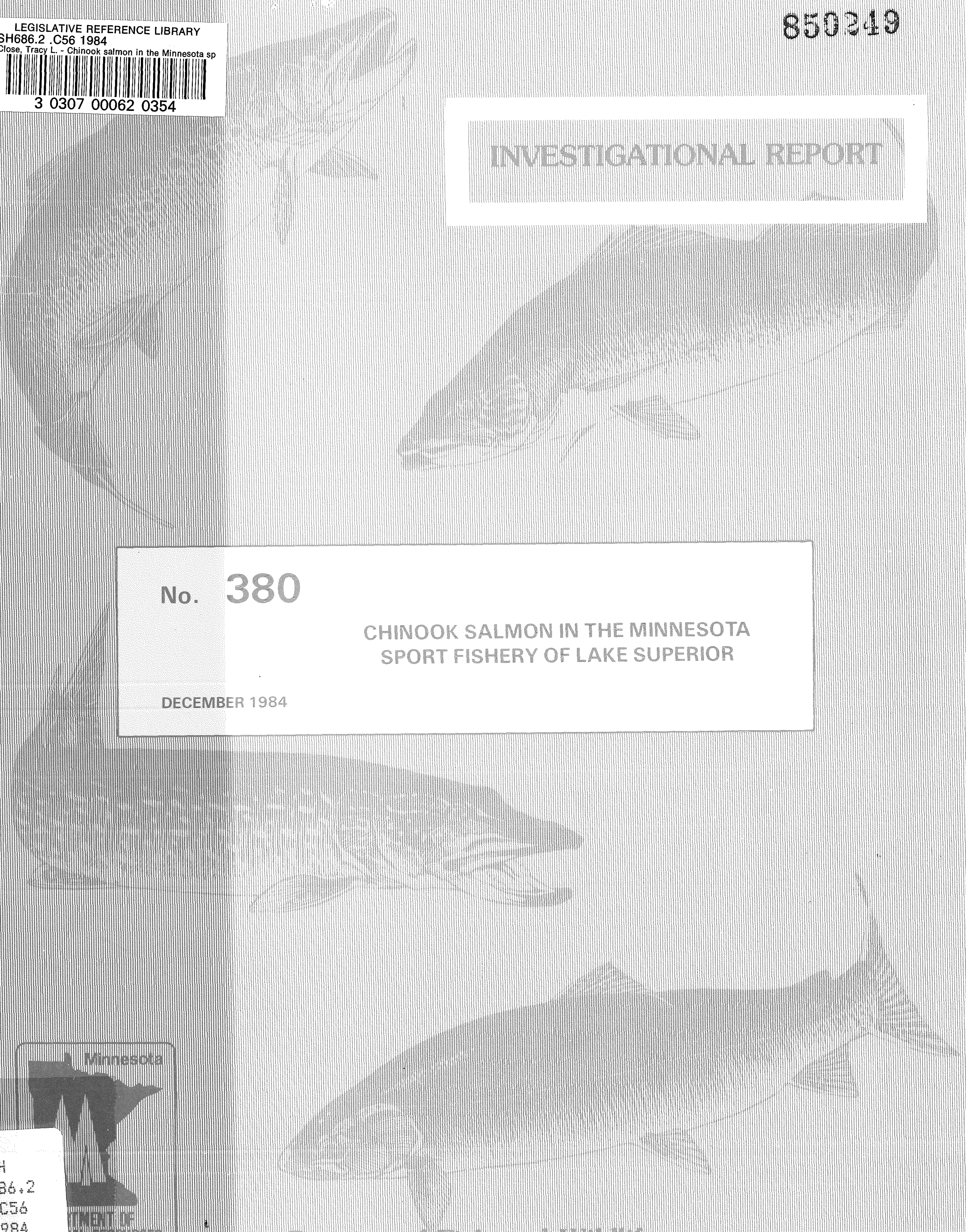

INVESTIGATIONAL REPORT

No. 380

CHINOOK SALMON IN THE MINNESOTA SPORT FISHERY OF LAKE SUPERIOR

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Minnesota
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Division of Fish and Wildlife

CHINOOK SALMON IN THE MINNESOTA SPORT FISHERY OF LAKE SUPERIOR[1]

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ABSTRACT

Exotic salmonids were introduced into the Great Lakes to provide and diversify sport fishing opportunities. Spring strain chinook salmon (Oncorhynchus tshawytscha) were stocked in Minnesota waters of Lake Superior during 1974-1978 and fall strain since 1979. Life history and sport fishery data were collected during 1976-1982 and evaluated to determine the benefit of the species in the Lake Superior sport fishery and to compare the strains.

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[1] This project was funded in part by Federal Aid Fish Restoration (Dingell-Johnson) Program. Completion Report, Study 213, Project DJ F-26-R Minnesota.

Angler caught spring chinook salmon averaged 546 ± 30 mm total length and fall chinook averaged 617 ± 24 mm. Spawning spring chinook averaged 725 ± 14 mm while fall strain chinook averaged 737 ± 10 mm. Spawners of both strains were predominently age 3+ but ranged from 2+ to 4+. Fish dominated the chinook diet but small chinook (<550 mm) also fed heavily on opossum shrimp (<u>Mysis relicta</u>). Spring chinook spawning migration peaked during September and fall chinook migration peaked during October. Straying to unstocked streams and natural reproduction was minimal. Seasonal harvest rates ranged upward to 0.008 chinook salmon per hour. Annual harvest ranged from 50 ± 10 to 1,306 ± 355 fish. Creel return rates increased annually reaching a maximum of 0.33% for the 1979 cohort. The benefit:cost ratio in the last two years was estimated to be 1.73:1 and increasing.

The chinook salmon appears to be a suitable species for the Lake Superior sport fishery and meets basic management objectives. Initial data suggest that the fall strain may perform the best overall. Additional work is needed to evaluate the species' impact in the Lake Superior ecosystem.

INTRODUCTION

Exotic salmonids provide fishing recreation and diversify angling opportunities. The rainbow trout (Salmo gairdneri) was introduced into Lake Superior in 1895 (Lawrie and Rahrer 1972) and has been the target of significant fishing effort (Hassinger et al. 1974; Close and Siesennop 1984). Coho salmon (Oncorhynchus kisutch) and chinook salmon (Oncorhynchus tshawytscha) were introduced into Lake Michigan and Lake Superior by the Michigan Department of Natural Resources in 1966 and 1967, respectively, and created popular salmon fisheries (Michigan Department of Natural Resources 1973). The Minnesota Department of Natural Resources formulated management objectives for a salmon species which would: 1) efficiently utilize Lake Superior's forage; 2) attain a size comparable to the lake trout but in a shorter time; 3) return to spawn at a time and at streams facilitating maximum harvest; 4) provide a self-sustaining egg source; and 5) allow optimum control of abundance. The coho salmon was selected for initial introduction and evaluation and were stocked from 1969-1972. Coho returned to near-shore areas too late for optimum harvest (Hassinger 1974) so stocking was discontinued. An alternate salmon species, the chinook salmon, was then selected for evaluation.

