–17.9	--	--	--	--	--	14	1	--	19	6	1	--	--	--	--
18.0–18.4	--	--	--	--	2	4	--	--	17	11	--	--	--	--	--
18.5–18.9	--	--	--	--	--	--	1	--	9	15	1	--	--	--	--
19.0–19.4	--	--	--	--	--	--	1	--	--	13	3	--	--	--	--
19.5–19.9	--	--	--	--	--	--	--	--	--	5	4	--	--	--	--
20.0–20.4	--	--	--	--	--	--	--	--	--	2	5	2	--	--	--
20.5–20.9	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--
21.0–21.4	--	--	--	--	--	--	--	--	--	--	2	1	--	--	--
21.5–21.9	--	--	--	--	--	--	--	--	--	--	4	2	--	--	--
22.0–22.4	--	--	--	--	--	--	--	--	--	--	4	1	--	--	--
22.5–22.9	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--
23.0–23.4	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--
23.5–23.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24.0–24.4	--	--	--	--	--	--	--	--	--	--	--	1	1	--	--
24.5–24.9	--	--	--	--	--	--	--	--	--	--	--	--	3	1	--
25.0–25.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25.5–25.9	--	--	--	--	--	--	--	--	--	--	--	--	1	1	--
26.0–26.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26.5–26.9	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
27.0–27.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
27.5–27.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
No. fish	306	63	2	261	125	52	5	4	97	55	29	9	6	2	1
Average length	10.5	14.1	14.5	14.2	15.9	17.1	18.0	15.9	17.9	18.7	20.8	21.9	25.0	25.1	27.6
Percent	82.4	17.0	0.6	58.9	28.2	11.7	1.2	1.9	47.9	27.1	14.3	4.4	2.9	1.0	0.5

numbers of large-sized immature fish taken in the four spring samplings indicate most females mature at age group IV.

Information on the size of walleyes at first maturity can be obtained from the catch of mature walleyes during the spawning runs (Table 9). No mature fish smaller than 10.5 inches in length were caught. A total of 80, or 4 percent of the sample of 1,994 males, were less than 13 inches long. Only 6 percent (52 of 840) of the females were mature at a length below 16 inches.

Length–Weight Relation

The majority of the measurements used in determining the relationship between length and weight were from fish obtained by electrofishing in early fall in 1961 and 1962. Some length and weight measurements were also taken of walleyes caught by anglers from May through September.

Hile (1954) stated: "Annual and seasonal fluctuations in the length–weight relation and variations related to sex, maturity, and state of organs have been observed so frequently that their occurrence can be accepted as general." He suggested that to arrive at a general length–weight relation the most satisfactory procedure was to combine all available data. This procedure was followed for the Pike Lake walleye in the preparation of Table 11.

The length–weight equation for the Pike Lake walleye was derived by fitting a straight line by least squares to the logarithms of the average lengths and weights. The logarithmic form used to compute the weights (grams were converted to ounces for the table) was: $\text{Log } W = 3.15399 \log L - 1.00949$, when W = weight in grams, and L = total length in inches.

The agreement between the empirical and calculated weights was fairly good (Table 11 and Fig. 1). The difference between the two did not exceed 0.5 ounces in the 23 intervals between 4.7 and 15.7 inches (corresponding range in weight 0.5 to 20.7 ounces). The greatest discrepancy at any length was at 23.2 inches where the actual weight of the single fish exceeded the theoretical value by 2.8 ounces.

Computed total lengths corresponding to selected weights of the Pike Lake walleye were 1 lb., 14.5 inches; 2 lbs., 18.1 inches; 3 lbs., 20.5 inches; 5 lbs., 24.2 inches; and 10 lbs., 30.1 inches.

Calculated Growth

Several studies have shown that calculation of linear growth of walleyes by direct proportion is unsatisfactory and that a body–scale relation must be determined. The body–scale relations of Carlander's (1945) Lake of the Woods and Eschmeyer's (1950) Michigan's Lake

TABLE 11

Length–Weight Relation of Walleyes

No. Fish	Total Length*	Weight (Ounces)	
		Calculated	Empirical
2	4.7	0.5	0.5
40	5.2	0.6	0.7
121	5.7	0.9	0.9
125	6.2	1.1	1.2
125	6.7	1.4	1.5
100	7.2	1.8	1.8
21	7.7	2.2	2.1
16	8.2	2.7	2.7
22	8.7	3.2	3.3
48	9.2	3.9	3.9
73	9.7	4.5	4.5
101	10.2	5.3	5.3
57	10.7	6.2	5.8
37	11.2	7.1	6.6
27	11.7	8.2	8.0
19	12.2	9.3	9.1
20	12.7	10.6	10.6
33	13.2	12.0	12.2
39	13.7	13.5	13.5
42	14.2	15.1	15.2
46	14.7	16.8	17.0
41	15.2	18.7	18.7
29	15.7	20.7	20.2
26	16.2	22.8	22.1
13	16.7	25.1	24.0
26	17.2	27.6	27.9
11	17.7	30.2	30.1
12	18.2	32.9	32.2
14	18.7	35.9	35.6
4	19.2	39.0	37.2
6	19.7	42.3	40.0
6	20.2	45.8	45.3
4	20.7	50.6	50.8
2	21.2	53.3	53.7
3	21.7	57.4	55.6
	22.2	60.8	----
2	22.7	66.1	65.3
1	23.2	70.8	73.6
	23.7	74.8	----
	24.2	79.8	----
	24.7	85.1	----

*Mid-point of 0.5-inch intervals.

