Changes in the harvest, mean size-at-age, length-weight relationship, and condition of cisco in Pallette Lake, 1946-1980. Report 122 [1983]

Hoff, Michael H.; Serns, Steven L.
Madison, Wisconsin: Dept. of Natural Resources, [1983]

https://digital.library.wisc.edu/1711.dl/TBQOTL35NJ4KN87

PARTMENT OF NATURAL RESOURCES

RESEARCH

REPORT 122

MAY 1983

CHANGES IN THE HARVEST, MEAN SIZE-AT-AGE, LENGTH-WEIGHT RELATIONSHIP AND CONDITION OF CISCO IN PALLETTE LAKE, 1946-1980

By
Michael H. Hoff and Steven L. Serns
Bureau of Research, Woodruff

John Mason - Nevin

ABSTRACT

Data on the harvest, mean size-at-age, length-weight relationship and condition of Pallette Lake cisco (Coregonus artedii) were analyzed for selected years between 1946 and 1980. Changes in these parameters were examined with respect to the great reduction in harvest after the access road to Pallette Lake was closed to motor vehicles in 1968. A 23-fold reduction in annual cisco harvest (number) and a 33-fold reduction in annual yield (lb) occurred during 1969-1980, as compared to annual cisco harvest and yield from 1946-1968 when motor vehicles had access to the lakeshore.

Mean lengths of cisco age groups were substantially lower in the years sampled after access road closure, particularly after the second year of life. Walford plots of length increase indicated that asymptotic length (L^{∞}) was greatest in the 1950's (10.6 inches), and lower in the 1960's (10.1 inches), 1947 (9.7 inches), and 1979-1980 (9.4 inches). Ford's growth coefficients (k) demonstrated that the rate with which asymptotic length was attained was highest in the 1950's (k = 1.0297), followed by the 1960's (k = 1.0281), 1979-1980 (k = 0.9163), and 1947 (k = 0.5108). In all decades, increases in mean size-at-age were greatest during the first two years of life. The greatest increases in weight per unit length of cisco from the four decades sampled were found in the 1950's and 1940's, when weight increased by more than the cube of the length. Cisco weight increased by slightly less than the cube of the length in the 1960's and by less than the square of the length in the 1979-1980 samples. Mean weight-at-age was substantially lower after the second year of life for cisco in the 1979 and 1980 samples compared to cisco from the decades sampled prior to access closure. Generally, mean length and weight-at-age of Pallette Lake cisco were markedly greater before access limitation severely limited harvest. T-tests revealed significantly lower ($p<0.001$) mean condition factors ($\overline{C}$) of 7.0- to 7.9-inch cisco and 8.0- to 8.9-inch cisco after the access road was closed. Linear regression analyses revealed that as harvest (number) and yield (lb) increased the mean condition factors of cisco would also increase two to three years later. Mean condition factors increased more abruptly as yield increased than as harvest increased in the two and three previous years, and the mean condition factors increased somewhat more sharply as both harvest and yield increased in the two previous years than in the three previous years. Samples of Pallette Lake cisco were dominated more by males than any other spawning ground surveys noted in the literature, although the percentage of females did increase with increased age.

CONTENTS

INTRODUCTION

In recent years the cisco, or lake herring (Coregonus artedii), has been one of the least studied food fishes in Wisconsin's inland waters.

Early studies of the Wisconsin cisco were few. Hile (1936, 1937) reported on the age, growth and morphometry of cisco from northern Wisconsin lakes, and Churchill (1951) reported the age and size distribution of cisco in three northeastern lakes. Later, Churchill ((1967) found in a statewide mail survey of fishermen who seined cisco and whitefish during the 1966 season that fishing pressure was highest in northeastern Wisconsin. Most respondents fished an average of four times during the season in an average seining party of four people. The average fishing trip lasted 3 hours, and the average catch was 8 lb of cisco and/or whitefish per trip (2 1/2 lb/hour). From this survey, the 1966 statewide harvest of these species was estimated at 26,400 fish, yielding 14,900 lb. In a three-year creel census (1967-69) conducted during the fall cisco and whitefish season on 41 lakes in northeastern Wisconsin, McKnight et al. (1970) found that fishing pressure for cisco and whitefish was light on most of the waters surveyed.

Although these studies aid our understanding of the Wisconsin cisco fishery, no analysis of the effects of major changes in harvest rates of cisco in Wisconsin's inland lakes has been made.

Pallette Lake offered a unique opportunity to study the effects of the changes in harvest on the growth and condition of the cisco over an extended time period (1946-1980). These parameters were analyzed with respect to the termination of motor vehicle access to the lakeshore after the 1968 seining season. Previous studies of the Pallette Lake cisco concentrated only on their movements and food habits in relation to introduced and native species (Engel 1976a, 1976b).