Chinook salmon are arbitrarily divided into three strains - spring, summer and fall, based on timing of return to natal streams (Fulton 1968). Spring chinook appeared to have the highest probability of meeting the management objectives. Eggs were obtained from West Coast hatcheries and fingerlings were stocked commencing in 1974 (Tables 1 and 2). Beginning in 1979, however, disease-free spring chinook eggs were unavailable from western sources and egg collections from Lake Superior brood stock were inadequate to meet stocking quotas. Fall chinook eggs were obtained at the

Table 1. Egg source, number and strain of chinook salmon eggs hatched for stocking in Lake Superior, 1974-1984.

Year class	Egg source	Number	Strain
1974	Rapid River Hatchery, Riggins, Idaho	579,000	Spring
1975	None available	0	-
1976	Cowlitz Hatchery, Salkum, Washington	466,000	Spring
1977	Cowlitz Hatchery, Salkum, Washington	535,000	Spring
1978	Cowlitz Hatchery, Salkum, Washington	400,000	Spring
1979	Little Manistee weir, Manistee, Michigan	675,000	Fall
1980	Little Manistee weir, Manistee, Michigan	675,000	Fall
1981	Little Manistee weir, Manistee, Michigan	675,000	Fall
	French River weir, Duluth, Minnesota	92,000	Spring
1982	Little Manistee weir, Manistee, Michigan	990,000	Fall
	French River weir, Duluth, Minnesota	37,000	Fall
1983	Little Manistee weir, Manistee, Michigan	1,050,000	Fall
	French River weir, Manistee, Michigan	430,000	Fall
1984	French River weir, Duluth, Minnesota	680,000[a]	Fall

[a] Filled egg quotas, more eggs possible.

Table 2. Lake Superior (Minnesota) chinook salmon stocking summary, 1974-1982. Numbers in parentheses are the size ranges of fingerlings (number of fish per kilogram). Fry were planted following absorption of the yolk sac. The letter "S" indicates spring strain and "F" indicates fall strain.

Stocking site	1974	1976	1977	1978	1979	1980	1981	1982
Brule River								F218,815 (fry)
Rosebush Creek						F20,580 (540)	F30,725 (518-600)	F19,890 (337)
Good Harbor Bay					F37,310 (143-181)			
Cascade River	S71,900 (26-168)	S86,600 (110-154)	S11,000 (24)	S44,455 (82)	F48,347 (357)	F60,022 (540)	F113,560 (518-600)	F66,555 (337)
Temperance R.						F24,304 (864)	F78,486 (fry)	F56,829 (337) F146,218) (fry)
Two Island River								F46,284 (1,343) F101,132 (fry)
Baptism River	S72,299 (26-170)	S86,600 (110-154)	S11,000 (24)	S43,333 (79)	F83,974 (153-357)		F144,759 (518-564)	F141,782 (390)

Table 2. Continued.

Stocking site	1974	1976	1977	1978	1979	1980	1981	1982
Beaver River						F81,095 (540)		
Silver Creek						F36,750 (540)		
Bluebird Landing					F45,697 (95-181)			
French River	S83,505 (26-170)	S88,700 (13-154)	S40,573 (18-66)	S58,925 (26-82)	F72,246 (362-395)	F46,795 (540)	SF86,844 (337-519)	F78,560 (309-362)
Lester River						F47,530 (540)	F57,240 (518-624)	F79,376 (362)
TOTALS								
Fingerling	S227,704	S261,900	S62,573	S146,713	F287,574	F317,076	SF433,128	F489,276
Fry							F78,486	F466,165

Little Manistee River, Michigan and juveniles stocked from 1979-1982.

This study was initiated in 1976 to determine the suitability of the spring chinook salmon as a sport fish in the Lake Superior and North Shore fishery. In 1979, the study was modified to include the fall chinook and to compare the two strains.

STUDY AREA

The study area included the Minnesota waters of Lake Superior (572,900 ha) and its drainage extending from Duluth northeast to the Pigeon River (304 km of shoreline). The Minnesota shoreline is rocky and the lake bottom drops off rapidly. Eighty-seven percent of the surface area is deeper than 73 m (Great Lakes Fishery Commission Memorandum, 11 November 1980). Thermal stratification occurs in late July when maximum surface temperatures range from 12.6 to 16.8 C (Upper Lakes Reference Group 1977). Primary productivity is low resulting in low zooplankton abundance. Principle forage for fish includes the oppossum shrimp (*Mysis relicta*), rainbow smelt (*Osmerus mordax*) and several species of Coregonidae. The major sport fish are lake trout (*Salvelinus namaycush*), brook trout (*S. fontinalis*), rainbow trout, brown trout (*Salmo trutta*), Atlantic salmon (*S. salar*), chinook salmon and coho salmon. The sea lamprey (*Petromyzon marinus*) is a significant species due to its parasitic behavior and impact on large sport fish.

The Minnesota portion of the Lake Superior watershed extends 24-40 km inland from the lakeshore (Smith and Moyle 1944) and is characterized by unproductive soils and rugged terrain. Twenty-eight major streams and a number of smaller streams and intermittent creeks provide spawning areas for anadromous fish. Stream flows are erratic and sustained principally by surface runoff. Highest flows generally occur in May during snow melt while low flows occur during midwinter and midsummer (Upper Lakes Reference Group 1977). Gravel bars at the stream mouths and barrier falls often limit upstream migration of anadromous fish. Vegetative cover and aquatic insect abundance are low, limiting fish production (Smith and Moyle 1944).

MATERIALS AND METHODS

Chinook salmon were sampled to obtain data relating to growth, longevity, food habits, timing and magnitude of spawning migrations, extent of straying and natural reproduction, and angler harvest. A large portion of the chinook were collected near the mouth of the French River during the spawning run. Fish were captured either in the permanent trap adjacent to the Area Fisheries Headquarters or by seining immediately downstream of the trap. Chinook salmon were taken incidentally in lake trout test nets of various lengths containing 114-165 mm stretch mesh. Salmon observed during the Lake Superior creel census were also sampled.

Growth and Longevity

Growth and longevity were evaluated by analysis of physical measurements and scale annuli. Physical data included total length (mm), weight (g), sex and type of fin clip from each fish. Length at age was calculated utilizing the Lee Method (Lagler 1956). Means of various population parameters were compared by Student's t tests at an alpha level of 0.05 (Snedecor and Cochran 1967). All confidence limits are reported at the 95% level. Weighted Walford line regressions were calculated for each strain (Ricker 1975) and slopes and elevations of the regressions were compared statistically by analysis of covariance (Snedecor and Cochran 1967).

Food Habits

Stomachs were obtained from fish observed in the creel census and caught in lake trout test nets. Stomach contents were analyzed separately for chinook less than and greater than 550 mm. The food volume in each stomach was measured by water displacement (Lagler 1956) and food items were identified to order. The estimated percentage of volume and percent occurrence were calculated for each.