Gogebic walleyes were both sigmoid curves. However, for his study of the Saginaw Bay (Lake Huron) walleye, Hile (1954) used Deason's unpublished work on the Lake Erie population where the relation was a straight line intersecting the axis of fish length at a standard length of 50 mm (2.0 inches).

The body–scale relation for the present study was derived by fitting a straight line by least squares to the means of average lengths and

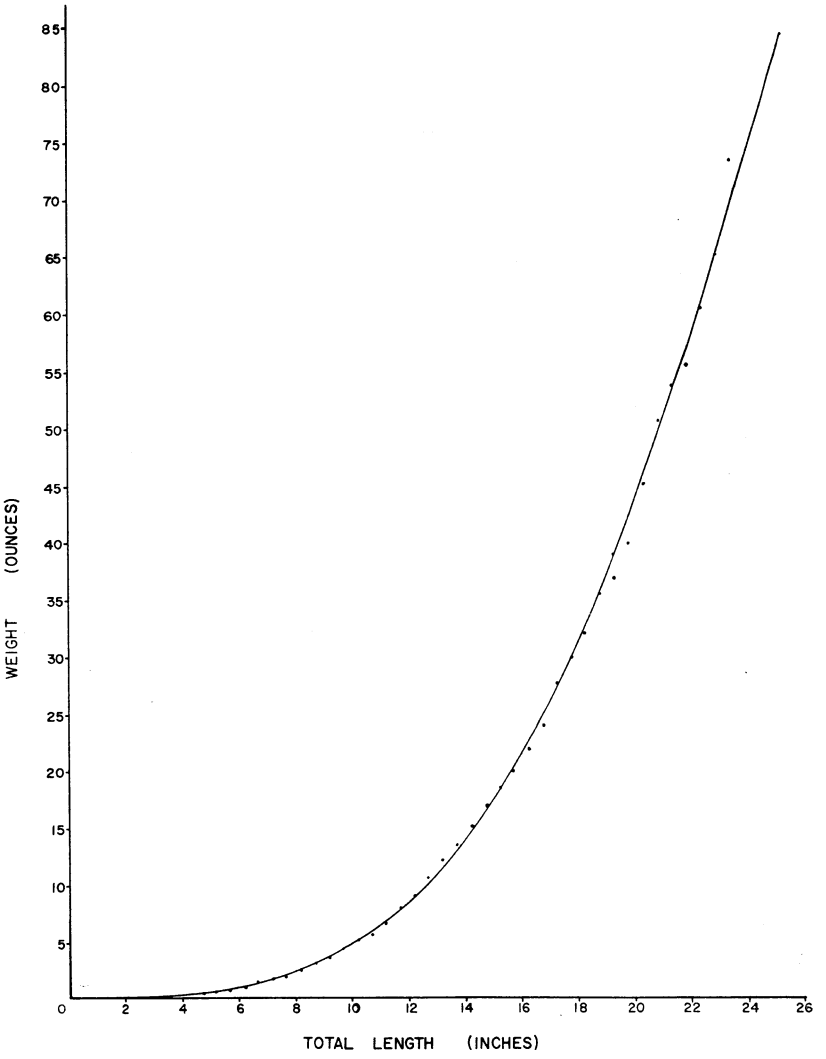


Figure 1. Length–weight relation of the Pike Lake walleye. Dots represent empirical data from Table 5. The smooth curve is derived from the length–weight equation given in the text.

scale radii from 746 fish, using this equation: $L = 2.0281 + 2.7575\ S$, where L = total length in inches, and S = scale radius (x43) in inches. A nomograph of the type described by Hile (1950), with an intercept of 2 inches on the axis of fish length, was used for calculations of growth.

Random samples of fish of both sexes were taken from the collections made on the spawning runs in 1959 and 1960. In 1962 all fish

TABLE 12

Relation Between Body Length and the Radius of Scales

No. Fish	Total Length (Inches)	Scale Radius (Inches X43)	Body Scale Ratio	No. Fish	Total Length (Inches)	Scale Radius (Inches X43)	Body Scale Ratio
1	5.3	1.6	3.31	55	14.2	4.5	3.15
1	5.6	1.2	4.66	51	14.7	4.6	3.19
18	6.2	1.6	3.87	39	15.2	4.5	3.37
10	6.7	1.7	3.94	30	15.7	4.8	3.27
10	7.2	1.9	3.78	16	16.2	5.2	3.11
11	7.7	2.0	3.85	22	16.7	5.4	3.10
6	8.3	2.2	3.77	12	17.2	5.7	3.01
3	8.8	2.5	3.52	11	17.6	6.2	2.84
8	9.2	2.6	3.54	7	18.2	5.6	3.25
40	9.7	2.8	3.47	12	18.7	6.3	3.00
76	10.2	3.0	3.40	7	19.2	6.4	3.00
80	10.7	3.1	3.45	7	20.2	6.8	2.97
54	11.2	3.2	3.50	1	20.7	6.7	3.09
26	11.7	3.4	3.44	1	21.2	6.8	3.11
24	12.2	3.5	3.48	4	21.6	6.6	2.67
16	12.7	3.9	3.26	1	22.3	8.1	3.21
35	13.2	4.1	3.22	3	22.8	7.1	3.21
45	13.7	4.4	3.11	2	24.2	7.3	3.31
				1	24.7	8.3	2.97

caught were sampled. All collections were combined to obtain a general growth curve (Table 12 and Fig. 2). The calculated lengths of the various age groups, are shown for males in Table 13 and for females in Table 14, and illustrated for each sex in Figure 3. Estimates of general growth were based on the sums of average increments of the previous tables.

