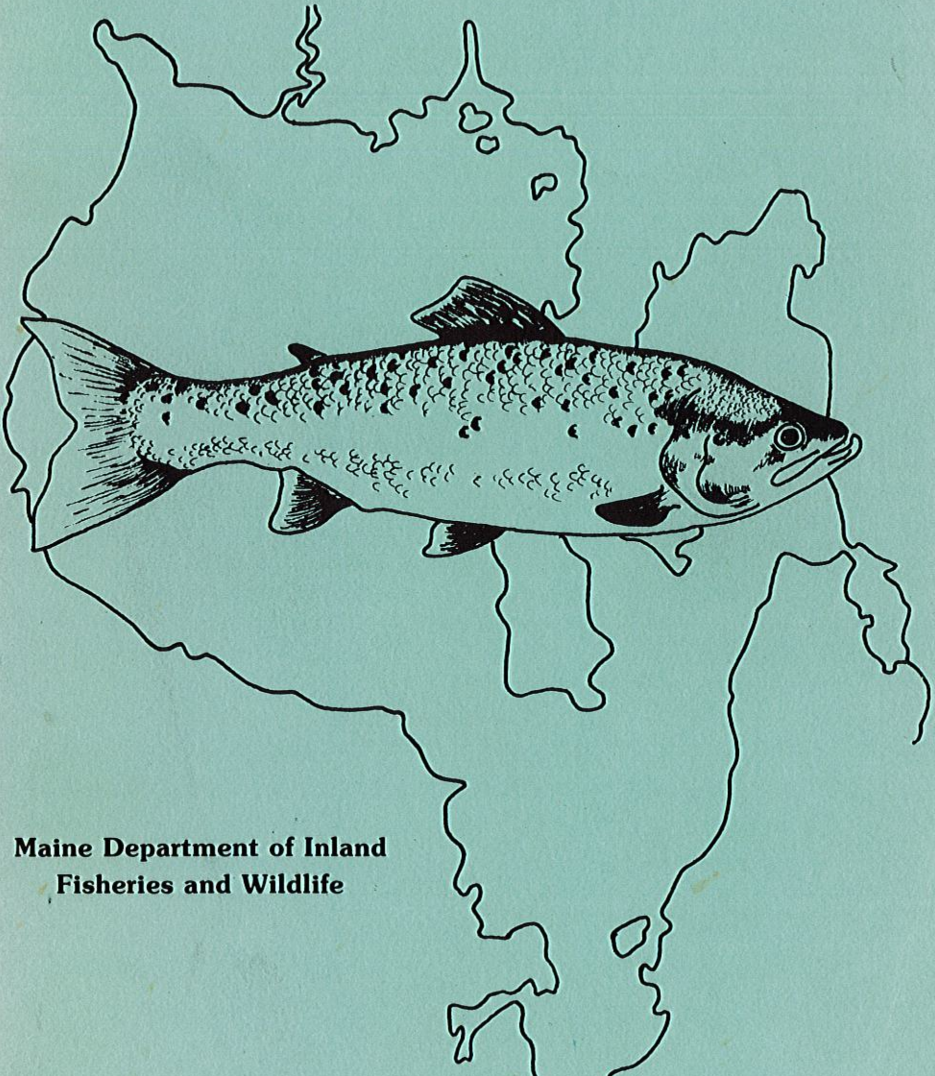
THE SEBAGO LAKE STUDY



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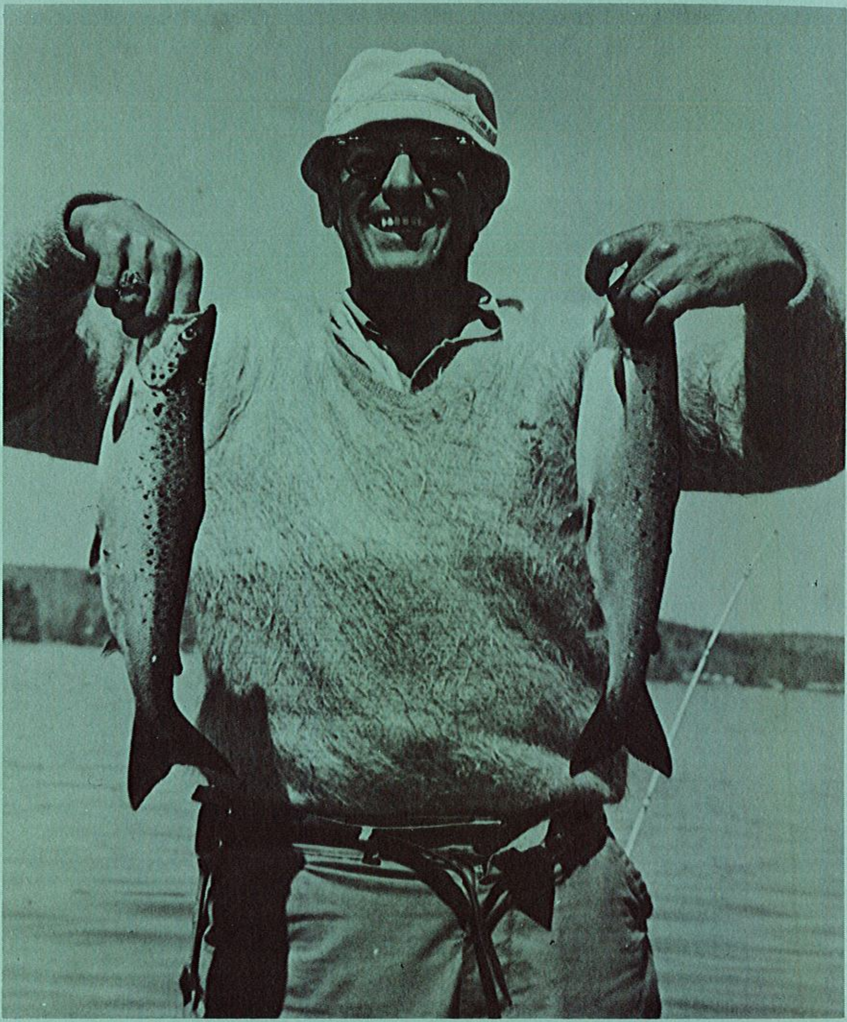

A successful Sebago Lake angler

THE SEBAGO LAKE STUDY

Dingell-Johnson Federal Aid Project

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by

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Introduction and Background

Sebago Lake is located in Cumberland County, Maine. Because of the excellent salmon fishing that has been popular there since the late 1800's, it has often been referred to as the "original home of the landlocked salmon." Until about 1957, salmon fishing remained at satisfactory levels. At that time a general decline in salmon fishing began. In 1960, the Maine Department of Inland Fisheries and Game[1] initiated a study at Sebago Lake to determine the cause for the decline in fishing success and to develop a program whereby salmon fishing could be ultimately restored to normal levels.