Timing and Magnitude of the Spawning Run

Spawning migrations (runs) were characterized by periodicity of chinook salmon capture in the French River. The French River fish trap was operated April through November and the catch enumerated daily. The pool immediately downstream of the trap was seined periodically (approximately once weekly) during major spawning runs and the catch enumerated. Total spawning escapement of each cohort (percent) was estimated by the ratio of the total of each cohort trapped or seined in the French River to the combined number stocked there and at the Bluebird Landing boat access near the French River.

Straying and Natural Reproduction

Evidence of stocked fish straying into unstocked streams was provided by contacts with anglers during the creel census, unsolicited angler reports, observations by fisheries personnel and electrofishing for juveniles. Several Lake Superior tributary streams were electrofished annually during August to determine reproductive success of chinook salmon.

Sport Fishery

A creel census of the Minnesota waters of Lake Superior was conducted annually from 1976 through 1982. The census period extended from the beginning of June through the end of September with additional data collected during October-December from 1976-1980. Two census clerks sampled 22 major landings and fishing areas between Duluth and Hovland. Creel census methods followed Schupp (1964) and Fleener (1971). Fishing contests were monitored separately and their harvest totals added to the census estimates.

The North Shore was divided into two geographic areas (eastern and western) with one clerk assigned to each. Census clerks obtained counts of the number of completed angler trips, the number of boat-angler cars and the number of boat-anglers per car. Fishing parties were interviewed to determine hours fished and harvest. Individual lengths, weights and scale samples were obtained from creeled chinook salmon. Fishing effort was calculated separately for boat and shore anglers. Harvest estimates were determined for each geographic area and then combined for total Lake Superior harvest. An age-class frequency distribution was applied to the chinook harvest to estimate relative creel return of individual cohorts.

Benefit:Cost Evaluation

A benefit:cost ratio was assessed considering benefit to the regional economy and cost of chinook salmon production for the same year. As the Lake Superior fishery is non-specific for any of several salmonids, an assumption was made that equal preference and value was given by anglers to each species. An average expenditure per fishing trip by a Minnesota angler was estimated to be $26 (U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of Census 1982). This expenditure times the percent composition of chinook salmon in the Lake Superior harvest provided a minimal estimate of chinook benefit. The cost included fish production expenses of egg collection, incubation and rearing but excluded amortized facility and distribution costs.

RESULTS

Size at Capture

The average total length and weight of chinook salmon caught by anglers were 575 ± 20 mm and 2,289 ± 289 g, respectively. Lengths ranged from 300 mm to over 950 mm (Fig. 1). Spring chinook averaged 546 ± 30 mm and 2,012 ± 482 g (n = 59) while fall chinook averaged 616 ± 24 mm and 2,553 ± 332 g (n = 46). The significant difference in average length was a result of a large difference between the 1977 spring chinook cohort and fall chinook (one cohort, 1979). All other spring chinook cohorts (1974, 1976 and 1978) were similar in length to the fall chinook.

Total lengths of both strains of prespawning adult chinook captured in the French River were also similar. Adult spring chinook averaged 725 ± 14 mm (n = 216) while fall chinook averaged 737 ± 10 mm (n = 183). No differences between individual cohorts of spring chinook and fall chinook occurred.

Growth Rates

Fall chinook were significantly larger than spring chinook at all compared annuli (Fig. 2). Age 4+ fall chinook were not available for comparison. The greatest difference in length at age between the strains occurred at annulus 2 when fall chinook averaged 87 mm longer than spring chinook.

Walford line equations were:

Spring: $L_{t+1} = 197.4 + 1.01\ L_t$ ($r^2 = + 0.864$, $n = 482$);

Fall : $L_{t+1} = 264.2 + 0.77\ L_t$ ($r^2 = + 0.800$, $n = 366$).

The slopes of the Walford lines for the two chinook strains were significantly different Spring chinook grew at an accelerating rate throughout their life span (slope > 1) while fall chinook exhibited a decelerating growth rate (slope < 1). Maximum theoretical length (L_{∞}) of fall chinook was 1,149 mm while the maximum theoretical length could not be calculated for spring chinook (slope must be < 1).

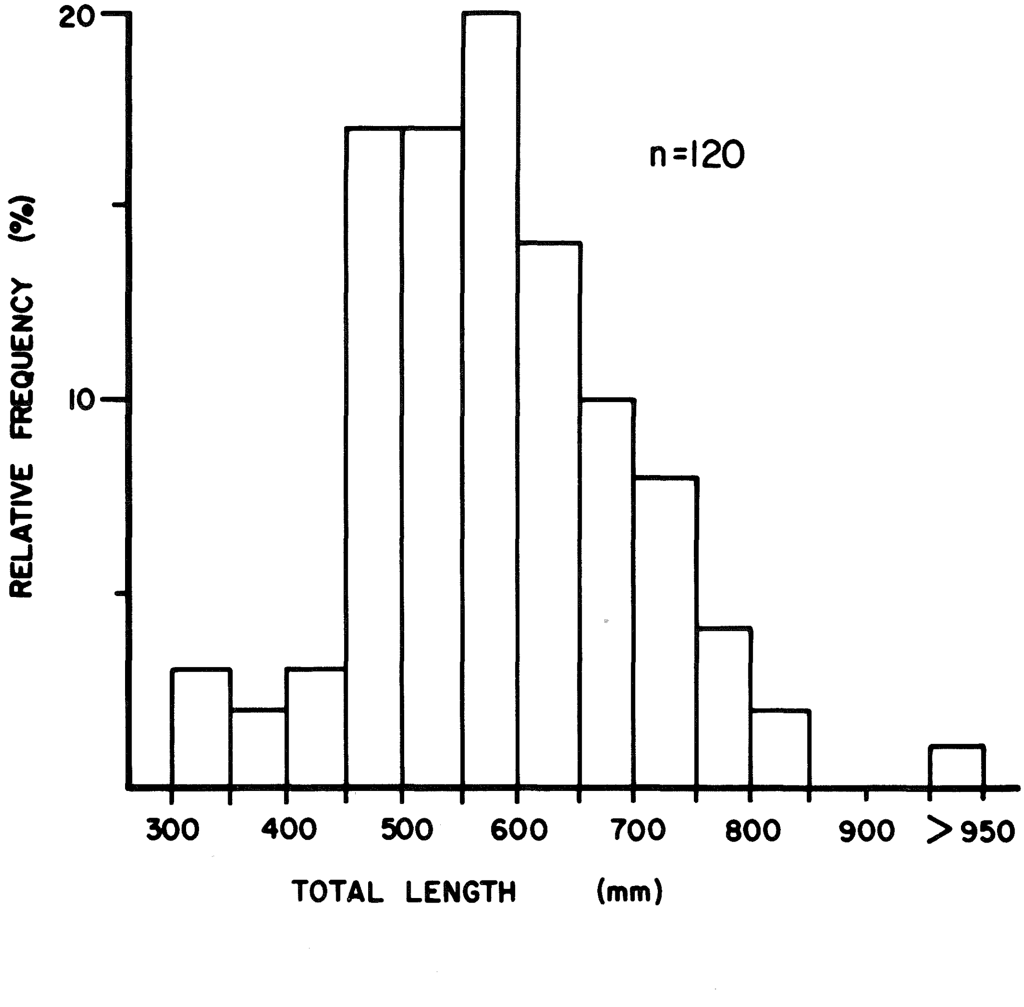

Figure 1. Length frequency distribution of chinook salmon in the Lake Superior, Minnesota sport fishery, 1976-1982.