DESCRIPTION OF STUDY AREA

Pallette Lake is a 176-acre seepage lake located in the Northern Highland State Forest in central Vilas County in northcentral Wisconsin. Its maximum depth is approximately 60 ft, with 70% of the basin more than 20 ft in depth and only 9% of the basin under 3 ft. The basin is slightly basic ($\bar{x}$ pH = 7.3, N = 34), low in total alkalinity ($\bar{x}$ = 5.9 mg/l as $CaCO_3$, N = 34), and low in specific conductance ($\bar{x}$ = 21.9 μmhos/cm at 25 C, N = 34) (J. M. Eilers and G. E. Glass 1981 unpubl. data).

The entire 2.5 miles of the Pallette Lake shoreline is owned by the state with no public or private developments. And, since the 1968 cisco seining season, the 0.3-mile access road to the boat landing has been closed to all motor vehicles year-round. In 1968, the access road was open for the cisco seining season, but we believe that many fishermen did not seine during that season because they assumed that the access road was permanently closed.

Pallette Lake is one of five lakes under experimental management in the Northern Highland Fishery Research Area (established in 1946). Fish species known to inhabit Pallette Lake either presently or historically include: smallmouth bass (Micropterus dolomieui), largemouth bass (Micropterus salmoides), northern pike (Esox lucius), yellow perch (Perca flavescens), pumpkinseed (Lepomis gibbosus), rock bass (Ambloplites rupestris), burbot (Lota lota), black bullhead (Ictalurus melas), white sucker (Catostomus commersoni), brook stickleback (Culaea inconstans), bluntnose minnow (Pimephales notatus), common shiner (Notropis cornutus), creek chub (Semotilus atromaculatus), golden shiner (Notemigonus chryoleucas), logperch (Percina caprodes), mottled sculpin (Cottus bairdi), Iowa darter (Etheostoma exile), rainbow trout (Salmo gairdneri), coho salmon (Onchorhynchus kisutch), splake (Salvelinus fontinalis x Salvelinus namaycush namaycush) and the cisco. Rainbow trout, coho salmon and splake are no longer found in the lake, while densities of all game fish except smallmouth bass remain quite low. After the introductory stockings of rainbow trout, splake and coho salmon in 1959, 1963-64 and 1968-70, respectively, a bag limit of 10 rainbows and minimum size limits of 10 inches on coho and 17 inches on splake were imposed. No other size limits, bag limits or season restrictions have been in effect from 1946 through 1980.

METHODS

All cisco data analyzed in this study were from fish captured by fishermen with seines during the cisco spawning season in October and November. In some years, cisco were also caught by hook and line. The three years with highest hook-and-line harvest since 1946 were 1967-69, with a harvest of 246, 81 and 58 cisco, respectively. Since the Pallette Lake cisco population was not appreciably affected by this fishing method, hook-and-line harvest was excluded from data analysis in this report.

Since 1946, a complete compulsory creel census has been in effect on Pallette Lake. All fishermen were required to obtain a free fishing permit at the Northern Highland Fishery Research Area Headquarters (located on nearby Escanaba Lake) prior to fishing and to return the permit after fishing. At this time, all fish creeled were submitted to the creel census clerks for registration.

During most years (1946-61, 1964-65, 1968, 1970-71, 1973), each fish in a subsample of one cisco catch was measured for total length to the nearest 0.1 inch, weighed to the nearest gram or 0.01 lb, and a scale was removed from above the lateral line anterior to the dorsal fin. After treating the subsample of one cisco catch in this manner, the remaining catches were counted and/or weighed as a whole. In the remaining years (1962-63, 1966-67, 1969, 1972, 1974-76), the cisco were simply counted and the catch weighed as a whole. Creel clerks also recorded the number of persons in each seining party and the total hours (to the nearest 0.5 hour) each seine was fished.

Scales were either pressed between two acetate slides and the resultant impressions used for aging or they were aged without pressing. Scale images were projected on a tabletop using a Bausch and Lomb Microprojector equipped with a 12X objective. Ages were assigned as completed summers of growth (i.e., the anterior edge of the scale was considered an annulus).

Walford plots for evaluating maximum attainable lengths ($L\infty$) and Ford's growth coefficients for determining the rate of length increase (k) were performed according to Ricker (1975). Analyses of growth rates were computed with the sexes combined since a poorer sample size of females precluded any statistical testing for sexually dimorphic growth patterns. In addition, cisco data from 1946 were not used in conjunction with data from 1947 to evaluate asymptotic length and rate of growth in the 1940's, since representation of all age groups except three-year-olds was poor in the small 1946 sample.

Condition factors (C) were calculated in accordance with Bennett (1970).