Male and female Pike Lake walleyes grew at much the same rate the first 2 years when differences between sexes at calculated lengths were only 0.2 inch. Annual increments for the females then exceeded those of the males by 0.5 to 0.9 inch for the next 4 years; females were the larger by 2.8 inches (21.3 compared to 18.5 inches) at the end of 6 years. This nearly equal growth by the sexes the first 2 years and then substantially faster growth of females, starting in the third year, was also reported by Eschmeyer (1950), Hile (1954) and Carlander and Whitney (1961).

The fine internal agreement in the growth data presented in Tables 13 and 14 show that the calculated lengths for the age groups give no evidence of Lee's (1912) phenomenon of decrease of growth rate with increase in the age of the fish for which lengths are computed.

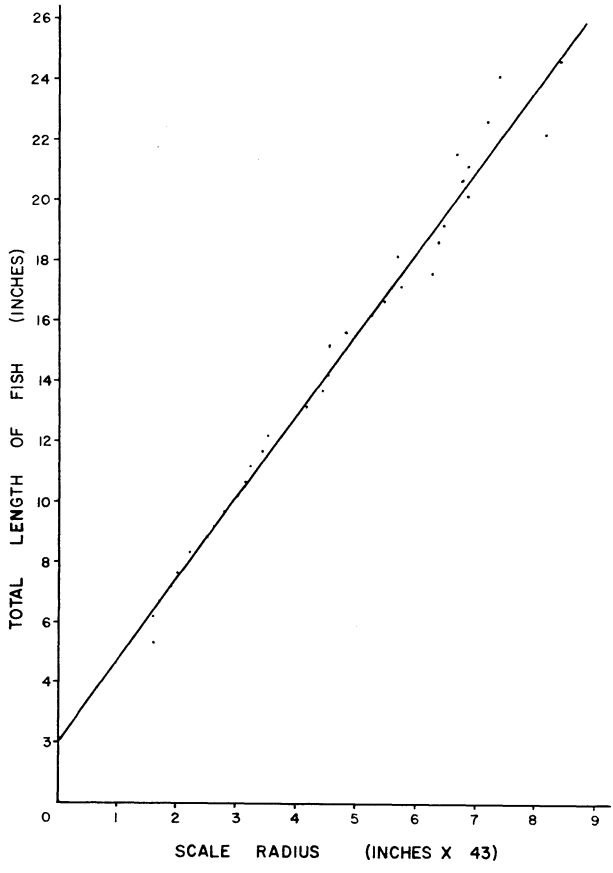


Figure 2. Relation between total length of fish and magnified (X 43) scale radius. The dots show the empirical data; the slope of the line is the mean body–scale radio.

TABLE 13

Calculated Total Length (Inches) of Male Walleyes

Age Group	No. Fish	Calculated Length at End of Year of Life					
		1	2	3	4	5	6
III	261	6.8	11.5	14.2*	----	----	----
IV	125	6.7	11.1	14.0	15.9*	----	----
V	52	6.6	10.8	13.8	15.5	17.1*	----
VI	5	6.8	12.3	14.0	15.9	17.0	18.0*
Grand average calculated length		6.8	11.3	14.1	15.8	17.0	18.0
Increment of average		6.8	4.5	2.8	1.7	1.2	1.0
Grand average increment of length		6.8	4.5	2.8	1.9	1.5	1.0
Sum of average increments		6.8	11.3	14.1	16.0	17.5	18.5

*Length at time of capture.

TABLE 14

Calculated Total Length (Inches) of Female Walleyes

Age Group	No. Fish	Calculated Length at End of Year of Life									
		1	2	3	4	5	6	7	8	9	10
III	4	7.2	12.4	15.9*	----	----	----	----	----	----	----
IV	97	7.2	11.9	15.2	17.9*	----	----	----	----	----	----
V	55	7.1	11.2	14.3	16.7	18.7*	----	----	----	----	----
VI	29	7.0	11.1	14.4	17.0	19.0	20.8*	----	----	----	----
VII	9	6.7	10.7	14.2	16.9	18.9	20.5	21.9*	----	----	----
VIII	6	7.6	11.7	15.3	17.9	20.7	22.6	23.9	25.0*	----	----
IX	2	7.6	11.2	15.0	17.6	18.6	21.4	22.7	23.8	25.1*	----
X	1	6.0	12.2	14.6	17.2	19.4	21.8	23.8	25.4	26.8	27.6*
Grand average calculated length		7.0	11.5	14.8	17.3	18.9	21.0	22.6	24.8	25.7	27.6
Increment of average		7.0	4.5	3.3	2.5	1.6	2.1	1.6	2.2	0.9	1.9
Grand average increment of length		7.0	4.5	3.3	2.5	2.1	1.9	1.4	1.1	1.3	0.8
Sum of average increments		7.0	11.5	14.8	17.3	19.4	21.3	22.7	23.8	25.1	25.9

*Length at time of capture.