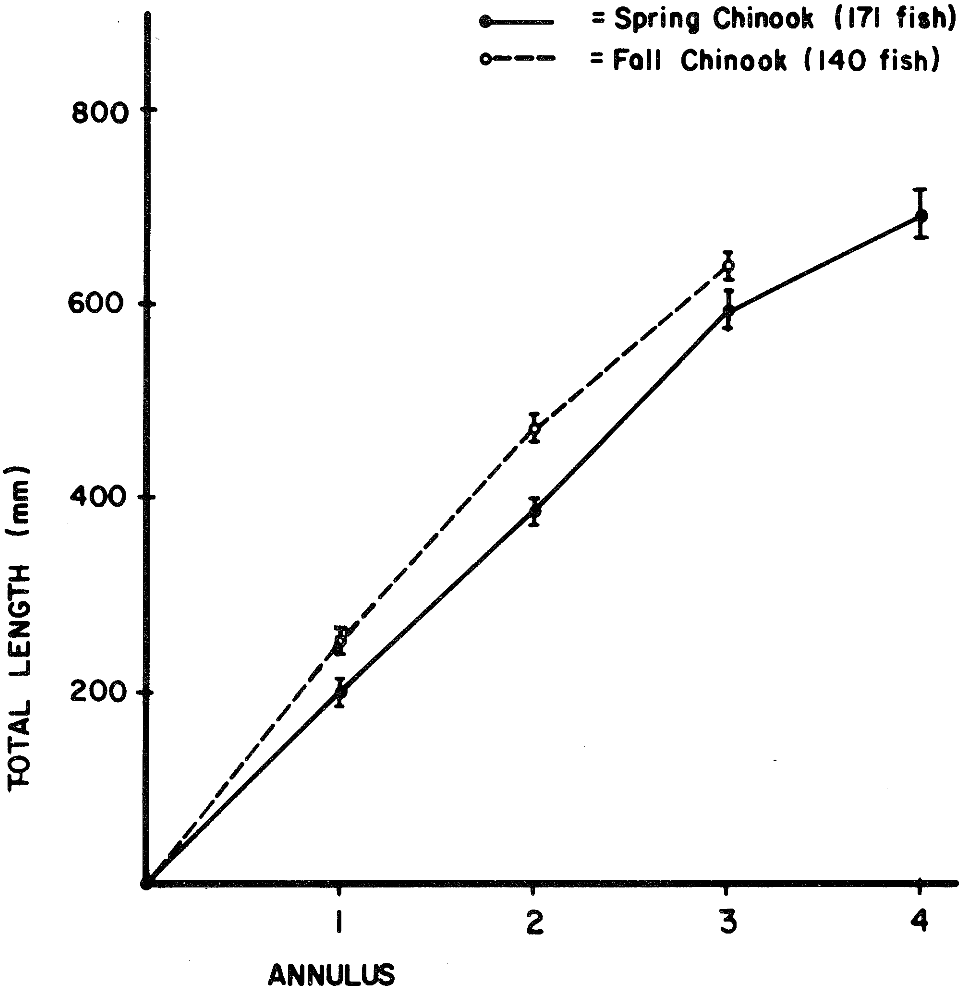

Figure 2. Average calculated total length at annulus formation and its 95% confidence interval of fall and spring strain chinook captured in Minnesota waters of Lake Superior from 1976-1982.

Longevity

The mean age of angler caught chinook salmon was 2.4 ± 0.1 while the mean age of spawners was 2.8 ± 0.1 (Fig. 3). Spring and fall strain spawners of both sexes were predominantly age 3+ (Fig. 4). The mean age of spring chinook males was 2.8 ± 0.1 and females 2.9 ± 0.1 while the average age of male fall chinook was 2.7 ± 0.2 and females 2.9 ± 0.2. Age differences between the sexes were not significant for either strain. The study was terminated before a fall strain cohort reached age 4.

Food Habits

Stomach contents of 21 large salmon averaging 696 ± 32 mm (range 599-800 mm) and 22 small salmon averaging 428 ± 22 mm (range 300-521 mm) were analyzed (Table 3).

Table 3. Contents of chinook salmon stomachs examined during 1981-1982. Large chinook are those greater than 550 mm total length (N = 21) and small chinook are those less than 550 mm total length (N = 22).

	Percent of total volume		Frequency of Occurrence[a] (%)	
	Large chinook	Small chinook	Large chinook	Small chinook
Mysidacea	0.0	45.8	0.0	64.7
Orthoptera	0.0	trace	0.0	5.9
Chironomidae	0.1	2.4	20.0	11.8
Other Diptera	0.0	trace	0.0	35.3
Unid. Insecta	0.0	0.5	0.0	11.8
Smelt	99.6	43.6	60.0	23.5
Unid. fish	0.3	7.7	20.0	17.6

[a] In stomachs which contained food.