Linear regressions for analysis of length vs. weight, and harvest vs. condition factor were computed by the method of least squares.

Analyses of age, mean length-at-age, mean weight-at-age, and length-weight relationships were limited to samples from two selected years from each decade (beginning with the 1940's), with the exception of the 1970's when adequate scale samples and individual length and weight data existed only for 1979. Since scale samples and length-weight data existed for 1980, samples from that year were paired with those of 1979. Years selected for the analyses contained the greatest number of scale samples representing the entire cisco length range. A subsample of up to 15 specimens from each inch class was then randomly selected for each year, with the exception of 1964, 1969, 1979 and 1980 when all scale samples were used.

RESULTS

Fishing Pressure, Harvest and Yield

Before the access road to Pallette Lake was closed, the average cisco seining season consisted of 108 people seining with 39 nets for 63 net-hours (Table 1). During this period, seiners harvested an average of 4,896 cisco (28/acre, 78/net-hour), yielding 1,242 lb (7 lb/acre). The average harvested cisco measured 9.3 inches and weighed 0.25 lb. Harvest and yield were highest in 1947 (100/acre, 25 lb/acre), 1948 (60/acre, 15 lb/acre) and 1949 (45/acre, 13 lb/acre) (Table 1).

After the access road was closed (1969-1980), the average Pallette Lake cisco seining season consisted of seven people using two nets for 5 net-hours (Table 1). Seiners harvested an average of 369 cisco (2/acre, 81/net-hour), yielding 57 lb (0.3 lb/acre). During these years, the average harvested cisco measured 7.7 inches and weighed 0.16 lb.

A comparison of mean annual catch statistics before and after the access road was closed to the Pallette lakeshore indicates that seiners exerted approximately 14 times more fishing pressure (net-hours) and harvested 13 times more cisco (yielding 22 times more total weight) before access was restricted than after access restriction. However, no harvest was reported in 5 of the 12 years after the access road was closed. When these years were included in calculations of the average annual cisco harvest after access closure, only 215 cisco (1/acre) were harvested, yielding 33 lb (0.2 lb/acre). This represents a 23-fold reduction in annual cisco harvest and a 33-fold reduction in annual cisco yield after the access road was blocked.

From 1956-1976 when both fishing pressure and harvest were recorded, a highly significant relationship existed between fishing and cisco harvest ($r = .89$, $df = 16$, $p<0.01$).

Sex Ratio

Cisco males dominated the catch in Pallette Lake (Table 2). Of the years selected for study, the most biased sex ratio occurred in the 1980 season when only 12% of the cisco examined were female. However, the percentage of females in Pallette Lake generally increased with increased age.

A review of the literature revealed only one other population sampled on the spawning grounds in which males were so predominant (Blind Lake, Cooper 1937). In other studies of cisco populations sampled on the spawning grounds, two populations (Swains Lake, Brown and Moffett 1942; Blind Lake, Cooper 1937) were sampled with gill nets and two (Saginaw Bay, Van Oosten 1929; Irondequoit Bay, Stone 1938) were sampled with pound nets. The Swains Lake cisco population showed an increase of females with increased age, while the Blind Lake and Saginaw Bay populations exhibited a decrease of females with increased age, and the Irondequoit Bay cisco population showed no distinct sex pattern. Thus, no distinct pattern in sex selectivity of pound and gill nets set on the spawning grounds was apparent. In addition, there was no distinct trend toward an increase or decrease of female cisco with increased age. The sex ratio of spawning ground samples may be due more to timing of the collection than to gear selectivity or sex-age patterns.

TABLE 1. Catch statistics of fall-seined Pallette Lake cisco, 1946-1980.

