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[1]Contribution from Dingell-Johnson Project F-53-R, Michigan

ABSTRACT

Data on size, age, and fecundity of mature pink salmon (Oncorhynchus gorbuscha) were collected during 1973–84. Most salmon matured when 2 years old and the males were significantly longer than females in all three lakes. Mean lengths (mm) of males and females were: Lake Superior—387 and 379, Lake Huron—468 and 436, and Lake Michigan—482 and 443. Salmon that matured in 3 years were found only in Lake Superior tributaries and again males were significantly longer than females (487 versus 467). Until the middle 1970's all pink salmon were assumed to mature when they were 2 years old but a mature 3-year-old salmon was found in 1976 and 3-year-old salmon have since become common. Mean fecundity of 127 pink salmon from lakes Superior and Huron was 1,030 eggs. Fecundity of 2- and 3-year-old salmon was similar.

INTRODUCTION

Pink salmon (Oncorhynchus gorbuscha) of an odd-year spawning stock were introduced into Lake Superior in 1956 (Schumacher and Eddy 1960). They have become common in Lake Superior (Wagner and Stauffer 1982) and have extended their range into all of the Great Lakes (Emery 1981). Three-year-old pink salmon were discovered in Lake Superior and these have produced even-year spawning runs (Wagner and Stauffer 1980 and 1982). The pink salmon in the Great Lakes is the only known population that spends its entire life cycle in fresh water. Some biological differences have been noticed between pink salmon that live in the oligotrophic waters of the upper Great Lakes and those that spend nearly their entire life in the nutrient-rich waters of the Pacific Ocean. In this paper I describe size, age, and fecundity of pink salmon collected during their spawning runs from Michigan tributaries and compare these parameters with those of other pink salmon.

METHODS

Most mature pink salmon for this study were collected with electrofishing gear from Upper Peninsula tributaries that were checked annually to estimate the magnitude of the spawning runs. The streams were Elm, Huron, and Laughing Whitefish rivers and Harlow Creek, tributaries of Lake Superior; Albany Creek and Carp River, tributaries of Lake Huron; and Black River, tributary of Lake Michigan.

All fish were measured to total length unless the caudal fin had been eroded by spawning activity. In that case, fork or standard length was measured. All three measurements were made on many fish to establish conversion factors so all lengths could be given as total length. The fork length conversion was necessary to compare my data with length data from Pacific Ocean pink salmon.

A sample of fish from Lake Superior tributaries was weighed each year except 1980 and 1981 and a sample from Lake Huron tributaries was weighed in 1975, 1979, 1983, and 1984. The fish were not separated by state of maturity so the samples included gravid, partly spent, and spent fish. Length-weight relationships were calculated for each sex from each lake.

Scale samples were taken for age analysis. Prior to 1978, no more than 10 fish of each sex per stream were scale sampled. After the discovery in 1978 that 3-year-old pink salmon were not rare in the Great Lakes, most fish were scale sampled. Scales were removed from an area under the posterior insertion of the dorsal fin, just above the lateral line. Scales were aged by methods described by Wagner and Stauffer (1980). All scales collected in 1978, 1980, 1983, and 1984 were examined. Scales from larger fish (those in the size range of 3-year-old pink salmon) collected in other years were aged.

Ovaries were taken from 99 gravid salmon that had been collected from tributaries of lakes Superior and Huron during 1975–83. In addition, eggs were taken from 28 gravid fish that were collected with gill nets in upper Lake Huron about 2 weeks prior to the spawning runs in 1981. Only ovaries that were incased in the ovarian sac were used for this study to exclude partially spent fish. Eggs generally were preserved immediately in 5% formalin but a few samples were frozen for 3 months to 2 years before preservation in formalin. Egg counts were made with a counting board. A random sample of 5% of the eggs from each female was taken to determine average egg diameter. Total volume of each sample was found by water displacement. The average egg diameter was calculated from the formula $D = \sqrt[3]{6V/\pi n}$. Where: D=diameter in cm, V=volume in ml, and n=number of eggs in sample. Although pink salmon eggs are not perfectly spherical this procedure gives an accurate measurement of average diameter. No adjustment was made for possible changes in volume due to preservation.