Sebago Lake, encompassing 28,771 acres, is Maine's second largest lake. It has a maximum depth of 316 feet and an average depth of 105 feet. The lake stratifies thermally, with the top of the thermocline usually located at about 40 feet. The thermocline and the hypolimnion have concentrations of dissolved oxygen up to 12.7 ppm, contributing to a water quality that makes Sebago Lake ideal habitat for coldwater fish. In addition to landlocked salmon (*Salmo salar*), Sebago Lake supports thriving populations of the following gamefish in order of their importance to fishermen:

- Lake trout (*Salvelinus namaycush*)
- Brook trout (*Salvelinus fontinalis*)
- Rainbow smelt (*Osmerus mordax*)
- Smallmouth bass (*Micropterus dolomieui*)
- Burbot (cusk) (*Lota lota*)
- Lake whitefish (*Coregonus clupeaformis*)
- Largemouth bass (*Micropterus salmoides*)
- White perch (*Morone americana*)
- Chain pickerel (*Esox niger*)
- Black crappie (*Pomoxis nigromaculatus*)

A cursory study of Sebago Lake from 1960 to 1962 confirmed angler-reports that salmon fishing had deteriorated alarmingly. In 1962, for example, it took anglers about 34 hours to catch a legal sized salmon (14 inches long). Growth rate of salmon had decreased to such an extent that 5-year-old salmon that averaged 20 inches long in 1957, barely reached 16 inches long in 1962. Jaw tag and recapture studies conducted on spawning salmon in 1960 and 1961 produced only a 3.7% return of tagged fish. Warner (1959) reported tag returns from salmon of up to 45% from angler

[1] Now Department of Inland Fisheries and Wildlife

reports and spawning run returns at the Fish River Lakes in Northern Maine.

Observations from seining, SCUBA diving, and trapping in the littoral areas around Sebago Lake from 1960 to 1962, revealed that numbers of all species of warmwater fish were exceptionally low. Even the various species of minnows, which had been abundant along the shores of Sebago Lake in previous years, were almost non-existent. Smallmouth bass had become so scarce that a skin diver would oftentimes swim several hundred yards before seeing a single bass. Numbers of smelts observed and dipped on spawning runs in the Crooked and Songo Rivers declined steadily after 1960, and by 1963 it was difficult to find appreciable numbers of spawning smelts anywhere in these rivers.

Following the 3-year cursory census of Sebago Lake, it became extremely clear that something was happening there that was greatly reducing the numbers of fish that inhabited the lake, especially the shallow water species of minnows and basses, and some deep water species like salmon and smelts that spend a part of their existence in shallow water.

Discussions with fishermen, sporting camp operators, cottage owners, and businessmen in the Sebago Lake area revealed that large amounts of DDT had been used annually since 1955 to control mosquitoes. By 1962, about 25% of the shoreline of Sebago Lake was receiving two or more annual applications of DDT. In addition to spraying DDT along the shores, annual aerial spraying of DDT was conducted in the Songo-Crooked River area to control mosquitoes and blackflies in the State Park camping and beach areas. The Songo and Crooked Rivers, in addition to supplying huge volumes of water to Sebago Lake, are the major spawning tributaries for smelts, salmon, and brook trout which inhabit Sebago Lake. No records were available relative to the amounts of DDT used on ground applications around Sebago Lake, but there are valid reasons to suspect that they were considerable. Records of 59 aerial applications from 1955 to 1963 reported a range of DDT content from 6 to 12% by weight, applied in an oil base. The procedure for spraying called for two applications yearly—one in June and another in July.

On the strength of overwhelming evidence that use of DDT was the major cause for the drastic reductions in certain species of fish in Sebago Lake, an intensive biological study of Sebago Lake was planned in 1962. The following is a list of jobs that were planned to determine the various parameters necessary to reveal the causes of problems in Sebago Lake and to begin a fishery management program that would solve these problems:

1. Pesticide levels in certain species of Sebago Lake fish.
2. Fish Species Composition.
3. Salmon Study:
   (a) Food
   (b) Natural reproduction
   (c) Migration and homing tendencies
   (d) Evaluation of salmon stocking
   (e) Age and growth
   (f) Angling success

PESTICIDES

Procedures and Methods:

In order to establish baseline levels of pesticides in Sebago Lake fish, samples from several species were collected for pesticide analysis. As soon as the fish were collected, they were packaged either in polyurethane bags or wrapped in acetate-treated aluminum foil, frozen at 0°F, and shipped by air freight to the Alumni Research Foundation, University of Wisconsin, Madison, Wisconsin for pesticide assay. Assays were conducted by using electron capture gas chromatographic procedures. The assay reports were in ppm of DDT, DDE, and DDD in relation to the total wet weight of the sample. The percent of fat of each sample was included in the analysis in order that amounts of pesticides in the fatty tissues of the samples could be determined.

Until 1967, a 10-fish sample of salmon, ages II through VI were taken from the Jordan River spawning run for pesticide analysis. It seemed most important at that time to measure pesticide levels from the various age groups represented in the spawning runs, and to draw the greatest number of salmon to be sampled from age groups most prevalent in the run. The samples from 1962 to 1966 consisted on one, age II male, one age III male, three age IV males, two age IV females, two age V males, and one age VI female. The condition of each fish in the sample was visually classified as "good" or "poor."