Year	Date	No. Nets	Net-Hours Seined	No. Seiners	Harvest (no./acre)	Total Harvest/ Hour	Yield (lb/acre)	Ave. Total Length (inches)	Length Range (inches)	Ave. Weight (lb)
Access Road Open										
1946	*	*	*	*	21	*	5	9.4	8.5-10.2	0.25
1947	10/26-11/7	73	*	*	100	*	25	*	6.9-10.5	0.25
1948	10/23-11/6	71	*	236	60	*	15	*	7.2-10.3	0.25
1949	10/20-11/13	64	*	*	45	*	13	*	7.4-10.9	0.28
1950	10/23-11/21	49	*	174	16	*	5	9.7	8.5-10.7	0.30
1951	10/20-11/15	55	*	180	15	*	5	9.9	8.9-10.8	0.32
1952	10/15-11/15	53	*	*	26	*	9	10.0	4.9-11.1	0.32
1953	*	*	*	*	28	*	7**	8.5	6.5-10.8	*
1954	10/14-11/17	41	*	140	20	*	3	8.3	7.0-10.7	0.16
1955	10/22-11/14	39	*	135	26	*	5	*	*	0.20
1956	10/30-11/14	38	112	124	26	41	7	9.4	9.0-10.4	0.25
1957	10/26-11/15	35	82	113	22	48	7	9.6	8.8-10.8	0.29
1958	11/02-11/16	28	71	88	27	67	6	9.0	7.8-11.6	0.22
1959	10/17-11/8	23	56	67	10**	33**	2**	9.4	7.6-11.6	0.23
1960	10/29-11/26	30	71	95	28	69	6	8.9	7.2-10.3	0.21
1961	11/01-11/19	27	55	86	34	108	7	8.9	8.1-10.7	0.21
1962	10/31-11/15	45	107	140	39	64	9	*	*	0.24
1963	11/09-11/30	32	88	109	28	57	8	9.4	8.5-10.5	0.28
1964	10/30-11/19	21	51	64	24	84	6	9.3	7.8-10.3	0.26
1965	11/01-11/19	17	30	56	17	102	4	9.4	8.3-10.6	0.26
1966	10/31-11/17	17	29	53	9	57	3	*	*	0.29
1967	11/01-11/14	19	53	59	18	59	5	10.1	9.2-11.2	0.30
1968	11/02-11/27	6	13	17	1	16	***	9.3	6.2-10.7	0.23
Access Road Closed										
1969	10/30-11/10	2	3	6	***	8	***	*	*	0.18
1972	11/11 only	2	7	9	1	33	***	*	*	0.17
1974	11/19-11/22	2	5	10	2	52	1	*	*	0.35
1975	11/18-11/19	2	6	15	1	40	***	*	*	0.20
1976	11/10 only	1	2	4	2	239	***	*	*	0.14
1979	11/8 only	1	*	2	3	*	***	7.6	6.9-8.9	0.12
1980	10/28-10/30	3	*	6	6	*	1	7.8		0.11
1946-1968		$\bar{x}$ = 39	$\bar{x}$ = 63	$\bar{x}$ = 108	$\bar{x}$ = 28	$\bar{x}$ = 78	$\bar{x}$ = 7	$\bar{x}$ = 9.3		$\bar{x}$ = 0.25
1969-1980		$\bar{x}$ = 2	$\bar{x}$ = 5	$\bar{x}$ = 7	$\bar{x}$ = 3	$\bar{x}$ = 81	$\bar{x}$ = ***	$\bar{x}$ = 7.7		$\bar{x}$ = 0.16

*Data not available.
**Estimate.
***Less than 1.0.

Table 2. Sex distribution by age group of fall-seined Pallette Lake cisco in selected years.

	Age II*		Age III		Age IV		Age V		Total	
Year	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1947	7		3		49	26	15		74	26
1954			54	32	1	5		10	55	47
1959	1		51	5	4	10	3	18	59	33
1964	6		1		16	6			23	6
1980	3	—	130	18	2	—	2	—	137	18
Total	17	0	239	55	72	47	20	28	348	130

*Roman numerals indicate completed summers of growth.

Mean Length-at-Age

Mean lengths of Pallette Lake cisco at the end of each summer of life (Table 3) were generally lowest in 1979, 1980 and 1947, and highest in the 1950's and 1960's. Mean length-at-age of Pallette Lake cisco for 1946-1980 is approximately in the middle of the ranges reported for other cisco populations (Hile 1936, Stone 1938 and Smith 1972). Even after the reduced harvest rates due to access closure, the Pallette Lake cisco mean length-at-age was greater than the mean length at age of cisco through the second year of life in four northern Wisconsin populations studied by Hile (1936), and was greater through all ages (both before after access closure) than in all inland Wisconsin cisco populations but the Clear Lake population (Hile 1936). However, the mean length-at-age of the Pallette Lake cisco, even before the access road was closed, was substantially lower than the mean length-at-age of the Oneida Lake, New York, cisco population (Smith 1972) and the Irondequoit Bay, New York, cisco population (Stone 1938).

The estimated maximum attainable length (L_∞) was highest in cisco samples from the 1950's (10.6 inches), and decreasingly lower in the 1960's (10.1 inches), 1947 (9.7 inches) and 1979-80 (9.4 inches). Computation of Ford's growth coefficients (k) demonstrated that the rate with which the maximum attainable length was attained was also highest in the 1950's (1.0297), followed by the 1960's (1.0281), 1979-1980 (0.9163) and 1947 (0.5108).

TABLE 3. Mean total lengths (±SD) of Pallette Lake cisco at completion of each summer of growth (sexes combined).