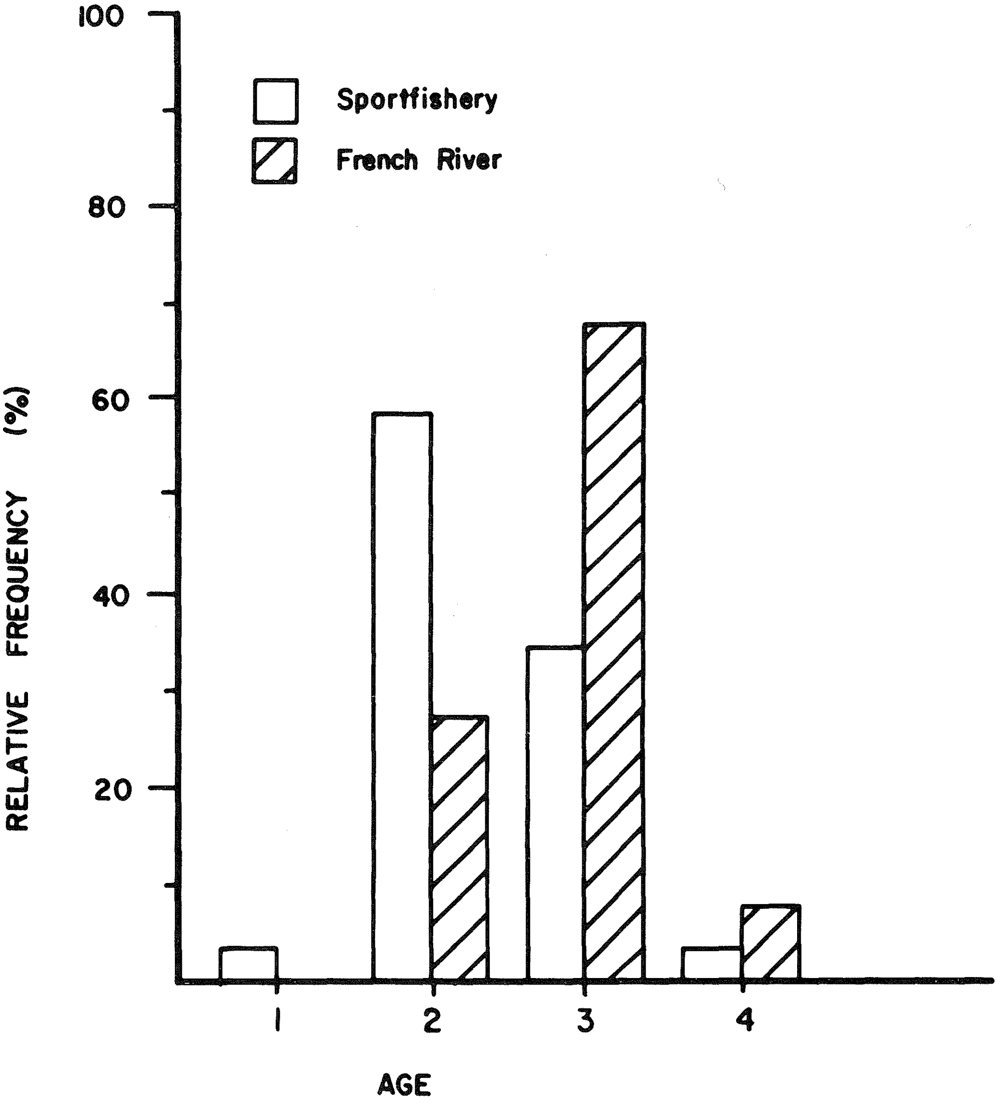

Figure 3. Age-class frequency distribution of chinook salmon caught in the Lake Superior sport fishery and in the French River escapement trap and pool, 1976-1982.

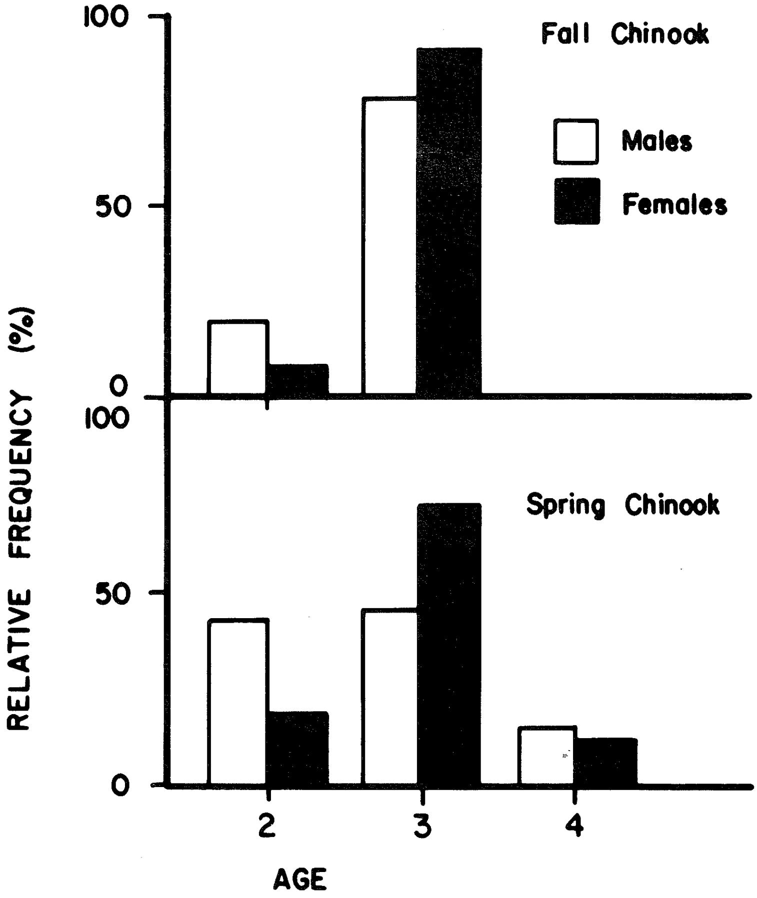

Figure 4. Age distribution of fall and spring strain chinook salmon (males and females indicated) captured in 1982 and 1976-1980, respectively, in the French River trap and pool.

Twenty-four percent (5) of the stomachs from the large salmon contained food. Smelt and other fish remains comprised 99.9% of the food volume. Seventy-seven percent (17) of the stomachs from the small salmon contained food. Opossum shrimp were found in 65% of the stomachs of small salmon and comprised 46% of the food volume. Smelt and fish remains comprised 51% of the food volume

Timing and Magnitude of the Spawning Migration

Spring strain fish spawned earlier than fall strain fish. The spring chinook spawning runs began in May and peaked in September (Table 4). The fall chinook run in 1982 began in June and peaked during October. The run during 1981 was not included in Table 4 because it contained significant numbers of both strains which were not readily identifiable.

Table 4. Average monthly catch of adult spring and fall chinook salmon trapped and seined in the French River, 1976-1980 and 1982.

	Spring chinook 1976-1980		Fall chinook 1982	
Month	No. of fish caught	Percentage of total	No. of fish caught	Percentage of total
May	9	2.5	0	0.0
June	12	3.3	1	0.1
July	32	8.8	32	3.9
August	104	28.7	83	10.0
September	157	43.2	269	32.5
October	49	13.5	437	52.8
November	0	0.0	6	0.7
TOTAL	363	100.0	828	100.0

The spawning escapement to the French River trap increased annually from 4 fish in 1976 to 828 fish in 1982 (Fig. 5) as did spawning escapement of individual cohorts (Table 5). The catch of spring chinook increased from 0.04% to 0.58% of the 1974 and 1978 stocked cohorts, respectively. Spawning escapement (through 1982) of the 1979 fall chinook cohort was 0.53% with age 4+ fish yet to return.

Table 5. Spawning escapement of chinook salmon cohorts planted in French River and at Bluebird Landing and captured in the French River fish trap and pool.

	Cohort						Totals
	1974	1976	1977	1978	1979[a]	1980[b]	1974-1979
Number captured	29	141	175	341	642	223	1,328
Percent of number planted	0.04	0.16	0.43	0.58	0.53	---	0.34

[a] Incomplete return. Age 4+ fish not yet returned.
[b] Incomplete return. Age 3+ and 4+ fish not yet returned.

Straying and Natural Reproduction

Straying of adult chinook salmon into unstocked North Shore streams was neither reported by the public nor observed by fisheries personnel. Juvenile chinook, however, were first electrofished in unstocked streams in 1981 when young-of-the-year chinook salmon were observed in Onion Creek and Indian Camp Creek (Table 6). Young-of-the-year without parr marks were again found in 1982 in the lower reaches of several streams.