By the end of 1966, questions arose concerning the validity of comparing annual pesticide assays because of the small size of the sample and the obvious degrees of variance that existed between samples. Consequently, all DDT assays conducted from 1962 to 1966 were analyzed by an IBM computer to determine whether there were valid relationships between the assays, and whether meaningful statements could be made relative to results obtained from one year to the next. From the computer analysis, significant variations were found to exist between annual assays. These variations were thought to be caused by inadequate sample size. Therefore, to insure that valid year-to-year comparisons could be made in ensuing years, a more sophisticated sampling procedure seemed necessary. In 1967, a sample of 59 male salmon, ages III through V were assayed for DDT in order to establish the variations that existed between age groups and between salmon in "good" and "poor" condition within each age group. A composite sample of all 59 salmon was assayed for DDT content of the various ages of salmon that were represented in the total sample. This assay included the following:

12 Age III	low fat males
8 Age III	high fat males
7 Age IV	low fat males
13 Age IV	high fat males
10 Age V	low fat males
9 Age V	high fat males

The results of this assay made it possible to design a new sampling procedure whereby an annual sample of 30, Age III, "good"-condition male salmon would be taken for assay. Ten of these fish would be assayed individually to determine the degrees of variance existing between Age III salmon, and a composite of all 30 salmon would indicate the amount of DDT present in all Age III, male salmon. Pesticide levels were to be reported on a wet weight basis, and the fat content for each salmon assayed was provided so that levels of pesticides in the fatty tissues could be calculated.

Pesticide assays of species of fish other than salmon were made simultaneously in 1963 to determine if the same levels of DDT were present as found in salmon. The same methods of collecting and preparing these fish for assays were used.

All spraying of DDT and related pesticides in Sebago Lake stopped in 1964. The cessation of spraying gave a unique opportunity to study what effects the discontinuation of the use of DDT would have on the residual levels of DDT in Sebago Lake salmon; therefore, annual pesticide monitoring was continued throughout the life of this study.

Findings:

The basic pesticide data analysis reports from Sebago Lake salmon from 1962 through 1966 show tremendous variations, especially between individuals. However, there is little doubt that the amounts of DDT found in Sebago Lake salmon were sufficient to cause serious problems in survival, rates of growth and the general behavior of salmon (Table 1).

Table 1. Pesticide analysis of 10-salmon samples from Sebago Lake, with DDT and DDE reported in ppm by total weight and DDT reported in ppm on a fat basis, 1962-1966.

	1962		1963			1964			1965			1966		
Age	DDT	DDE	DDT	DDE	DDT[a/]	DDT	DDE	DDT[a/]	DDT	DDE	DDT[a/]	DDT	DDE	DDT[a/]
II	1.0	2.4	0.3	6.8	23	0.4	4.0	188	0.41	4.0	19	0.94	13.8	10
III	0.8	2.2	0.8	9.2	40	0.3	3.8	207	0.27	3.8	19	0.96	4.8	13
IV	2.2	9.4	2.7	0.7	132	0.5	7.4	347	0.51	7.4	35	0.56	9.3	6
IV	0.5	5.0	1.5	8.4	57	1.3	7.9	56	1.80	9.8	54	1.08	10.0	11
IV	0.7	8.0	4.5	35.0	1,047	2.9	13.7	80	2.50	13.9	100	1.08	7.8	15
IV	0.9	7.8	3.9	31.0	419	1.8	9.8	54	1.37	7.9	56	1.25	8.0	12
IV	0.8	6.7	0.4	15.0	62	2.5	13.9	100	2.90	13.7	80	0.80	7.8	11
V	1.8	10.1	8.0	31.0	1,194	1.6	3.7	37	1.90	8.6	66	0.78	7.0	8
V	0.7	10.0	7.8	39.0	247	1.9	8.6	66	1.60	3.7	37	2.08	8.0	24
VI	1.6	7.8	2.3	3.9	25	4.4	18.8	84	4.40	18.8	84	1.58	11.5	29
AVE.	1.1	6.9	3.2	18.0	325	1.8	9.2	122	1.80	9.2	55	1.11	8.8	14

a/. ppm in the fat

Sampling errors and variations of pesticide residues between individuals will be dealth with later on in this report, but from an annual 10-salmon pesticide assay taken between 1962 and 1966, some meaningful observations can be made:

1. In 1963, DDT levels in Sebago Lake salmon were extremely high, with an average of 325 ppm in the fat of all 10 salmon in the sample. Two of these salmon had in excess of 1,000 ppm in their fatty tissues.

2. After all use of DDT ended in 1963, a steady decline occurred in DDT residues in the annual assays through 1966. This was perhaps a most important observation at the time, because it indicated that not only were levels of DDT in salmon decreasing, but also the assimilation of DDT from the food chain and from the ecosystem itself was declining. Previously it had been predicted that the harmful effects of DDT would be felt in the environment for up to 20 years after its use was curtailed. Sebago Lake, in only 3 years following cessation of use of DDT, levels of DDT and its metabolites in salmon were significantly reduced.

In 1967, computerized analysis of all pesticide assays of salmon taken from 1962 to 1966 was made to determine if statements made during that period relative to pesticide levels were valid (Anderson and Fenderson, 1970). Great variations between individual salmon and between the various age groups included in the samples did in fact exist and, therefore, statements made regarding these assays were not entirely valid. However, these variations do not preclude the basic conclusions that levels of DDT in Sebago Lake salmon were sufficient to create serious problems and could very possibly be the major reason for the great decline in salmon fishing during that period.

Computerized analysis of pesticide assays made in 1967 of Age III, IV, and V male salmon was conducted to determine appropriate sample size and age group that would produce the most meaningful data so that valid, yearly comparisons of data could be made. Results from this analysis indicated that a sample of 30 male, Age III salmon with a high fat content (good condition) would provide adequate information so that meaningful comparisons of pesticide levels in salmon could be made with an accuracy of 90% Samples of salmon from older age groups could have produced acceptable assay results, but the number of fish needed for a satisfactory sample would have been prohibitively high (Table 2).

All samples of Sebago Lake salmon collected for pesticide analysis from 1967 to 1973 consisted of 30, Age III males with a high fat content. Annual comparisons of pesticide residues in Sebago Lake salmon from

Table 2. Variations in mean ppm of DDT contained in a 59[a]-salmon sample from Sebago Lake in 1967.

Sample Type	Number	DDT Mean	Variance	SE	Confidence Limits	Sample Size
Age III, low fat	12	0.68	0.104	0.093	0.48-0.88	110
Age III, high fat	8	1.92	0.162	0.142	1.58-2.26	25
Age IV, low fat	7	0.60	0.810	0.106	0.34-0.86	143
Age IV, high fat	13	1.81	1.370	0.324	1.10-2.52	202
Age V, low fat	10	0.75	0.268	0.163	0.38-1.12	245
Age V, high fat	9	0.85	0.260	0.170	0.46-1.24	190
Composite of all	59	1.07	0.577	0.099	0.87-1.27	202

a. All fish in sample were males.

1969 to 1973 showed highly significant decreases in all pesticides that were scanned in the assays (Table 3).