	Age II*		Age III		Age IV		Age V		Age VI	
Year	No.	Mean Length (inches)	No.	Mean Length (inches)	No.	Mean Length (inches)	No.	Mean Length (inches)	No.	Mean Length (inches)
1947	7	7.5 ± 0.3	3	8.5 ± 0.2	75	9.0 ± 0.3	15	9.3 ± 0.2		
1954			86	8.1 ∓ 0.3	6	9.4 ∓ 0.5	10	10.3 ∓ 0.2		
1959	2	8.4 ± 0.1	61	8.9 ∓ 0.3	16	10.0 ∓ 0.4	21	10.3 ∓ 0.5		
1964	9	8.1 ∓ 0.3	1	9.9 —	28	9.6 ∓ 0.4	1	10.3 —		
1968	11	6.4 ∓ 0.1	8	7.2 ± 0.6	8	9.5 ∓ 0.2	14	10.0 ± 3	1	10.7
1979	1	7.0 —	47	7.6 ∓ 0.3	1	8.9 —				
1980	3	7.0 ± 0.1	148	7.8 ∓ 0.3	2	8.7 ± 0.1	2	9.1 ± 0.3		

*Roman numerals indicate completed summers of growth.

Mean Weight-at-Age

The mean weight of Pallette Lake cisco at the end of each summer of life (Table 4) suggested that there was very little weight increase after the second year of life for the 1979 and 1980 specimens, in comparison to Pallette Lake cisco sampled in all other decades. Mean weight-at-age of Pallette Lake cisco before the access was closed was greater than the mean weight-at-age of cisco from other Wisconsin lakes--Muskellunge Lake, Silver Lake and Trout Lake--but markedly lower than Clear Lake, Wisconsin, cisco (Hile 1936). After access closure, mean weight-at-age of Pallette Lake cisco was roughly equivalent to that of cisco from Muskellunge and Silver lakes, greater than that of Trout Lake cisco, and substantially lower than that of the Clear Lake cisco (Hile 1936). Mean weight-at-age of the cisco from Irondequoit Bay in New York (Stone 1938) far exceeded the mean weight-at-age of the Pallette Lake cisco even before the access road was closed.

TABLE 4. Mean weights (±SD) of Pallette Lake cisco at completion of each summer of growth (sexes combined).

	Age II*		Age III		Age IV		Age V		Age VI	
Year	No.	Mean Weight (lb)	No.	Mean Weight (lb)	No.	Mean Weight (lb)	No.	Mean Weight (lb)	No.	Mean Weight (lb)
1947	7	0.12 ± 0.02	3	0.20 ± 0.02	75	0.24 ± 0.02	15	0.25 ± 0.02		
1954			86	0.14 ∓ 0.02	6	0.21 ∓ 0.04	10	0.29 ∓ 0.04		
1959	2	0.19 ± 0.01	61	0.22 ∓ 0.02	16	0.31 ∓ 0.03	21	0.32 ∓ 0.04		
1964	9	0.16 ∓ 0.02	1	0.28 —	28	0.25 ∓ 0.03	1	0.30 —		
1968	11	0.08 ∓ 0.01	8	0.11 ± 0.02	8	0.24 ∓ 0.03	14	0.28 ± 0.03	1	0.26
1979	1	0.09 —	47	0.12 ∓ 0.01	1	0.18 —				
1980	3	0.07 ± 0.01	148	0.11 ∓ 0.01	2	0.14 ± 0.00	2	0.15 ± 0.01		

*Roman numerals indicate completed summers of growth.

TABLE 5. Comparison of calculated vs. observed mean weights (lb) of 7.0-, 8.0- and 9.0-inch fall-seined Pallette Lake cisco during selected years, 1946-1980 (number of fish in parentheses).

Years	7.0-inch Cisco		8.0-inch Cisco		9.0-inch Cisco	
	Calculated* Weight	Observed Mean Weight	Calculated Weight	Observed Mean Weight	Calculated Weight	Observed Mean Weight
1946, 1947	0.11		0.16		0.23	0.23 (17)
1954, 1959	0.10		0.15	0.14 (13)	0.21	0.21 (7)
1964, 1968	0.10		0.15	0.15 (2)	0.21	0.22 (1)
1979, 1980	0.09	0.09 (2)	0.12	0.12 (14)	0.15	

*Calculated weight from length using the following formulae:

1946, 1947 $\log_{10} w\ (x10^2) = -1.56 + 3.06 \log_{10} l$; r = .94, N = 135
1954, 1959 $\log_{10} w\ (x10^2) = -1.64 + 3.10 \log_{10} l$; r = .95, N = 202
1964, 1968 $\log_{10} w\ (x10^2) = -1.42 + 2.86 \log_{10} l$; r = .98, N = 81
1979, 1980 $\log_{10} w\ (x10^2) = -0.69 + 1.96 \log_{10} l$; r = .95, N = 204

Length-Weight Relationship

Then length-weight relationship of Pallette Lake cisco for selected years from 1946-1980 is expressed as: $\log_{10}$weight $(x10^2) = -1.90 + 3.36 \log_{10}$length (r = .95, N = 522). The greatest increase in weight per $\log_{10}$ unit length in any single decade was in the 1950's (3.10, r = .95, N = 202), followed by the 1940's (3.06, r = .94, N = 135). During those years, Pallette Lake cisco were increasing in weight (as they increased in length) by more than the cube of the length. Conversely, cisco captured in the 1960's were increasing in weight by less than the cube of the length (2.86, r = .98, N = 81), and in 1979-80 they were increasing in weight by less than the square of the length (1.96, r = .73, N = 204).