For fish in general, the relationship of egg numbers to length is curvelinear but because the range of length at maturity of pink salmon is small, the linear regression adequately describes this relationship (Foerster and Pritchard 1941). However, both linear and curvelinear regressions were calculated for number of eggs and diameter of eggs on total length of fish. The differences in r by the two methods were so small that the simpler linear regression was used.

RESULTS

Mean lengths of male and female pink salmon were compared each year by age and lake (Table 1). Only once in 20 comparisons were females longer than males. Within lakes, for all years combined, males were significantly longer (based on overlapping 95% confidence limits) than females. There was some variation in length from year to year but no trend was apparent.

For 2-year-old fish from Lake Superior tributaries, the mean length and weight of 495 males were 389 mm and 515 g and for 280 females were 386 mm and 487 g. The length-weight equations were: male: $\log W = -5.1076 + 3.0190 \log L$, and female: $\log W = -4.6020 + 2.8175 \log L$.

The mean length and weight of 67 males and 64 females from Lake Huron tributaries were 477 mm and 944 g and 447 mm and 788 g, respectively. The length-weight equations were: male: $\log W = -4.6509 + 2.8470 \log L$, and female: $\log W = -4.5889 + 2.8253 \log L$.

The numbers of fish for which ages were determined are shown in Table 1. Scale analysis showed that all pink salmon collected from Lake Superior during odd years through 1981 were 2 years old. Only 3-year-old salmon were caught in 1976 and 1978 but both 2- and 3-year-old salmon were collected in 1980, 1982, and 1983. This proved that 3-year-old fish reproduced.

All pink salmon collected from lakes Huron and Michigan were 2 years old. The 2-year-old fish caught in 1984 probably were progeny of undetected 3-year-old pink salmon in lakes Huron and Michigan but they could have originated from 3-year-old Lake Superior salmon.

Number of egg samples examined and the mean and range of fish length, number of eggs and diameter of eggs are shown in Table 2. The regressions of egg number on fish length were:

$$\text{Age 2 - Lake Superior, } Y = -1456 + 6.31\,\underline{X},\ \underline{r} = 0.55;$$
$$\text{Age 2 - Lake Huron, } Y = -1299 + 5.46\,\underline{X},\ \underline{r} = 0.79;$$
$$\text{Age 3 - Lake Superior, } Y = 3465 - 5.18\,\underline{X},\ \underline{r} = -0.53.$$

Both regressions for 2-year-old fish were highly significant, but Lake Superior pink salmon had more eggs per unit length than Lake Huron salmon. The difference was significant for fish 374 mm in length and longer. The regression of egg number on length of 3-year-old fish was not significant, this was probably due to the small number of samples examined.

The regressions of egg size on length were:

$$\text{Age 2 - Lake Superior, } Y = 3.52 + 0.00456\,\underline{X},\ \underline{r} = 0.39;$$
$$\text{Age 2 - Lake Huron, } Y = 2.62 + 0.00719\,\underline{X},\ \underline{r} = 0.62;$$
$$\text{Age 3 - Lake Superior, } Y = 4.67 + 0.00210\,\underline{X},\ \underline{r} = 0.28.$$

The regressions of egg size on 2-year-old fish length also were highly significant but were not significantly different from each other. The regression for 3-year-old salmon was not significant.

Comparison with other pink salmon

I was able to compare lengths of 16 year-age-sex groups (Table 3) with those reported by Kwain and Lawrie (1981) for 1973–79 and Nicolette (1983) for 1981 and 1982. Fork length was reported in both papers but Nicolette gave conversion factors for each river and year to convert his lengths to total lengths. His average conversion factors were 1.094 and 1.076 for males and females, respectively, which were similar to the factors of 1.101 and 1.083 that I found. I used our combined conversions of 1.098 and 1.080 to convert the lengths reported by Kwain and Lawrie.