Table 3. "T" tests to determine significant differences between the 1969, 1971 and 1973 pesticide residues in Sebago Lake salmon.

Pesticide	ppm levels 1969	1971	1973	Results
DDT	3.46	1.92	0.29	Highly significant decrease
DDE	5.81	2.71	1.26	Highly significant decrease
DDD	0.88	0.44	0.12	Highly significant decrease
DIELDRIN	0.04	0.02	0.01	Highly significant decrease
TOTALS	10.75	5.52	2.15	Highly significant decrease
BHC	0.015	0.25	0.00	Less than 0.005 ppm in 1973
PCB's	—	1.04	0.48	Highly significant decrease
FAT CONTENT	5.57	5.31	5.27	No significant change

There were some rather strong indications during the early stages of this study that as salmon got older and fatter they stored higher levels of DDT and DDE (Anderson and Everhart, 1966) (Table 4).

From work of Anderson and Everhart (1966) it became apparent that older salmon did appear to contain levels of DDT, DDE and DDD. Later, Anderson and Fenderson (1970) conducted analysis of variance tests to determine whether or not older salmon did in fact have higher levels of pesticides in their body tissues. Their studies concluded that levels of insecticide residues were highly dependent on age and fat content, and that

Table 4. **DDT and DDE content of 24 salmon from Sebago Lake, grouped by age, sex and condition.**

Age	Number	Sex	Condition	DDT	DDE	% Fat Content	DDT On Fat Basis
III	2	M	Good	1.2	13.0	2.13	56
	2	M	Poor	1.7	13.0	1.29	132
	2	F	Good	1.3	9.1	1.57	83
	2	F	Poor	1.0	9.5	1.53	65
			Average	1.3	11.2	1.63	84
IV	2	M	Good	14.0	37.0	1.79	782
	2	M	Poor	5.7	31.0	2.29	249
	2	F	Good	8.1	42.0	2.96	274
	2	F	Poor	4.0	32.0	1.46	247
			Average	7.4	35.5	2.12	345
V	2	M	Good	14.0	39.0	5.14	272
	2	M	Poor	4.8	34.0	1.02	471
	2	F	Good	11.0	29.0	6.45	171
	2	F	Poor	5.3	33.0	1.59	333
			Average	8.8	33.7	3.55	312

DDD and DDE increased with age and fat content, but age and fat content were inter-dependent in their effects on DDT levels (Table 5).

Table 5. **Summary of analysis of variance of DDT, DDE, DDD and Dieldrin in salmon from Sebago Lake, 1967.**

Item	Age and fat		
DDT (ppm)	Main effects not significant alone but show significant interaction: DDT varies under combined effects of age and fat (c)	Trend for interaction of main effects NS.	Main effects not significant alone but show significant interaction: DDT varies under combined effects of age and visual condition (c)
DDE (ppm)	Trend to increase with fat (a). Increases with age (b).	Does not vary with condition factor NS. Increases with age (b).	Does not vary with visual condition NS. Increases with age (b).

(continued)

DDD (ppm)	Increases with fat (b). Increases with age (b).	Trend to increase with condition factor NS. Increases with age (b).	Increases with visual condition (c). Increases with age (b).
Dieldrin (ppm)	Increases with fat (b). Does not vary with age.	Trend to increase with condition factor NS. Trend to increase with age NS.	Increases with visual condition (c). Trend to increase with age NS.
NS—Not significant.			

NS—Not significant.
(a) No statistically significant relationship.
(b) Significant F-ratio at 0.01 level.
(c) Significant F-ratio at 0.05 level.

The variations in insecticide residues found in tissues of Sebago Lake salmon leads one to speculate relative to these vast differences. The presence of high levels of DDT in young, high-fat-content salmon seems reasonable, because they are the faster growing individuals in their age groups. Therefore, assimilation of more food than the slower growing individuals would increase the intake of DDT from the food chain. Higher pesticide content in older salmon seems reasonable too, because they are exposed to pesticide contamination for a longer period of time.

Older salmon tend to demonstrate differences in the amount of DDT found in their tissues compared to young salmon. There is a decrease in DDT with age in high-fat fish. Perhaps this is due to martalities of the older, faster-growing fish that have been exposed to DDT poisoning for a longer period of time. The slower growing individuals in the older age groups would have assimilated lesser amounts of DDT over their lifetimes; therefore, pesticide levels in their tissues would be expected to be lower. There are also possibilities that great differences in metabolism, feeding habits, assimilation of food, mortality rates, and exposure to varying degrees of pesticide dosages could be responsible for the variations of pesticide residues between fish within the same age group and between fish with high and low fat content. It can also be speculated that older, low-fat fish which have been exposed to pesticides for a longer period may not have the ability or the desire to actively feed; therefore, DDT levels in such individuals might be low. In such cases, one might conclude (after looking at pesticide assays) that some older fish are not in danger from the effects of DDT, but in fact, because of the individual fish's physiological make-up, DDT has already created its damaging effects and the fish is actually either near death, or in such condition that it no longer functions normally.

Dieldrin, BHC, and PCB reached detectable levels in Sebago Lake salmon throughout this study, but these contaminants never reached levels that were considered dangerous. Concern was expressed at the time they first appeared in assay results that any one of them might reach dangerous proportions; therefore, their presence was monitored each year, and results from the monitoring program appear in Table 3 of this report.

In 1964, pesticide assays were conducted on several species of fish from Sebago Lake other than salmon to determine if they were assimilating DDT and its metabolites in the same proportions as salmon (Table 6).

Table 6. DDT, DDD and DDE content of five species of fish from Sebago Lake, taken in 1963.

Species	Number	Age	DDT	DDE	DDD	Total Residue
Brook trout	2	II	6.2	—	—	6.2
SM bass	20	IV, V, VI	2.9	4.0	0.78	7.68
Whitefish	11	V	6.2	5.8	0.84	12.84
Minnows	46	unknown	0.55	—	—	0.55
Smelts[a]	50	II, III	0.78	1.36	1.43	3.57
Herring gulls	25	unknown	0.90	2.22	0.26	3.38

a. 24-hour exposure to 0.3 to 0.4 ppm would cause serious mortalities to smelts.

Results of these assays revealed that all five species of fish sampled, as well as a sample of Herring Gulls had significant levels of DDT, DDE and DDD in their body tissues.