Sport Fishery

Chinook salmon contributed to the Lake Superior sport fishery. The highest observed seasonal catch rate was 0.008 ± 0.007 chinook per hour (Table 7). Harvest estimates for the summer fishery ranged from 50 ± 10

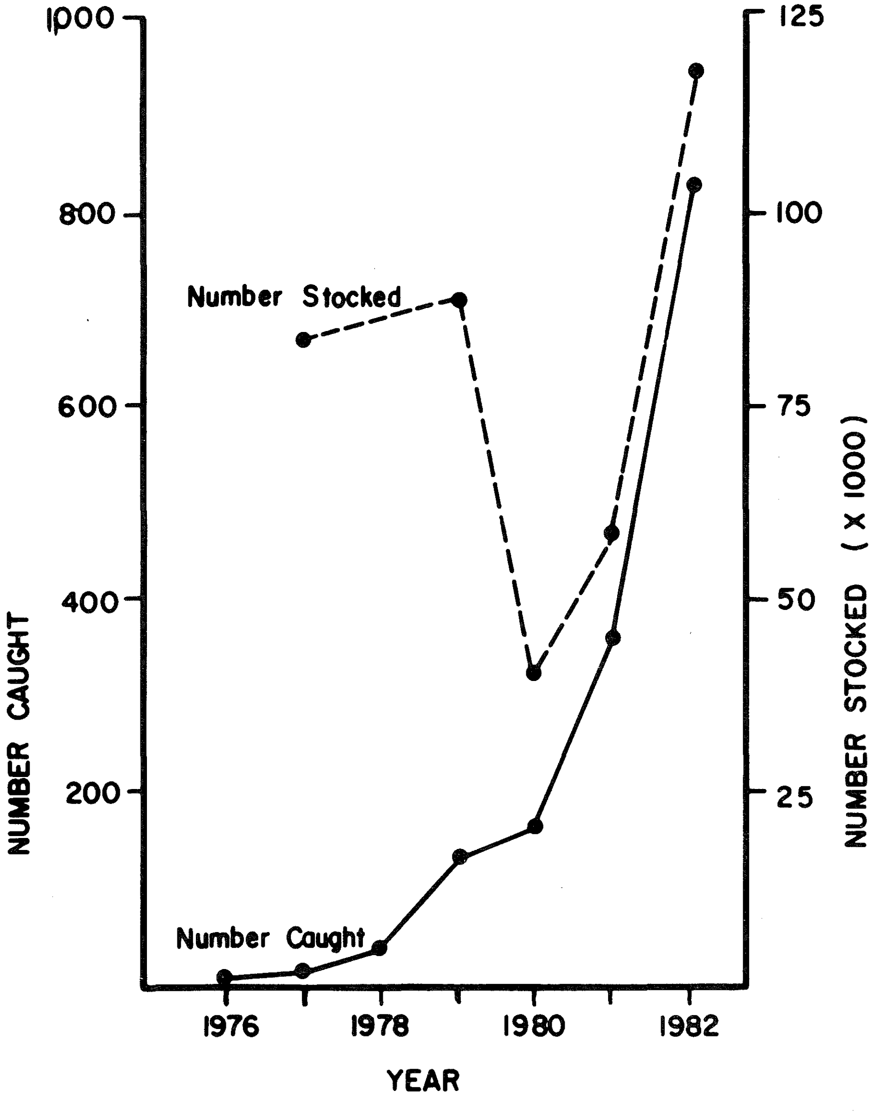

Figure 5. Annual catches of chinook salmon in the French River fish trap and pool, and number of chinook stocked at French River and Bluebird Landing three years prior to capture, 1976-1982.

Table 6. Lake Superior tributary streams electrofished to determine the presence of chinook salmon natural reproduction (indicated by an X), streams where juvenile salmon were found (indicated by an O) and those stocked (1980-1982) with chinook (indicated by an S).

		Years sampled							
Streams	County	1975	1976	1977	1978	1979	1980	1981	1982
Silver Creek	Carlton			X	X	X	X	X	
Blackhoof R.	Carlton			X	X	X	X	X	
Lester River	St. Louis	X	X	X	X	X	X	XS	XS
Amity Creek	St. Louis					X	X	X	X
Talmadge R.	St. Louis	X	X	X	X	X	X	X	X
Sucker River	St. Louis	X	X	X	X	X	X	X	X
Knife River	Lake	X	X	X	X	X	X	X	X
Silver Creek	Lake	X	X	X	X	X	XS	X	X
Split Rock R.	Lake				X	X	X	X	
Temperence R.	Cook						S	XS	S
Onion River	Cook							O	
Rollins Creek	Cook						X	X	
Jonvick Creek	Cook						X	X	
Deer Yard Cr.	Cook							X	X
Indian Camp Cr.	Cook						X	O	O
Cascade River	Cook						S	XS	S
Cutface Creek	Cook						X		X
Rosebush Creek	Cook						XS	S	XS
Devil Track R.	Cook							X	O
Durfee Creek	Cook						X		X
Cliff Creek	Cook						X		
Kimball Creek	Cook							X	X
Stone Creek	Cook						X		X
Kadunce Creek	Cook							X	O
E. Colville Cr.	Cook						X		X
Little Brule R.	Cook						X		
Brule River	Cook								XS
Myhr Creek	Cook						X		O
Flute Reed R.	Cook							X	O
Carlson Creek	Cook							X	O
Farquhar Creek	Cook						X		X

Table 7. Chinook salmon harvest rates (fish/h ± 95% confidence interval) for the Minnesota Lake Superior sport fishery, 1976-1982.

	1976	1977	1978	1979
Western area, shore anglers	<0.001 ± 0.001	0	0	0
Eastern area, shore anglers	0	0.007 ± 0.014	0	0
Unweighted avg., shore anglers	<0.001 ± 0.001	0.004 ± 0.010	0	0
Western area, boat anglers	0.002 ± 0.002	0.003 ± 0.005	0.004 ± 0.005	0.003 ± 0.002
Eastern area, boat anglers	0.003 ± 0.003	0.008 ± 0.007	0	0
Unweighted avg., boat anglers	0.003 ± 0.003	0.006 ± 0.006	0.002 ± 0.004	0.002 ± 0.001
Unweighted avg., Catch Rate	0.002 ± 0.002	0.005 ± 0.008	0.001 ± 0.003	0.001 ± 0.001

Table 7. Continued.