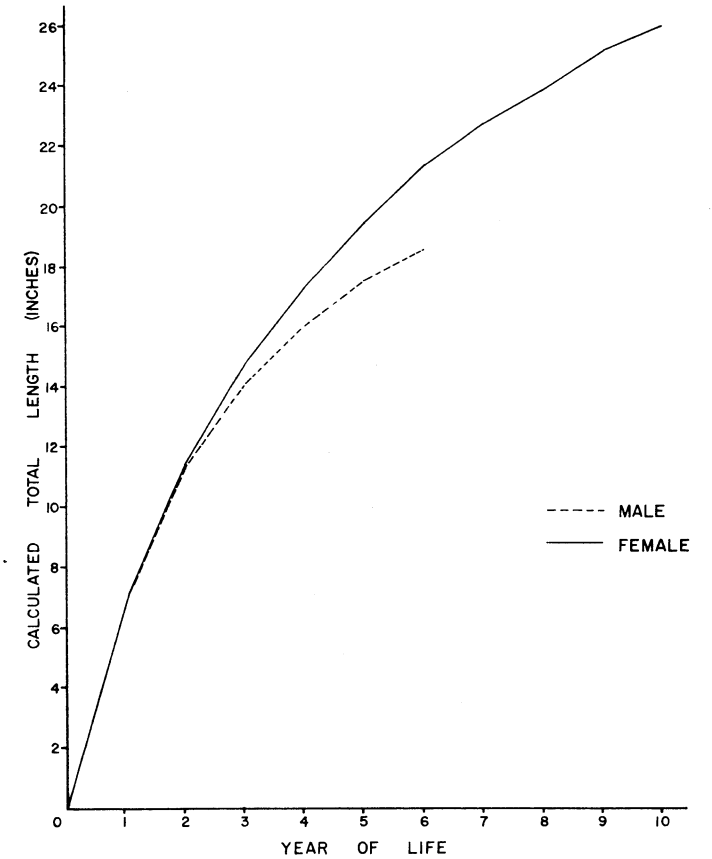


Figure 3. Calculated general growth in length of male and female walleyes.

Fluctuation of Growth of Young-of-the-Year and Yearlings

A study of first-year growth was based on the measurements of 5,791 young-of-the-year fish collected during the fall in 1959–62. The greatest first year's growth was 7.4 inches in 1959, and the poorest was 6.3 inches in 1961 (Table 15). The average for the 4 years was 6.9 inches, which is between the calculated first-year lengths of 6.8 inches for males and 7.0 inches for females (see Tables 13 and 14).

Total growth through the first and second years was determined empirically for three year classes (1959, 1960 and 1961). Actual measurements of lengths were made of 502 fish fin-clipped as young-of-the-year and recaptured as yearlings the following fall. Here again growth varied considerably and the average lengths of year classes at 2 years ranged from 9.9 to 11.6 inches (Table 16).

TABLE 15

Distribution (Total Length in Inches) of Young-of-the-Year Walleyes Caught by Electrofishing in the Fall

Length Interval	Year of Capture				
	1959	1960	1961	1962	Total
4.5–4.9	-------	-----	3	-------	3
5.0–5.4	2	1	65	14	82
5.5–5.9	13	10	382	84	489
6.0–6.4	61	75	814	316	1,266
6.5–6.9	226	198	510	467	1,401
7.0–7.4	459	245	176	363	1,243
7.5–7.9	538	193	29	135	895
8.0–8.4	253	100	6	8	367
8.5–8.9	36	7	-------	-------	43
9.0–9.4	2	-----	-------	-------	2
Number of Fish	1,590	829	1,985	1,387	5,791
Average Length	7.4	7.2	6.3	6.7	6.9

The year 1961 was apparently a very poor year for growth of both young-of-the-year and yearling walleyes in Pike Lake. First-year growth was poorest (6.3 inches) as was also the second year increment (2.9 inches) during the 4-year study period.

TABLE 16

Distribution (Total Length in Inches) of Yearling Walleyes Caught by Electrofishing in the Fall

Length Interval	Year of Capture			
	1960	1961	1962	Total
8.0– 8.4	-----	----	3	3
8.5– 8.9	-----	8	10	18
9.0– 9.4	1	8	35	44
9.5– 9.9	4	14	64	82
10.0–10.4	9	22	60	91
10.5–10.9	35	10	29	74
11.0–11.4	47	8	10	65
11.5–11.9	57	2	2	61
12.0–12.4	39	2	-----	41
12.5–12.9	14	----	-----	14
13.0–13.4	8	----	-----	8
13.5–13.9	1	----	-----	1
Number of Fish	215	74	213	502
Average Length	11.6	10.1	9.9	10.6

Effect of Fin-Clipping on Growth

Since all of the 5,791 young-of-the-year fish sampled for growth studies were marked by removing a pectoral fin, the effect on growth rate was investigated. The removal of a pectoral fin from 5- to 9-inch walleyes from the 1959 year class (age group III in 1962) had no significant effect on their growth during the first 3 years of life (Table 17). The maximum difference was 0.2 inches (11.5 and 11.7), favoring the unmarked males at the end of the second year of life.