Levels of DDT found in smelts are interesting when compared to experimental work done by Donald Mairs (1964, D-J Progress Report, unpublished). Mairs found that a 24-hour exposure of smelt fry to 0.40 ppm of DDT killed 30% of the individuals tested, and 0.50 ppm killed 74% of them. He concluded from his tests, that the 24-hour Tlm for smelt fry was between 0.40 and 0.50 ppm of DDT. Mairs, in the same study, determined that yearling smelts exposed to various levels of DDT had a 24-hour Tlm of about 1 ppm. In observing the levels of pesticide residues in Sebago Lake smelts (Table 6), it is easily understood why the Sebago Lake smelt population collapsed in the mid-1960's.

Discussion:

The significant reduction of pesticides in Sebago Lake salmon after the cessation of DDT use was remarkable. It points out that once pesticide use is completely stopped, significant reductions in pesticide levels in fish can be expected within 6 or 8 years. The tendency of DDT to persist in fish for a longer period of time, however, is evidenced by the fact that 10 years following the cessation of DDT use in the Sebago Lake drainage, salmon still have detectable amounts of DDT, DDE and DDD in their body tissues. Current levels of DDT seem to be well within the tolerance levels of salmon in order to grow, mature and be healthy; therefore, it is probably only academic that detectable levels still occur. One must keep in mind, however, that should the use of DDT in Sebago Lake drainage be resumed, even on a small scale, the accumulative effect of the additional assimilation by salmon of DDT through the food chain and absorption from the environment could increase DDT levels in body tissues to a point where it would lead to high mortalities. Now that less persistent pesticides to control insects are available, there seems to be little need to use DDT.

The Sebago Lake salmon fishery fully recovered by 1969, only 6 years following the cessation of spraying DDT along the shores and along the major tributaries. The simultaneous recovery of the smelt population was mainly responsible for the recovery of the salmon fishery. The recovery of the smelt population owes its success to the cessation of aerial spraying of DDT in the lower reaches of the Songo and Crooked Rivers, because these are the major smelt spawning and egg-hatching tributaries of Sebago Lake. Attempts were made to restore the smelt population by stocking eyed eggs, deposited on burlap sacks and suspended on wooden racks at the mouths of the major smelt spawning tributaries of Sebago Lake. The writer feels that stocking of eyed smelt eggs had little if any real effect in re-establishing the smelt population. It became clear that the Sebago Lake smelt population made its start toward recovery from successful spawning of the small population of adult smelts that had survived the DDT spraying era. Once the use of DDT along the shores of the Crooked and Songo Rivers ceased, the survival of smelt eggs and fry was sufficient to restore the population to levels satisfying the food needs of salmon. This conclusion is based upon age determinations of smelts taken from the first significantly large spawning run that occurred following the cessation of DDT spraying. These smelts were one and two years older than the smelts from the eyed smelt eggs that were stocked at the mouths of the tributaries. There is no positive way, however, of knowing the exact role that introduction of eyed smelt eggs played in the total recovery of the Sebago Lake smelt population.

SPECIES COMPOSITION

Procedures and Methods:

In a comprehensive study of Sebago Lake, it seemed appropriate to identify the major fish species present in the lake and to determine their relative abundance. This information would help in determining whether or not the abundance of the various fish species present would alterably change over the years as Sebago Lake recovered from the effects of DDT. Gillnets were used to sample the various species of fish. Skin diving and SCUBA diving were utilized to evaluate the relative abundance of certain species of warmwater fish living in the littoral areas.

Gillnetting was conducted during the first 2 weeks in July each year in 30 pre-designated locations around Sebago Lake in water depths ranging from 20 to 150 feet. Every effort was made to net these exact locations during each netting period so that comparable results could be obtained. Annual SCUBA diving and snorkeling observations were conducted during the same period to inventory the relative abundance of the species of fish commonly found in shallow water. These species include: smallmouth bass, largemouth bass, yellow perch, white sucker and various species of minnows. Observations were made in water depths of 20 feet and less.

Findings:

Gillnetting in Sebago Lake from 1962 to 1973 revealed the presence of 9 major fish species (Table 7).

Minnows and smelts are not included in Table 7, because they were not vulnerable to the mesh sizes in the gillnets used. The relative abundance of smelts was evaluated by annual observations on the spawning runs and measurements of the occurrence of smelts in the stomachs of gillnetted fish. Since lake trout were not introduced into Sebago Lake until 1972, they did not become vulnerable to gillnetting until 1973, and then only to a minor degree.

Confining our interests primarily to salmon, whitefish, cusk (burbot), suckers and smallmouth bass, it is evident that some significant changes in these fish populations have occurred since the study began in 1962. The presence of salmon in the gillnet catches has changed from an average of about 7% in the early 1968's, to about 11% during the late 1960's and early 1970's. This increase in the relative abundance of salmon correlates well with the levels of DDT in the body tissues of salmon which were showing significant declines during this period. The low occurrence of salmon in the 1973 catch is probably due to the drastic decrease in older

Table 7. Species[a] captured by gillnetting and the percent of the total catch by species, Sebago Lake 1962-1973.

Species	1962	1963	1964	1965	1966	1967	1968	1969	1971	1973
Salmon	7.5	9.8	4.8	14.8	10.7	5.6	7.5	15.1	17.2	6.2
Lake trout	—	—	—	—	—	—	—	—	—	3.1
Brook trout	1.6	1.3	12.8	0.7	1.0	0.3	0.4	0.2	0.4	0.0
Whitefish	53.4	60.9	61.9	58.1	72.4	71.1	67.1	69.3	68.8	29.1
Cusk (burbot)	0.7	0.9	0.0	0.0	0.7	1.3	1.1	1.7	10.8	3.8
Suckers (white and longnose)	6.5	8.1	8.4	1.2	5.9	4.0	6.1	6.0	1.2	46.7
White perch	24.6	15.3	5.2	18.6	3.4	3.0	10.0	3.1	0.0	4.4
Yellow perch	2.6	2.6	6.2	5.2	5.2	18.5	6.1	0.4	0.0	0.7
Smallmouth bass	0.3	0.0	0.7	1.4	0.0	2.3	1.4	4.0	1.6	6.0

a. Smelts are not included because they were not vulnerable to the mesh sizes used.