The marked reduction in cisco harvest after access closure presumably reduced the observed mean weight of an 8.0-inch fish by 0.02 to 0.03 lb and reduced the calculated weight of an 8.0-inch fish by 0.02 to 0.04 lb (Table 5). Similarly, the calculated weight of a 9.0-inch cisco was reduced from 0.05 to 0.08 lb after access closure. However, no 9.0-inch cisco were sampled in the 1979 and 1980 seasons, and no 7.0-inch fish were present in samples from the 1940's, 1950's and 1960's, precluding any comparisons between observed mean weights for these cisco length groups before and after the access road was closed.

Condition

The mean coefficients of condition for 7.0- to 7.9-inch ($\bar{C}$ = 24.0) and 8.0- to 8.9-inch ($\bar{C}$ = 22.2) Pallette Lake cisco were lowest during the 1979 and 1980 seining seasons (Table 6). The highest mean coefficients of condition for 7.0- to 7.9-inch Pallette Lake cisco were recorded in 1964 ($\bar{C}$ = 30.1), 1947 ($\bar{C}$ = 29.7) and 1958 ($\bar{C}$ =28.9), while the best recorded conditions for 8.0- to 8.9-inch fish were in 1947 ($\bar{C}$ = 32.8), 1948 ($\bar{C}$ = 31.6) and 1959 ($\bar{C}$ = 30.8). However, the 8.0- to 8.9-inch cisco presumably exhibited more reliable trends since sample sizes of this group were generally greater than the samples sizes of 7.0- to 7.9-inch fish (exceptions to this were the 1979 and 1980 seasons when 7.0- to 7.9-inch cisco outnumbered 8.0- to 8.9-inch cisco). T-tests revealed that the mean coefficients of condition for both the 7.0- to 7.9-inch cisco ($\bar{C}$ = 28.3 and 25.0 before and after access closure, respectively) and 8.0- to 8.9-inch cisco ($\bar{C}$ = 29.8 and 22.9 before and after access closure, respectively) were significantly lower after the access road was closed ($p < 0.001$, t = 9.043, df = 232 and $p < 0.001$, t = 13.009, df =311 for 7.0- to 7.9-inch and 8.0- to 8.9-inch cisco, respectively).

When values for the mean coefficients of condition of 8.0- to 8.9-inch Pallette Lake cisco were plotted against the number of cisco harvested per acre in the two and three previous years, significant linear relationships were found (r = .82, $p<0.01$, df = 7; r = .82, $p < 0.05$, df = 6 for two and three years previous to condition appraisal, respectively). This indicates that as the cisco harvest increased, mean coefficients of condition would increase two and three years later. Similarly, when the yields of Pallette Lake cisco (lb/acre) for the two and three previous years were plotted against cisco mean coefficients of condition, linear relationships were again found (r = .81, $p < 0.01$, df = 7; r = .80, $p < 0.05$, df = 6 for two and three previous years, respectively). This indicates that as yield increased, so did subsequent cisco condition values. However, the mean coefficients of condition increased more sharply (as indicated by the slopes of the regression lines) with an increase in yield than with an increase in harvest in the previous two and three years. In addition, the mean coefficients of condition were influenced more by both harvest and yield in the two previous years than in the three previous years.

TABLE 6. Mean coefficient of condition ($\bar{C}$) for 7.0-to 7.9 inch and 8.0- to 8.9-inch fall-seined Pallette Lake cisco during selected years, 1947-1980.