TABLE 17

Effect of Pectoral Fin Removal on Growth

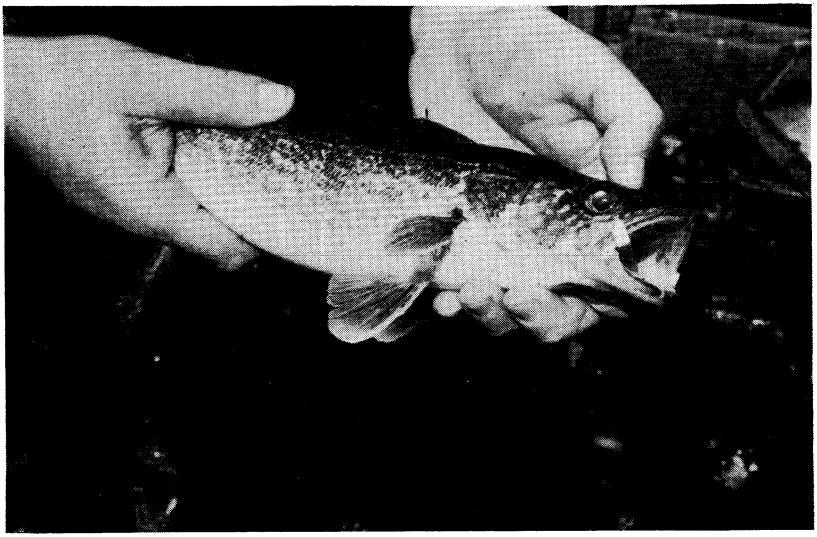
Condition and Sex	No. Fish	Length at End of Year of Life		
		1	2	3
Male				
Marked	42	7.0	11.5	14.1
Unmarked	149	7.1	11.7	14.2
Unknown				
Marked	20	6.9	11.3	14.0
Unmarked	43	6.9	11.3	14.1

Churchill (1963) studied the effect of fin removal on survival, growth, and vulnerability to capture of stocked walleye fingerlings in Nebish Lake, Vilas County, Wisconsin. He concluded that removal of one fin (a left pelvic or pectoral) from 3-inch pond-reared walleyes had no significant effect on either survival or growth.

Effect of Tagging on Growth

Aluminum strap tags 0.2 inches wide and 2.0 inches long (before bending for attachment) were placed on the upper jaw of 2,065 walleyes during the spring in 1959 and 1960. Sex and length to the nearest 0.1 inch were recorded for all fish. Subsequent netting recaptured tagged fish exactly 1 or 2 years after they were tagged; these fish were again measured to the nearest 0.1 inch. Some of the tagged fish showed no increase in length and it was apparent that the tagged group as a whole was not growing at a normal rate.

Usable data on retardation of growth by tagging were available from 763 tagged fish. The recaptured fish were placed in groups that had an average length at time of tagging identical to the calculated growth rate for the Pike Lake walleye at the end of various years of



Tagged walleye.

life. The average lengths of the groups one and two years after tagging were determined and the annual increments compared to the anticipated annual increments determined from the calculated general growth rate.

Excluding the comparison for females at 22.7 inches, where data were available from only one fish, the growth retardation at the end of one year was similar for males and females. Retardation was progressive; the smaller and faster-growing fish suffered the least (the ratio of observed to expected increments was 0.71 for the males at 11.3 inches, and 0.72 for females at 14.8 inches) and the larger fish the most (ratio of 0.30 for males at 17.5 inches and 0.35 for females at 21.3 inches). Females in the 23.8-inch and larger groups showed no growth at all (Table 18).

The trends for males and females at the end of 2 years were also similar; the smallest size groups showed the least effect. The progressive decline was not as uniform as at the end of one year but for both sexes the ratios of observed to expected 2-year increments fell in the narrow range of 0.40 to 0.50 for three groups each. Again no growth was found in the very large fish.

If data are restricted to the groups that exhibited an increase in length, the average of the ratio of increments for males was 0.48 at the end of one year and 0.49 at the end of 2 years. The average ratio for females was 0.59 at both the end of one and 2 years. Obviously, the aluminum strap tag attached to the lower jaw retarded the growth of these fish by approximately 50 percent.

TABLE 18

Comparison of Expected and Observed Annual Increments of Growth of Tagged Walleyes

Length at Tagging (Inches)	Expected 1-Year Increment (A)	Observed 1-Year Increment (B)	Ratio of Increments (B/A)	Expected 2-Year Increment (C)	Observed 2-Year Increment (D)	Ratio of Increments (D/C)
Males						
11.3	2.8	2.0	0.71	4.7	3.0	0.64
14.1	1.9	1.1	0.58	3.4	1.7	0.50
16.0	1.5	0.5	0.33	2.5	1.0	0.40
17.5	1.0	0.3	0.30	1.0+	0.4	0.40
Females						
14.8	2.5	1.8	0.72	4.6	3.5	0.76
17.3	2.1	1.1	0.52	4.0	1.6	0.40
19.4	1.9	1.0	0.53	3.3	1.6	0.48
21.3	1.4	0.5	0.35	2.5	1.2	0.48
22.7	1.1	0.9	0.82	2.4	2.0	0.83
23.8	1.3	0.0	0.00	2.1	0.0	0.00
25.1	0.8	0.0	0.00	0.8+	0.0	0.00

Eschmeyer and Crowe (1955) observed that walleyes marked with a No. 3 jaw tag grew on the average only 62.9 percent of normal.

ANGLER EXPLOITATION

To obtain a reasonable estimate of rates of exploitation by anglers, 2,065 walleyes were tagged in the springs of 1959 and 1960 during netting operations. The tagging program was given extensive publicity through news releases to local papers, posters placed about the lake, and a form letter to each resident on the rural mail route in the vicinity of Pike Lake. Most valuable probably was the assistance from several boat-livery operators who served as collecting agents at the lake, for a large majority of the tags returned to us came through them.