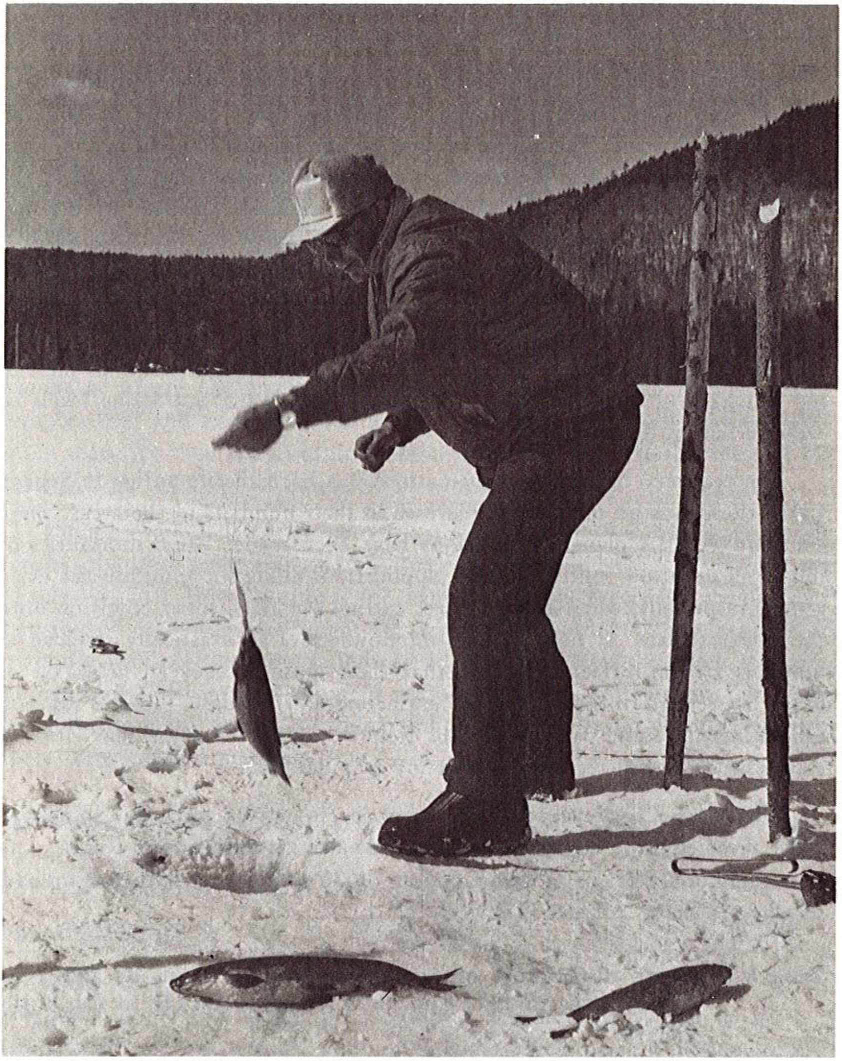
salmon in the lake population which occurred between 1971 and 1973 as a result of over-harvest by anglers. The older salmon seem to be more vulnerable to gillnetting because they inhabit the deeper water, while young salmon prefered the upper levels, where they are not vulnerable to bottom-fishing gillnets.

Numbers of whitefish increased significantly in the net catches throughout the study, averaging about 59% of the catches from 1962 to 1965, and increasing to 70% from 1966 to 1971. There was no established whitefish sport fishery in Sebago Lake in the early 1960's. Consequently, there was no reason to suspect that whitefish were affected much by DDT, especially when 53-62% of the gillnet catches between 1962 and 1964 consisted of whitefish. The 1964 bioassays of whitefish (Table 6) showed that their body tissues contained 6.2 ppm of DDT. These data indicate that the whitefish population must have been adversely affected by DDT, and the increases in their numbers in the gillnet catches from 1966 to 1971 were probably due to their recovery following the cessation of the use of DDT in Sebago Lake and its tributaries in 1964.

There is no logical explation for the tremendous decrease of whitefish in the 1973 gillnet catch. Because whitefish numbers were the lowest since the study began in 1962, it appears that something drastic happened to the population between 1971 and 1973. There was no significant increase in angling pressure from 1971 to 1973 that would drastically alter the whitefish numbers, nor was there any noticeable or reported die-off of whitefish during that period. Therefore, it can only be speculated that for some unknown reason, whitefish were not fully vulnerable to the gillnets in 1973.

Cusk, because of their dependence upon invertebrates for their main source of food, must have been appreciably affected by DDT; gillnetting results from 1962 to 1966 bear this out. Sport fishing for cusk has improved remarkably during the past 2 or 3 years, and although the 1973 net catches for cusk were low, the 1971 catch shows a significant increase over previous years. The ice fishing seasons of 1973 and 1974 produced exceptional catches of cusk, not only in terms of number of fish caught, but also in size. One cusk caught in the Dingley Islands area weighed in excess of 16 pounds; several others weighing between 8 and 10 pounds were also reported.

Suckers constituted the greatest increase in the gillnet catches, averaging about 5% through the first 9 years of the study and increasing to 47% in 1973. Studies in 1966 involving the use of DDT in Worthley Pond, Peru, Maine, in Oxford County showed that suckers are significantly affected by



Winter fishing for whitefish at Sebago Lake

DDT. Pesticide assays of dead suckers collected from this pond revealed that they had up to 5.1 ppm of DDT in their body tissues. It was concluded from these assays that DDT was responsible for these mortalities. Although no pesticide assays were made on suckers from Sebago Lake, the levels of DDT found in whitefish, which have similar food habits, and live in similar water depths, were sufficient to cause significant mortalities of suckers.

Smallmouth bass in particular, but many other shallow water species of fish as well, have made a miraculous recovery since the use of DDT at Sebago Lake ceased. The gillnet catches of smallmouth bass do not indicate such a recovery, but this is probably due to low vulnerability of bass to the smaller mesh sizes used. Nevertheless, the presence of bass in the net catches increased from 0.5% in the early 1960's to 6% in 1973. SCUBA diving and snorkeling observations made annually from 1963 to 1974 in shallow water along the shorelines and over rocky reefs and bars showed a progressive increase in numbers of smallmouth bass, largemouth bass, yellow perch, white suckers, and pumpkinseed sunfish. This trend of increasing numbers of shallow water fish coincides with the decreasing levels of DDT in Sebago Lake fish.

The recovery of minnow populations has been disappointing in Sebago Lake; there was no measurable increase in their numbers in the areas where skin and SCUBA diving observations have been made. Large mortalities of minnows occurred following DDT applications along shorelines in the early 1960's, especially when shore breezes carried the DDT spray emulsion onto the lake's surface. It may be that minnows were so drastically reduced in numbers by the effects of DDT that their natural recovery in a lake as large as Sebago is impossible. The increase in predator species of fish inhabiting the same areas that are frequented by minnows may also be suppressing the full recovery of minnow populations.