	7.0- to 7.9-inch Cisco					8.0- to 8.9-inch Cisco				
Year	Mean Length (inches)	Mean Weight (lb)	$\bar{C}$	SD*	N**	Mean Length (inches)	Mean Weight (lb)	$\bar{C}$	SD*	N**
Access Road Open										
1947	7.6	0.13	29.7	1.6	6	8.7	0.22	32.8	2.3	30
1948	7.7	0.13	28.2	2.0	16	8.6	0.20	31.6	3.7	18
1954	7.8	0.13	27.8	3.0	37	8.3	0.16	27.4	2.7	50
1958	7.9	0.14	28.9	1.3	4	8.3	0.16	28.2	1.8	46
1959						8.7	0.20	30.8	2.2	34
1960	7.5	0.11	26.6	1.9	8	8.5	0.17	27.0	1.9	50
1961						8.7	0.19	28.2	1.7	31
1964	7.9	0.15	30.1	1.6	3	8.3	0.16	29.0	1.2	7
1968	7.6	0.12	28.7	2.2	5					
Access Road Closed										
1979	7.5	0.12	27.7	2.0	42	8.3	0.15	26.0	1.3	8
1980	7.6	0.11	24.0	1.6	113	8.3	0.12	22.2	1.9	39
1947-1968	7.7	0.13	28.1	2.6	79	8.5	0.18	28.9	3.0	266
1979-1980	7.6	0.11	25.0	2.4	155	8.2	0.13	22.9	2.3	47

*SD = standard deviation
**N = number of fish in sample.

DISCUSSION

The 23-fold reduction in annual harvest and 33-fold reduction in annual yield of Pallette Lake cisco, resulting from the 29-fold reduction in annual seining pressure after the access road to Pallette Lake was closed in 1968, presumably caused the decreases in cisco mean length-at-age, mean weight-at-age, asymptotic length ($L\infty$), and the mean coefficient of condition ($\bar{C}$) of fish collected in 1979 and 1980. The low mean length-at-age and asymptotic length exhibited by cisco collected from Pallette Lake in 1947 probably resulted from the lack of cisco harvest prior to 1946 (Williamson 1947).

Hile (1936) theorized that the variations in cisco growth rates for the four Wisconsin populations he studied were determined more by the relative densities of cisco in these lakes than on the basic productive capacities of the waters they inhabited. Assuming that Pallette Lake cisco densities and standing stock were lowest in the 1950's and 1960's (when substantial annual harvest occurred), reduction in intraspecific competition was apparently responsible for the higher mean length-at-age, mean weight-at-age, asymptotic length and condition values during those decades. Similarly, when Healey (1980) exploited lake whitefish (Coregonus clupeaformis) at 10%, 20% and 30% annual rates using gill nets in three Canadian lakes (while monitoring one unexploited lake as a control), he found significant increases in whitefish mean length-at-age in the exploited lakes. He also found that the degree and persistence of the increase in mean length-at-age was proportional to the intensity of exploitation.

One characteristic common to most cisco populations is rapid growth during the first two years of life. Van Oosten (1929) found that nearly 50% of the cisco's length reached in the sixth year was completed at the end of the first year for the Lake Huron population. He also indicated that growth in the first year of life largely determined the ultimate length, and indirectly the weight, of most cisco at time of capture. Clady (1967) noted that cisco growth in Birch Lake, Michigan, was density independent during the first two years of life, but was negatively influenced by increased density thereafter. This would account for the relatively high mean length-at-age of Pallette Lake cisco through the second year of life in the 1979 and 1980 samples, even though cisco densities were presumably high due to the lack of substantial harvest after access road closure. If mortality were also positively related to density after the first two years of life, it would account for the reduced longevity of Pallette Lake cisco in 1979 and 1980 compared to the years before access closure (based on the age-frequency distribution of the seine catches).

Length-weight equations can vary from year to year for any species in a particular population, depending on variations in food supply, oscillations in year-class strength, sex ratio of the sample, and other variables. However, the large variation between the slopes of the Pallette Lake cisco length-weight equations before and after the access road was closed suggests that the cisco body form was substantially changed because of the reduced harvest following access road closure.

Two- and three-year-old cisco have historically constituted the most important age groups in the Pallette Lake seine fishery, with two-year-olds generally the dominant age group. Since the harvest and yield of cisco in the two and three previous years increased the mean condition coefficient of fall-seined fish, cisco young-of-year and yearlings were apparently positively affected by thinning of the adult spawning population.

Although the diet of immature Pallette Lake cisco has not been studied, it may be quite similar to that of the adults. Engel (1976a) found that the food of 5.1- to 10.2-inch Pallette Lake cisco consisted mostly of the copepods Cyclops sp. and Diaptomus sp., and the cladocerans Chydorus sp., Daphnia sp., and Bosmina sp. Cahn (1927) noted that the food of immature cisco up to 6.3 inches in length in southern Wisconsin lakes also was composed mainly of these copepod and cladoceran genera.

Because Pallette Lake is infertile and contains low densities of cisco predators, increased seine harvest of adult cisco probably increases the food available to young-of-year and yearling cisco. This may have resulted in higher condition factors for these cohorts when they entered the seine fishery two and three years later.