Kwain and Lawrie (1981) stated that "The even-year spawners in Lake Superior were significantly larger than the odd-year spawners, regardless of age". My data and Nicolette's indicated there was no significant difference in length between odd- and even-year spawners of the same age. I collected 2-year-old pink salmon during 6 odd years and 3 even years. The average mean lengths of odd- and even-year males and females were nearly identical. Nicolette

also found no significant difference in mean length of his 2-year-old salmon collected in 1981 and 1982. The mean lengths (471 mm) of 3-year-old females that I collected during 3 even years were the same as those collected in 1983, the only odd year that I collected 3-year-old pink salmon. Males collected in 1983 were longer than those collected in even years (500 mm versus 485 mm) but the difference was not significant.

Three-year-old males were 100 mm longer than 2-year-old males and 3-year-old females were 83 mm longer than 2-year-old females; both differences are highly significant (Table 3). Three-year-old pink salmon sampled by Nicolette (1983) were also about 100 mm longer than 2-year-old fish.

Perhaps some of the fish reported as 2 years old by Kwain and Lawrie (1981) were 3 years old but had absorbed the second annulus. Wagner and Stauffer (1980) found that this occurred on scales of 6 of 27 3-year-old salmon from Lake Superior. If Kwain and Lawrie's salmon were aged incorrectly, their even-year fish would have all been 3 years old and males would have averaged 472±21 mm and females 462±12 mm. Their mean lengths for both 2- and 3-year-old fish would then be similar to those that Nicolette and I found.

Pink salmon from the Pacific Ocean are larger than those from the Great Lakes. Fish from the Tsolum River, British Columbia, were among the smaller sizes reported; in the 1972 spawning run they averaged 43 cm long and weighed 1.02 kg (Bams 1974). Those from McClinton Creek, British Columbia, were among the larger sizes; the females averaged 57 cm and weighed 1.70 kg (Foerster and Pritchard 1941). Only two 3-year-old pink salmon from the Pacific Ocean have been reported (Anas 1959; Turner and Bilton 1968). I have found that 3-year-old pink salmon are fairly common in Lake Superior but have found none in lakes Huron and Michigan.

Nicolette (1983) reported an average of 1,016 eggs per 2-year-old female, which is nearly the same as the 1,002 eggs from Lake Superior fish that I found. He reported that 3-year-old females were less fecund than 2-year-old females but gave no average number of eggs found.

The number of eggs produced by Lake Superior 2-year-old pink salmon was significantly related to size of fish. Thus, the larger Pacific Ocean pink salmon can be expected to produce more eggs than those from Lake Superior. Table 4 shows the mean number of eggs and length of fish for eight fecundity studies of Pacific Ocean pink salmon. Correlation of the data shown in the table gave an $\underline{r}$ of 0.98, which indicates that the tendency of larger fish to produce more eggs is great.

A strict comparison of the egg diameters that I found and those reported from the Pacific Ocean was not possible because of the different procedures used on the eggs before they were measured and in the methods used to measure the eggs. However, Scott and Crossman (1973) give the diameter as 6 mm, and the diameter of eggs from Olson Creek in 1962, that

were water hardened for 3 hours was 6.68±0.22 mm (95% confidence limits) (unpublished data, Jack E. Bailey and John H. Helle, National Marine Fisheries Service, Auke Bay Laboratory, Auke Bay, Alaska). The mean lengths of fish in Olson Creek were among the larger shown in Table 3. Diameter of eggs of the smaller Lake Superior salmon was slightly less.

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Table 1. Age (years) and average length (mm) of pink salmon collected with electrofishing gear during spawning runs, 1973–84.