The depth distribution of five major species of fish gillnetted in Sebago Lake revealed that all species except lake trout, whitefish and cusk were most commonly taken in water depths of 20 to 60 feet, with few individuals netted below 60 feet (Table 8).

Table 8. Depth distribution of five species of fish taken by gillnets in Sebago Lake in 1971 and 1973. Number and (%) of fish in the catches.

Depth Range	Salmon	Whitefish	Cusk	Suckers	Lake Trout	Total	Year
20'-60'	30(67)	78(45)	1(4)	0	0	109(45)	1971
61'-90'	12(28)	76(44)	13(48)	0	0	101(41)	1971
91'-150'	1(5)	18(11)	13(48)	3(100)	0	35(14)	1971
20'-60'	20(95)	130(55)	11(50)	136(84)	0	297(66)	1973
61'-90'	1(5)	76(32)	5(27)	25(16)	3(37)	110(25)	1973
91'-110'	0	30(13)	6(23)	0	5(63)	41(9)	1973

Generally, salmon are taken at depths of 20 to 60 feet, but some are occasionally netted in depths down to 90 feet. Whitefish and cusk are quite often taken at depths of well over 100 feet; however, they are most frequently taken in depths of 30 to 60 feet. Lake trout were introduced into Sebago Lake in 1972 from eggs of the deep-dwelling strain of lake trout living in the Finger Lakes in New York State. Gillnetting results in 1973 showed that 2-year-old lake trout were found in depths of 60 to 110 feet, which was gratifying because this strain of fish was introduced into Sebago with the assumption that they would maintain their deep-dwelling characteristics and not pose a real problem by competing with salmon for food and space. The sport fishery for lake trout that developed in 1973 dispelled this hope, however, because lake trout were caught at nearly all depths from 30 to 100 feet, wherever suitable water temperatures and adequate food supplies occurred. Hopefully, as these fish reach maturity they will confine themselves to water depths in excess of 60 feet, well out of range of competition with salmon.

Gillnet catches of spring- and fall-stocked salmon were compared with results obtained from trapping the spawning runs and from angler returns (Table 9). All three methods of capture agreed precisely: spring- and fall-stocked salmon were caught on a ratio of about 1:1. The capture of naturally produced salmon varied considerably between the three methods of capture. There are no apparent reasons for these differences, but quite possibly there are degrees of vulnerability of naturally produced salmon to these three capture methods.

Table 9. Catches of hatchery-reared and naturally produced salmon by three different methods in Sebago, 1973.

Capture Methods	Ratio Spring:Fall	Percent Naturally Produced
Trapping	1:1	10
Angling	1:1	18
Gillnetting	1:1	33

Discussion:

Results from this study showed quite conclusively that the five major species of fish gillnetted in Sebago Lake increased in numbers as Sebago Lake recovered from the effects of DDT. Shallow water fish species and smelts, increased tremendously in numbers following the cessation of the use of DDT. Minnows have not recovered as well as expected. This is quite possibly due to the extremely high mortalities that were experienced during the DDT spraying era and to the strong recovery of several predator fish species that inhabit the same areas as minnows. There could also be some adverse effects resulting from the trapping of minnows for bait which occurs along the shores of Sebago Lake.

It should be acknowledged at this time that gillnetting catches are subject to many variables that may bias the results of such a study; therefore, the results obtained from this phase of the study may not accurately reflect the true fish species composition of Sebago Lake. There are many convincing pieces of evidence, however, that support the findings of this study, and the writer believes that the species composition of Sebago Lake is fairly well characterized by these findings.

SALMON

Sebago Lake has been noted for its landlocked salmon fishing since the early 1800's. Therefore, it seemed appropriate to concentrate as much effort as possible on salmon studies to ascertain what changes might occur subsequent to the cessation of the use of DDT. This phase of the Sebago Lake Project involved the following parameters which are analyzed as distinct segments in this report.

1. Food
2. Natural reproduction
3. Migration and homing
4. Evaluation of stocking
5. Age and growth
6. Angling

1. *Food*

Methods and Procedures:

Stomachs were removed from angled and gillnetted salmon from May through September each year from 1963 to 1973. All stomachs taken for food analysis were preserved in 10% formalin solution. Four major categories were utilized to evaluate food use on a percentage of occurrence basis: (1) smelts, (2) fish other than smelts and unidentifiable fish remains, (3) aquatic and terrestrial insects and larvae, and (4) empty.

Findings:

Smelts were the most frequently occurring food item found in stomachs of Sebago Lake salmon (Table 10).

Table 10. **Percentage of occurrence of food types in salmon stomachs taken from Sebago Lake from 1963 to 1973.**

	Percent Occurrence Each Year								
Food Types[a]	1963	1964	1965	1966	1967	1968	1969	1971	1973
(1)	38	70	52	18	31	42	51	58	39
(2)	5	10	19	18	22	47	2	8	5
(3)	57	20	29	64	47	11	10	6	9
(4)	0	0	0	0	0	0	37	28	47

a. (1) smelts, (2) fish and unidentifiable fish, (3) insects, (4) empty.

Insects seemed to play a major role as a source of food for salmon during periods when smelts were at low abundance levels, and generally, they were found to occur periodically during peak hatching periods in June and early July. Most of the "fish-other-than-smelts" category in the stomachs of salmon was comprised of sticklebacks, yellow perch, and various species of minnows. Most of the fish in the "unidentified" category were probably smelts.

A number of stomachs taken for analysis were empty, quite possibly because gillnetted fish had regurgitated their stomach contents. A preponderance of the salmon with empty stomachs were heavily infested with the tapeworm, *Diphyllobothrium sebago* (identified by Marvin C. Meyer, 1973) and it was difficult to identify either the stomach or its contents. Salmon, grossly infested with tapeworms, have their internal organs adhered to the body wall and are probably incable of ingesting food in sufficient quantities for normal body maintenance. Fortunately, such severe infestations of tapeworms in Sebago Lake salmon are fairly uncommon. With the improved methods of solid waste disposal at local dumps, which are the major sources of food for the herring gull, the primary host of the tapeworm, infestations of this magnitude should become less common.