A voluntary creel census was designed primarily to encourage anglers to leave tags with the cooperators but also to obtain some information on the total number of walleyes caught. Coin envelopes were left with boat-livery operators who were asked to fill in the date, number of untagged walleyes caught, and place tags, if the angler had any, in the envelopes.

Such a voluntary creel census suffered from the normal disadvantage of this type of program, namely reaching only a portion of the actual number of anglers fishing on the lake, varied interest, and biased reporting. As the system was designed to encourage the

reporting of tags, data on the number of untagged fish captured were of questionable accuracy. It was not uncommon to find envelopes containing 10 or 15 tags that an angler had accumulated over a period of several weeks but without mention of the numbers of untagged fish caught.

Reported Catch

Anglers reported catching 1,277 walleyes in 1959; 1,308 in 1960; 761 in 1961; and 438 in 1962 for a total of 3,784 over the 4 angling seasons. The reported catch, which is the minimum for this period, averaged 1.8 fish per acre per year.

Differential Catch Rate

Data obtained from the 1959 tagging series showed that over the first 5 years the tagged fish were at large, 52.2 percent of the females and 44.1 percent of the males were caught. The 1960 series after 4 years also showed that females were caught at a higher rate but the difference was not nearly as great—41.2 percent for females and 39.2 percent for males (Table 19). This is in line with findings in other states. Olson (1958) assumed about equal vulnerability to the angler of males and females on the basis of 22.6 percent return for females and 20.3 percent for males in a Minnesota lake. Data from the small catches by anglers from the commercially fished walleye population in Minnesota's Red Lakes also showed that females were caught at a slightly greater rate than males (Smith, Krefting, and Butler, 1952).

The relation between catch rate and size is also shown in Table 19. Recoveries from male fish tagged in 1959 showed fairly consistent catch rates for all of the length classes where at least 16 fish were initially tagged. The greatest exceptions were fish in the 16.0–16.9-inch interval where 33.1 percent were caught compared to the return of 44.1 percent for the entire group. Females from the 1959 series showed much more variation. The smaller fish, 14–16 inches long, did show high rates of return (71.5, 54.6 and 68.0%) but so did those in the 19-inch intervals (66.7%). The 20- and 21-inch intervals, both with returns of 22.3 percent, were well below the 52.2 percent figure for the entire lot.

Returns of males tagged in 1960 varied considerably over the range of lengths, and no conclusions on relation of size to rate of catch can be made. Recaptures of females tagged in 1960 resembled those of fish tagged in 1959. Rate of recapture was highest for the smaller fish and the 20- and 21-inch intervals again showed the poorest return. Returns of the poorly represented largest fish, male or female, varied considerably.

TABLE 19

Angler Return of Tagged Walleyes

Sex	Total Length (Inches)	1959 Tagging Series: Number Tagged	1959 Number Recovered: 1959	1960	1961	1962	1963	1959 Total Recovered	1959 Percent Recovered	1960 Tagging Series: Number Tagged	1960 Number Recovered: 1960	1961	1962	1963	1960 Total Recovered	1960 Percent Recovered
Male	11.0–11.9	2	1	--	--	--	1	2	100.0	--	--	--	--	--	--	--
	12.0–12.9	19	6	--	2	--	--	8	42.1	1	--	--	--	--	0	00.0
	13.0–13.9	113	28	19	7	3	1	58	51.4	2	1	--	--	--	1	50.0
	14.0–14.9	208	45	27	18	8	--	98	47.1	110	26	8	6	1	41	37.2
	15.0–15.9	169	25	25	14	6	1	71	42.0	230	55	30	14	4	103	44.8
	16.0–16.9	109	15	10	6	4	1	36	33.1	196	37	19	13	2	71	36.3
	17.0–17.9	47	10	8	2	--	--	20	42.5	87	20	6	3	--	29	33.3
	18.0–18.9	16	3	4	--	1	--	8	50.0	18	4	2	1	1	8	44.5
	19.0–19.9	4	1	--	--	1	--	2	50.0	2	--	--	--	--	0	00.0
	20.0–20.9	1	--	--	--	--	--	0	00.0	--	--	--	--	--	--	--
Total		688	134	93	49	23	4	303	44.1	646	143	65	37	8	253	39.2
Female	14.0–14.9	7	3	1	1	--	--	5	71.5	--	--	--	--	--	--	--
	15.0–15.9	22	7	3	1	1	--	12	54.6	12	5	1	--	--	6	50.0
	16.0–16.9	50	18	12	2	2	--	34	68.0	53	20	5	--	--	25	47.2
	17.0–17.9	51	12	2	8	1	--	23	45.0	99	31	9	5	--	45	45.4
	18.0–18.9	26	5	3	2	1	1	12	46.1	85	20	12	6	1	39	45.9
	19.0–19.9	18	7	3	--	1	1	12	66.7	48	8	3	1	2	14	29.2
	20.0–20.9	9	2	--	--	--	--	2	22.3	22	4	2	--	--	6	27.2
	21.0–21.9	9	2	--	--	--	--	2	22.3	19	2	1	--	--	3	15.8
	22.0–22.9	5	2	1	1	--	--	4	80.0	10	3	3	--	--	6	60.0
	23.0–23.9	6	1	2	--	--	--	3	50.0	2	1	--	--	--	1	50.0
	24.0–24.9	10	1	2	--	--	--	3	30.0	5	1	--	--	--	1	20.0
	25.0–25.9	2	1	--	1	--	--	2	100.0	6	2	1	--	--	3	50.0
	26.0–26.9	1	--	--	--	--	--	--	0.0	--	--	--	--	--	--	--
	27.0–27.9	2	--	--	--	--	--	--	0.0	--	--	--	--	--	--	--
Total		218	61	29	16	6	2	114	52.2	361	97	37	12	3	149	41.2
Immature	10.0–10.9	1	--	--	1	--	--	1	100.0	--	--	--	--	--	--	--
	11.0–11.9	25	7	--	1	--	--	8	32.0	--	--	--	--	--	--	--
	12.0–12.9	41	6	5	1	--	--	12	29.3	--	--	--	--	--	--	--
	13.0–13.9	16	5	4	1	--	--	10	62.5	--	--	--	--	--	--	--
	14.0–14.9	19	5	2	2	--	--	9	47.4	2	--	1	--	--	1	50.0
	15.0–15.9	4	2	2	--	--	--	4	100.0	3	--	--	--	--	0	00.0
Total		106	25	13	6	--	--	44	41.5	5	--	1	--	--	1	20.0