MANAGEMENT IMPLICATIONS

1. This study indicates that a low level of harvest (and probably exploitation) of cisco, at least in a relatively small, infertile lake such as Pallette (where game fish populations are low and the impact of predation of the cisco population is probably minor), may adversely affect cisco growth and condition.

2. In lieu of increasing harvest levels of cisco to increase growth and condition in Pallette Lake where game fish populations are low, establishment of a suitable predator population may produce the same result.

APPENDIX

English-Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 20.48 centimeters or 0.3048 meters
1 mile = 1.609 kilometers
1 acre = 0.405 hectares
1 pound = 0.454 kilograms
1 gram = 0.0022 pounds

LITERATURE CITED

Bennett, G. W.
1970. Management of lakes and ponds. 2nd ed. Van Nostrand Reinhold Co., New York, N.Y. 375 pp.

Brown, C. J. D. and J. W. Moffett
1942. Observations on the number of eggs and feeding habits of the cisco (Leucichthys artedi) in Swains Lake, Jackson County, Michigan. Copeia 3:149-52.

Cahn, A. R.
1927. An ecological study of southern Wisconsin fishes. Ill. Biol. Monogr. 11:1-151.

Churchill, W.
1951. The cisco fishery in northeastern Wisconsin. Wis. Cons. Dep. Invest. Rep. 824. 3 pp.

1967. The cisco fishery in Wisconsin in 1966. Wis. Dep. Nat. Resour. Res. & Plann. Sur. Rep. Mimeo. 3 pp.

Clady, M. D.
1967. Changes in an exploited population of the cisco, Coregonus artedii Le Sueur. Mich. Acad. Sci., Arts, Lett. Pap. 52:85-99.

Cooper, G. P.
1937. Age, growth, and morphometry of the cisco, Leucichthys artedi (Le Sueur), in Blind Lake, Washtenaw County, Michigan. Mich. Acad. Sci., Arts, Lett. Pap. 22:563-71.

Engel, S.
1976a. Food habits and prey selection of coho salmon (Oncorhynchus kisutch) and cisco (Coregonus artedii) in relation to zooplankton dynamics in Pallette Lake, Wisconsin. Trans. Am. Fish. Soc. 105:607-14.

1976b. Vertical and horizontal distributions of coho salmon (Oncorhynchus kisutch), yellow perch (Perca flavescens) and cisco (Coregonus artedii) in Pallette Lake, Wisconsin. J. Fish. Res. Board Can. 33:3710-5.

Healey, M. C.
1980. Growth and recruitment in experimentally exploited lake whitefish (Coregonus clupeaformis) populations. Can. J. Fish. Aquat. Sci. 37:255-67.

Hile, R.
1936. Age and growth of the cisco, Leucichthys artedi (Le Sueur), in lakes of the northeastern highlands, Wisconsin. U.S. Bur. Fish. Bull. 48:211-317.

1937. Morphometry of the cisco, Leucichthys artedi (Le Sueur), in Lake Mendota. Int. Rev. Hydrobiol. 36:57-130.

McKnight, T. C., R. W. Wendt, R. L. Theis, L. E. Morehouse and M. E. Burdick.
1970. Cisco and whitefish sport netting in northeastern Wisconsin. Wis. Dep. Nat. Resour. Fish Manage. Rep. No. 41. 15 pp.

Ricker, W. E.
1975. Computation and interpretation of biological statistics of fish populations. Fish Res. Board Can. Bull. No. 191. 382 pp.

Smith, D. B.
1972. Age and growth of the cisco in Oneida Lake, New York. N.Y. Fish and Game J. 19:83-91.

Stone, U. B.
1938. Growth, habits, and fecundity of the ciscoes of Irondequoit Bay, New York. Trans. Am. Fish. Soc. 67:234-45.

Van Oosten, J.
1929. Life history of the lake herring (Leucichthys artedi) (Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. U.S. Bur. Fish. Bull. 44:265-428.

Williamson, L. O.
1947. Experimental lakes project, Vilas County. Progress Report No. 11. Wis. Cons. Dep. Fish. Manage. Invest. Rep. No. 514. 17 pp.

ACKNOWLEDGEMENTS

Most of the data were collected under the supervision of James J. Kiepinger and the late Warren S. Churchill, with assistance from O. C. Baccus. Critical review of this manuscript was provided by Lyle M. Christenson, Howard E. Snow, Eugene L. Lange, John J. Magnuson and Lars Rudstam. Eugene L. Lange and Donald Thompson also provided statistical advice. This research was supported in part by the Federal Aid in Fish Restoration Act under Wisconsin Dingell-Johnson Project F-83-R.

About the Authors

The authors are fishery biologists at the Northern Highland Fishery Research Area, Bureau of Research, Woodruff.

Production Credits

Editor: Lori Goodspeed
Word Processor: Susan J. Hoffman