Lake and year	Age	Male		Female	
		Number measured	Mean length and 95% C.L.	Number measured	Mean length and 95% C.L.
Lake Superior					
1973	2	32	420±8	21	397±10
1975	2	88	406±6	55	399±5
1977	2	77	423±8	35	406±6
1978	3	5	481±38	22	483±13
1979	2	494	372±3	320	372±3
1980	2	10	415±33	8	401±24
	3	16	481±20	44	466±10
1981	2	8	380±28	59	359±9
1982	2	81	380±7	41	376±7
	3	6	503±20	4	464±23
1983	2	59	412±11	72	391±8
	3	2	500	5	471±20
1984	2	10	413±19	16	383±9
Total	2	859	387±3	624	379±2
	3	29	487±13	78	467±2
Lake Huron					
1973–79	2	21	420±28	24	418±21
1981	2	28	434±16	35	408±12
1983	2	50	506±10	45	465±11
1984	2	2	481	4	472±65
Total	2	101	468±12	108	436±9
Lake Michigan					
1975–79	2	13	427±41	14	418±19
1981	2	32	473±13	32	436±10
1983	2	39	507±8	16	477±18
1984	2	1	499	0	
Total	2	85	482±10	62	443±9

Table 2. Number and diameter of eggs in pink salmon from lakes Superior and Huron.

Lake	Age	Number of fish	Mean and 95% confidence limits (range in parentheses)		
			Fish length (mm)	Egg numbers	Egg diameter (mm)
Superior	2	64	390±6 (338–439)	1,002±73 (534–1,672)	5.30±0.07 (4.46–5.98)
	3	9	475±28 (417–530)	1,003±276 (491–1,561)	5.67±0.02 (5.19–6.07)
Huron	2	54	433±11 (265–535)	1,069±78 (246–1,999)	5.74±0.12 (4.19–6.84)

Table 3. Comparison of mean length (mm) of Great Lakes pink salmon reported by various authors.

		Male		Female		
Year	Age	Number	Mean length and 95% C.L.	Number	Mean length and 95% C.L.	Reference
1973	2	32	420±8	21	397±10	Wagner
		22	414±8	14	390±8	Kwain and Lawrie
1975	2	88	406±6	55	399±5	Wagner
		180	411±4	82	392±4	Kwain and Lawrie
1977	2	77	423±8	35	406±6	Wagner
		324	416±	68	403±4	Kwain and Lawrie
1978	2	20	466±21	11	448±22	Kwain and Lawrie
	3	5	481±38	22	483±13	Wagner
		2	537±56	5	489±39	Kwain and Lawrie
1979	2	494	372±3	320	372±3	Wagner
		567	393±2	130	387±4	Kwain and Wagner
1981	2	8	380±28	59	359±9	Wagner
		1,247	394±2	701	384±2	Nicolette
1982	2	81	380±7	41	376±7	Wagner
		560	392±2	221	389±3	Nicolette
	3	6	503±20	4	464±23	Wagner
		12	496±14	31	482±9	Nicolette
Odd	2	758	386±3	562	379±2	Wagner[1]
		1,143[2]	404±2	307[2]	392±2	Kwain and Lawrie
		1,247	394±2	701	384[2]	Nicolette
Even	2	101	387±7	65	381±6	Wagner[1]
		20	466±21	20[3]	462±12	Kwain and Lawrie
		560	392±2	221	389±3	Nicolette
Odd	3	2	500±407	5	471±20	Wagner[1]
Even	3	27	485±12	70	471±8	Wagner[1]
		2	537±56	5	489±39	Kwain and Lawrie
		12	496±14	31	482±9	Nicolette

[1]Includes all fish shown in Table 1.

[2]Includes fish caught in 1971.

[3]Includes fish caught in 1976.

Table 4. Fecundity of pink salmon from various localities.

Locations	Mean total length	Mean number of eggs	Reference
Lake Superior tributaries (2-year-old fish)	390	1,002	This paper
Lake Huron tributaries	433	1,069	
Auke Creek, Alaska	588	2,035	Bailey et al. 1976
Tsolum River, British Columbia	473	1,326	Bams 1973
Tsolum River, British Columbia	439	1,204	Bams 1974
McClinton Creek, British Columbia	571	1,733	Foerster and Pritchard 1941
Olson Creek, Alaska	566	1,852	Helle 1970
Fraser River, British Columbia	562	1,765	Rounsefell 1958
Namu, British Columbia	582	1,841	
Sashin Creek, Alaska	593	2,074	

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