The differences in recapture rates by sex or size, though existing, do not present a serious problem when the entire series is treated as a single group.

Angler Exploitation Rates

Fish were tagged in 1959 and 1960 and fyke netting continued in 1961 and 1962. As some fish tagged in 1959 were recaught in nets set in 1960, 1961 and 1962 and some fish tagged in 1960 were recaught in nets in 1961 and 1962, it was possible to have at large known numbers from the two series at the start of different years.

Percentages of recapture were similar for the two series of tagged walleyes and are shown in Table 20.

The estimate of angler exploitation rates was determined from the total numbers of fish tagged regardless of sex, size or maturity and allows ready comparison with other studies, most of which have been based on similarly pooled data.

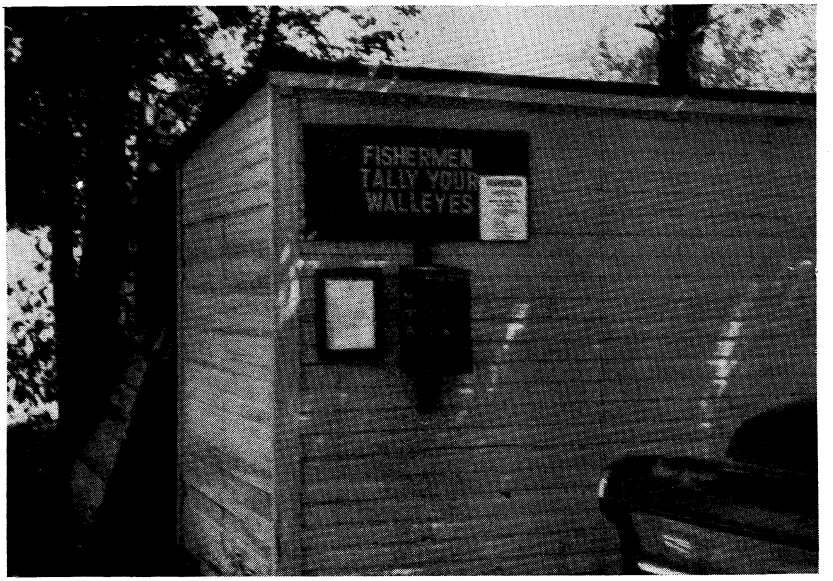
Olson (1958) believed at least 98 percent of the total fishing trips were tallied at 1,716-acre Many Point Lake in northwestern Minnesota; here the average rate of recapture was 26.8 percent per year over the 3-year period, 1955–57.

On 293-acre Escanaba Lake in northern Wisconsin, fishing is by permit only and a 100 percent creel census is maintained. Returns of marked fish have varied from 11 to 53 percent for open-water fishing (approximately mid-April to mid-November) over the seasons 1951–63. The average return has been 26 percent (Churchill and Kempinger, unpubl.).

TABLE 20

Numbers of Tagged Walleyes Reported by Anglers

Series and Year		Number Tagged or Known at Large	Number Reported	Percentage
1959				
	1959	1,053	231	21.9
	1960	368	71	19.2
	1961	189	37	19.5
	1962	43	4	9.3
	Total	1,653	343	Avg. 20.8
1960				
	1960	1,012	240	23.7
	1961	215	41	19.1
	1962	47	5	10.6
	Total	1,274	286	Avg. 22.4



Creel census box placed at Pike Lake to receive tags and information on number of walleyes caught.

Voluntary returns in Michigan showed 16.7 percent first-year recaptures of walleyes tagged in the Muskegon River impoundments in 1947–53, but in Lake Gogebic the percentage ran as low as 1.5 and 8.5 percent. Of the 4,400 fish tagged in Lake Gogebic in 1947 only 310 (7.0%) were reported recaptured over a 7-year period (Eschmeyer and Crowe, 1955).

Whitney (1958) reported that angler returns indicated a walleye harvest of 15.7 percent in 1952 and 6.3 percent in 1953 in Clear Lake, Iowa. Rose (1949), however, reported that anglers caught 28.2 percent of 556 walleyes tagged in Spirit Lake, Iowa in 1947.