	1980	1981	1982	Unweighted avg. 1976-1982
Western area, shore anglers	0	<0.001 ± 0.001	0.006 ± 0.012	0.001 ± 0.005
Eastern area, shore anglers	0	0	0.001 ± 0.002	0.001 ± 0.005
Unweighted avg., shore anglers	0	<0.001 ± 0.001	0.004 ± 0.009	0.001 ± 0.005
Western area boat anglers	0	0.007 ± 0.005	0.005 ± 0.002	0.003 ± 0.004
Eastern area, boat anglers	0.001 ± 0.001	0.003 ± 0.004	0.002 ± 0.003	0.002 ± 0.003
Unweighted avg., boat anglers	0.001 ± 0.001	0.005 ± 0.005	0.004 ± 0.003	0.003 ± 0.004
Unweighted avg.	<0.001 ± 0.001	0.003 ± 0.003	0.004 ± 0.006	0.002 ± 0.004

chinook in 1979 to 1,306 ± 355 fish during 1982 (Fig. 6). Harvest during the October and November fall season was negligible in censused years declining from 12 in 1976 to 0 in 1979 and 1980. Fall censuses were not conducted after 1980. Creel return rates of the 1974-1978 cohorts (spring strain) ranged from 0.06%-0.28% of the respective plants (Table 8). Creel return rate of the 1979 cohort (fall strain) totaled 0.33% of the plant with age 4+ individuals still available to anglers.

Table 8. Total harvest of each cohort and percent of chinook salmon cohorts captured in the sport fishery. Percent returns are based on lake-wide chinook plants.

	Cohort							Totals,
Census area	1974	1976	1977	1978	1979[a]	1980[b]	1981[c]	1974-1979
Western	184	125	88	347	815	680	39	1,559
Eastern	418	41	19	71	146	109	6	695
Total	602	166	107	418	961	789	45	2,254
Angler recoveries as percent of number stocked	0.26	0.06	0.17	0.28	0.33	-	-	0.23

[a] Ages 0-3+ only.
[b] Ages 0-2+ only.
[c] Ages 0-1+ only.

Benefit:Cost Ratio

The average annual benefit:cost ratio for the 1976-1982 period was 1.55:1 (Table 9). Annual benefit:cost ratios ranged from a low of 0.39 to a high of 7.16. Chinook salmon provided an average 4.6% of the annual Lake Superior sport fish harvest and $66,488 of economic benefit. Benefit:costs for 1981 and 1982 were both favorable, 1.98 and 1.48, respectively. Angler expenditures attributed to chinook were $128,759 and $110,108 each year, respectively.

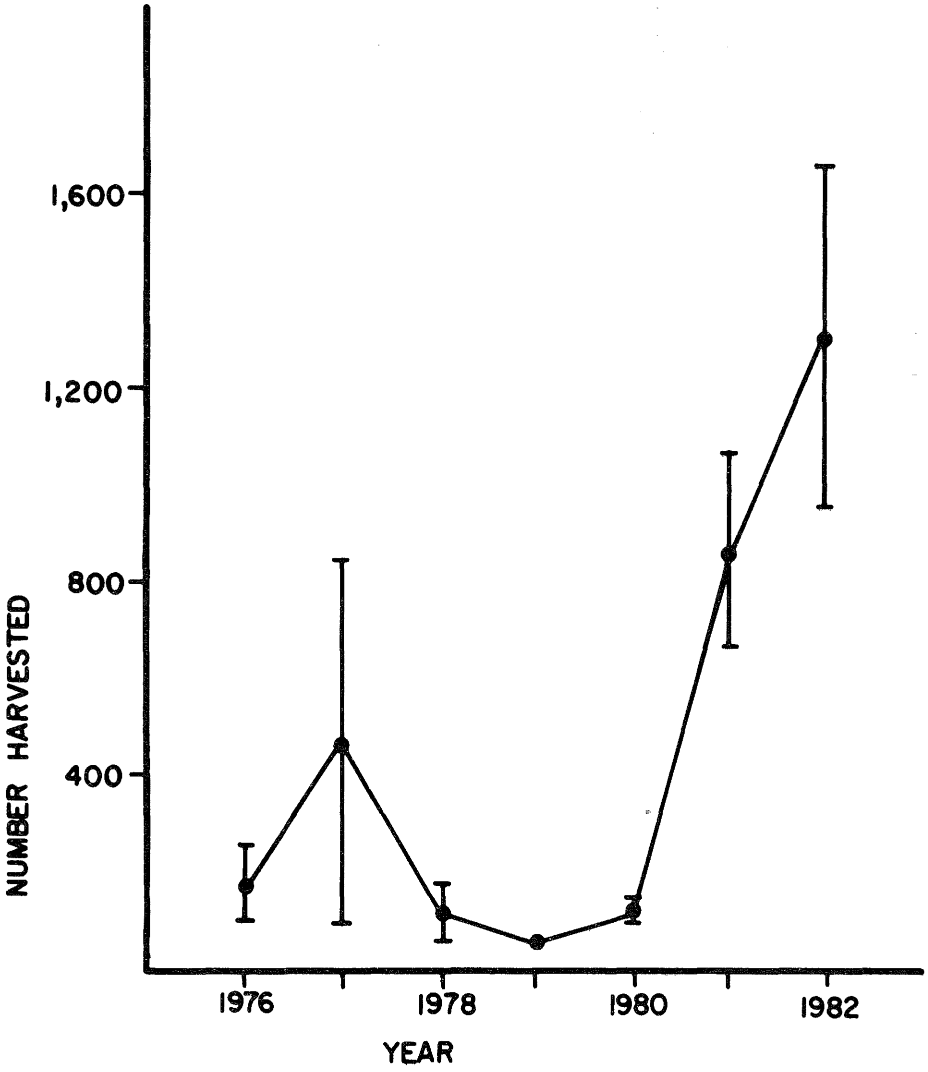

Figure 6. Chinook salmon sport fishery harvest in Minnesota waters of Lake Superior, 1976-1982. Vertical bars represent the 95% confidence intervals.

Table 9. Angling effort, angler expenditures, production costs at French River Coldwater Hatchery and benefit-cost ratios for chinook salmon stocked in Minnesota waters of Lake Superior, 1976-1982.

	1976	1977	1978	1979
Number of angler trips	39,246	52,569	32,764	38,331
Percent of harvest, chinook	3.1	4.9	3.5	2.7
Angler expenditures[a]	$1,020,396	$1,366,794	$851,864	$996,606
Angler expenditures, chinook	$32,074	$67,231	$29,742	$27,129
Chinook fingerling production costs	$39,285	$9,386	$22,007	$43,136
Chinook fry production costs	0	0	0	0
Total production costs	$39,285	$9,386	$22,007	$43,136
Benefit:cost ratio	0.82:1	7.16:1	1.35:1	0.63:1

Table 9. Continued.

	1980	1981	1982	Weighted average
Number of angler trips	75,233	70,190	81,086	55,631
Percent of harvest, chinook	1.0	7.1	5.2	4.6
Angler expenditures[a]	$1,956,058	$1,824,940	$2,108,236	$1,446,413
Angler expenditures, chinook	$18,625	$128,759	$110,108	$66,488
Chinook fingerling production costs	$47,561	$64,969	$73,391	$42,819
Chinook fry production costs	0	$157	$932	$156
Total production costs	$47,561	$65,126	$74,323	$42,975
Benefit:cost ratio	0.39:1	1.98:1	1.48:1	1.55:1

[a] $26 expenditure per angler trip (U.S. Dept. of Int., Fish and Wildl. Serv. and U.S. Dept. of Comm., Bur. of Census 1982).