A tagging program on 138,000-acre Lake Winnebago in east central Wisconsin, where there is no closed season and winter ice fishing is intensive, yielded a first-year voluntary return of 23.6 percent of 6,290 fish tagged (Priegel, pers. comm.).

Despite the great range in returns from these studies, we can see some relationships. Data from the 100 percent creel census at Escanaba Lake and the Olson data show that a catch rate of about 25 percent can be anticipated as an average annual exploitation rate for walleyes under those conditions. Voluntary returns of tagged walleyes approach and occasionally exceed this figure. While the length of season and amount of fishing pressure might also tend to alter the catch rate, any broad deviation from the 25 percent figure may be arbitrarily used to indicate an unusually high or low exploitation rate.

The annual angler catch rate of 19 to 24 percent agrees well with many other studies and certainly presents no problem of overharvest. This rate was achieved under a season opening in early May and continuing until February 15. Walleye spawning occurs from April 10–20 in this area of the state, so the season is closed during the spawning run and at least two weeks afterwards.

Pike Lake freezes over any time after mid-November and in certain years ice fishing pressure is heavy. This varies considerably, depending on weather factors such as amount of snow and comfortable temperatures. Walleye harvest can reach substantial proportions some years and is low in others. Thirty-four percent of the tags returned during the 1959–60 angling season came from fish caught through the ice. About 10 percent of tags reported during 1960–61 came from ice fishermen.

Mortality

The average annual mortality for the 1959 and 1960 series of tagged walleyes was calculated to be 34.9 and 34.2 percent respectively (Table 21). These figures agree well with Olson's (1958) figure of 30.9 percent and Whitney's (1958) estimated annual mortality of 35.2 percent.

As the minimum angling mortality on Pike Lake walleyes was known, the maximum unknown mortality ranged from 10.5 to 15.6 percent (Table 21). The term "maximum unknown mortality" includes tagged fish that suffered natural mortality, fish from which tags were lost, tagged fish caught but not reported, and tagged fish escaping the lake by the small outlet stream. The term therefore includes all of the various means by which an unreported tagged fish could be removed from the population. No way existed to determine the contribution of each of these but the combined figures of 10.5 to 15.6 percent appears to be reasonable. Johnson (1958) expressed 4.1 percent as

TABLE 21

Mortality of Tagged Walleyes

Series	Year	Average Annual Mortality	Minimum Angling Mortality	Maximum Unknown Mortality
1959	1959	34.9%	21.9%	13.0%
	1960	34.9	19.3	15.6
	1961	34.9	19.6	15.3
1960	1960	34.2	23.7	10.5
	1961	34.2	19.1	15.1

an expected natural mortality. If this figure is subtracted from the Pike Lake figures, 6.4 to 11.5 percent would remain unaccounted for.

Escapement of some fish did occur. A total of 10 tagged fish (7 males, 1 female, and 2 immature at time of tagging) were reported as caught from waters other than Pike Lake. The nearest recovery was about 15 river miles and the farthest 130 river miles from Pike Lake.

It would seem warranted to conclude that the Pike Lake walleye was exploited at the consistent annual minimum rate of 20 percent but probably closer to 25 percent and that calculated annual natural mortality did not exceed 5 to 10 percent.

MANAGEMENT IMPLICATIONS

1. Catch of adult fish on the spawning grounds, estimates of young-of-the-year and yearling fish, and angler exploitation rates all indicated that the walleye population in Pike Lake was extremely stable during the study period, 1959–62. A good walleye sport fishery was sustained in this 522-acre lake by the recruitment of 2,000 to 4,000 fish (3.8 to 7.6 fingerlings per acre) each fall, rapid growth, and the consistent exploitation rate of 20 to 25 percent by anglers each year. This offers a point of reference for assessing walleye recruitment and exploitation in other southeastern Wisconsin lakes.
2. The growth rate of the Pike Lake walleye shows that it can be turned over rapidly, which makes it a very productive species for the angler. It attained an average length of 11.4 inches at the end of 2 years and with no size limit was considered large enough at that size to be creeled by many anglers. An individual year class could be fished when the fish were as young as 2 years old and then through age group VI in the case of males, and through age group VIII in the case of females. Under the existing catch rates and no size limit, these ages were the last ones to make significant contributions to the population. Some larger fish did exist, however, and fish of 5 to 10 pounds were found.
3. A minimum size limit of 13 inches would not allow walleyes in this situation to reach spawning size and the differential sex growth (females mature at 17 inches) would require a minimum size limit that would virtually prohibit harvest of males (few males live long enough to reach 17 inches).
4. Ice fishing harvests ranged from 10 to 34 percent and did not appear to be of concern for overexploitation.
5. The closed angling period was sufficient to prevent angling during the spawning period.

6. Stocking of fingerlings in this lake with a good natural walleye population contributed little due to very poor survival.
7. Young-of-the-year walleyes in Pike Lake grow rapidly when compared to the above-average-size pond-reared fingerlings used in this study. They were approximately twice as long and four times as heavy.
8. Tagging with aluminum strap tags on the upper jaw is certain to retard growth—some 50 percent in this study.
9. Fin clipping young-of-the-year walleyes does not affect survival or growth.
10. Electrofishing with a 230-volt, 3,000 watt, 3-phase AC generator is a very effective method of capturing young-of-the-year and yearling walleyes. It was also shown that reasonably accurate estimates of these two groups of fish could be made.

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