DISCUSSION

The size (weight) of creeled chinook salmon compared favorably to lake trout and coho salmon. Weights of chinook and lake trout were similar but chinook growth rates were much faster. Creeled chinook averaged 2.4 annuli and 2,229 g while lake trout averaged 1,877 g and 7.1 annuli during the 1980-1982 fishing seasons (unpublished file data). Chinook salmon achieved comparable weights in roughly one-third the time. Creeled chinook were larger on average than coho which averaged 1,589 g (Hassinger 1974).

Fall chinook were larger on average than spring chinook at all annuli. In spite of this fact, the observed growth patterns resulted in similar average lengths by spawning time. Any difference may not have been large enough to be important to anglers.

The difference in growth rates may relate to stream residency periods of the two strains. Stream residency of juvenile spring chinook is longer than of fall chinook in the Columbia River (Koo and Isarankura 1967) and Minnesota fisheries personnel have observed similar behavior in North Shore streams. Stream growth circuli of Minnesota chinook scales were more tightly spaced than lake growth circuli indicating slower growth. Extended stream residency was apparently disadvantageous for spring chinook growth and their accelerating growth rate (shown by the Walford equation) was probably a compensatory mechanism.

Minnesota's chinook were similar to chinook in Lake Michigan with respect to longevity and lived longer than the coho. Age frequency distributions of fish sampled from French River spawning migrations were more similar to those of spawners in the Little Manistee River, Michigan (Hay 1982) than Columbia River fish (Young and Robinson 1974). Three age-classes (2-4) comprised the lake runs with age 3+ predominating. Sea runs combined up to five year-classes (2-6). Spawning coho at French River were predominately age 2+ with a small percentage of age 1+ males (Hassinger 1974).

Diet data indicate that chinook and lake trout had similar food habits. Hale (1960) found that smelt was the predominant food item of lake trout in Lake Superior. The chinook's rapid growth rate indicates that the species is a highly efficient and/or voracious predator. Sizable populations are capable of significantly reducing the forage base of Lake Superior and thus impacting the other predator species. Increased stocking should be approached cautiously and increased investigations of forage base dynamics are advised.

Timing of chinook salmon migrations was earlier than that of coho salmon. Coho migrations occurred in late October and November while chinook runs peaked in September and early October. Although the timing of the spring chinook migration was earlier, both strains had essentially completed their migrations by November allowing harvest before severe winter weather.

Spawning escapement of chinook salmon cohorts indicated minimal survival rates. The average spawning escapement of spring chinook cohorts was 0.30% compared to 1.75% for coho (Hassinger 1974). Spawning escapement of ripe chinook was inadequate to satisfy egg requirements during the evaluation but spawning escapement at French River in 1983 totaled 827 spawners and egg collections were adequate to meet stocking quotas. Continued spawning escapement of the magnitude observed in 1983 should result in sufficient numbers of eggs. The 1979 cohort (fall chinook) returned at a greater rate than the average for spring chinook but additional monitoring is needed before conclusive comparisons can be made.

The low level of straying to unstocked streams facilitates control of the harvest site and minimizes influence on other fisheries. Angler accounts of straying chinook salmon increased in 1983, however, with reports of "substantial" numbers of fish entering the Knife and Sucker rivers, Minnesota, and Brule River, Wisconsin. Increased straying may simply be a result of increased abundance. Estimates of the 1983 chinook harvest indicated a 2.8 fold (3,479 fish caught) increase in harvest over 1982 with only a 1.5 fold increase in effort (unpublished file data).

It was assumed that straying to the French River by chinook stocked in other states or provinces was minimal. Minnesota chinook were stocked before indications of smoltification appeared to insure imprinting and to maximize return to Minnesota anglers. It was assumed that other states imprinted their fish in a similar manner and for the same reason. The lack of strays in other North Shore streams suggests that our assumption was correct.

Observation of chinook smolts in unstocked streams was contrary to a management objective as natural reproduction detracts from the manager's ability to control abundance. However, the smolts may not have been from natural reproduction. All samples were collected in lower reaches and none of the fish had parr marks suggesting that the smolts could have migrated into the stream after first leaving a stocked stream. Smolts were observed in unstocked tributaries of stocked streams (J. Storland, Minnesota Dept. Nat. Res., personal communication 1984). Similar migratory behavior has been observed on the Pacific Coast (Cederholm and Scarlett 1982). Monitoring chinook natural reproduction should continue to evaluate straying with particular emphasis on noting the presence or absence of parr marks and capture location.

Angler harvest of chinook salmon in the earlier years of the evaluation was lower than that of coho. Seasonal catch rates of coho averaged 0.01 (summer) and 0.22 (fall) fish/h (Hassinger 1974) while the highest catch rate observed for chinook was 0.008 fish/h. Creel return of coho averaged 1.3% while the highest observed rate for chinook was 0.33%. Creel return rates increased during the study, however, and the 1983 harvest of 3,479 chinook represents 1.1% of the fingerlings stocked in 1980, a minimal estimate for the return rate of the 1980 cohort. The increasing recovery rates may be partially due to stocking better quality fingerlings because of improved culture techniques and/or the use of fall chinook which survived better in Lake Superior. In view of the increasing trend in harvest and the limited fall chinook data, further monitoring of the creel return is needed.

The benefit:cost assessment indicated that chinook salmon can be produced by fish culture at costs below the projected regional expenditures by anglers. On that basis, the chinook salmon program is favorable. In addition, the chinook fishery is complementary to the Lake Superior fishery but other species, particularly lake trout, provide the majority of the benefit. This simple assessment does not address differences of perceived value of each species to anglers and permit species to species comparison. Consequently, benefits of greater angler appeal for a species are ignored in favor of assessment of biologic performance and agency cost. A system of determining actual value to anglers (net worth and benefit) should be developed and incorporated in future benefit:cost assessments.

MANAGEMENT IMPLICATIONS

Chinook salmon appear to be a suitable component of the Lake Superior sport fishery and have basic advantages over coho salmon (size at maturity, longevity, earlier spawning runs). On the other hand, chinook demonstrated lower survival to maturity and lower returns to anglers. Survival and return of fall strain chinook in 1983, however, were similar to coho. If higher returns become consistent, then chinook will be decidedly more advantageous than coho. In that regard, decisions regarding future use of chinook salmon or use of a particular strain should be withheld pending evaluation of longer term data. At the same time, improved knowledge of forage base dynamics in Lake Superior is necessary to reduce the possibility of competition for forage by chinook salmon with traditional species.

Future plants of chinook salmon should be marked to validate our assumptions regarding straying as well as to determine the magnitude of straying from Minnesota to streams of other states. In addition, coincident plants of two or more strains require that at least one of the strains be completely marked if returns are to be evaluated.

Lake Superior anglers should be polled to ascertain a net worth (benefit) of fish of each traditional and newly introduced species in the fishery. The net worth function can be used for interspecies benefit comparisons.

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