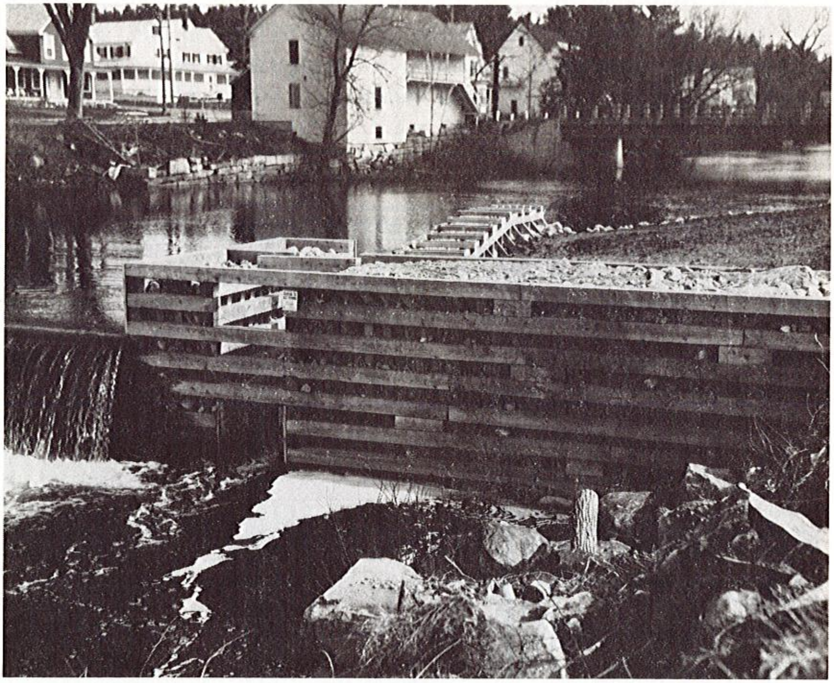
Food studies of Sebago Lake salmon showed conclusively that smelts are the preferred food for salmon, and unless they are present in great abundance, salmon growth is adversely affected. This was true at Sebago Lake even though other species of fish, which appeared to be good forage for salmon, were plentiful. Thus, maintenance of a healthy smelt population in Sebago Lake is *imperative* if satisfactory salmon growth is to be attained.

Smelt dipping during the spring spawning run in the Songo River

2. *Natural Reproduction:*

Background:

For about 150 years, Sebago Lake salmon were denied access to the best spawning habitat, that exists in the Crooked River, by two impassable dams, one at Scribner's Mill and the other at Bolster's Mills. In 1971, a section of the Scribner's Dam was removed, and in 1972, a fishway was constructed in the Bolster's Dam. These two operations made the entire Crooked River accessible to Sebago Lake spawning salmon. The impact of fish passage facilities on both the river fishery for adult salmon and the recruitment of salmon smolts into Sebago Lake should be tremendous. Electrofishing below the Bolster's Mill Dam in 1973 showed a significant increase in smolt production in this 500-foot section of river. In the mid-1960's, electrofishing in this section produced only an occasional salmon smolt, but in 1973, 164 salmon smolts were estimated to be present.



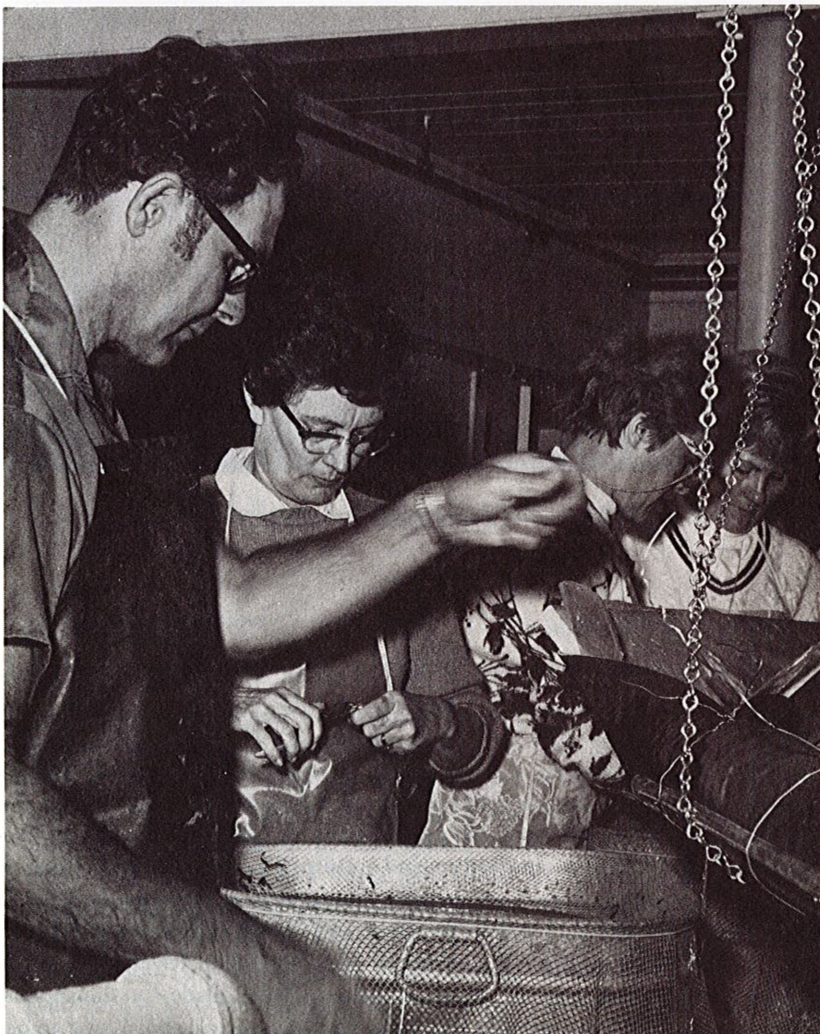
Bolster's Mill fishway on the Crooked River

Methods and Procedures:

In the early 1960's, when the full effect of DDT was being felt by Sebago Lake salmon, spawning runs in the Crooked River and the Northwest River had dwindled alarmingly. To restore the Crooked River spawning runs, a program of stocking hatchery-reared yearling salmon directly into the river was initiated in 1962. It was hoped that these salmon would migrate downstream to Sebago Lake where they would grow, reach maturity, and return to the Crooked River as spawning adults 3 or 4 years later. These salmon were marked by fin clipping making it possible to determine when they returned to the Crooked River as spawning adults. In the Northwest River, attempts to restore depleted runs of spawning salmon were made by transporting spawning adults to suitable upstream spawning areas above two impassable barriers.

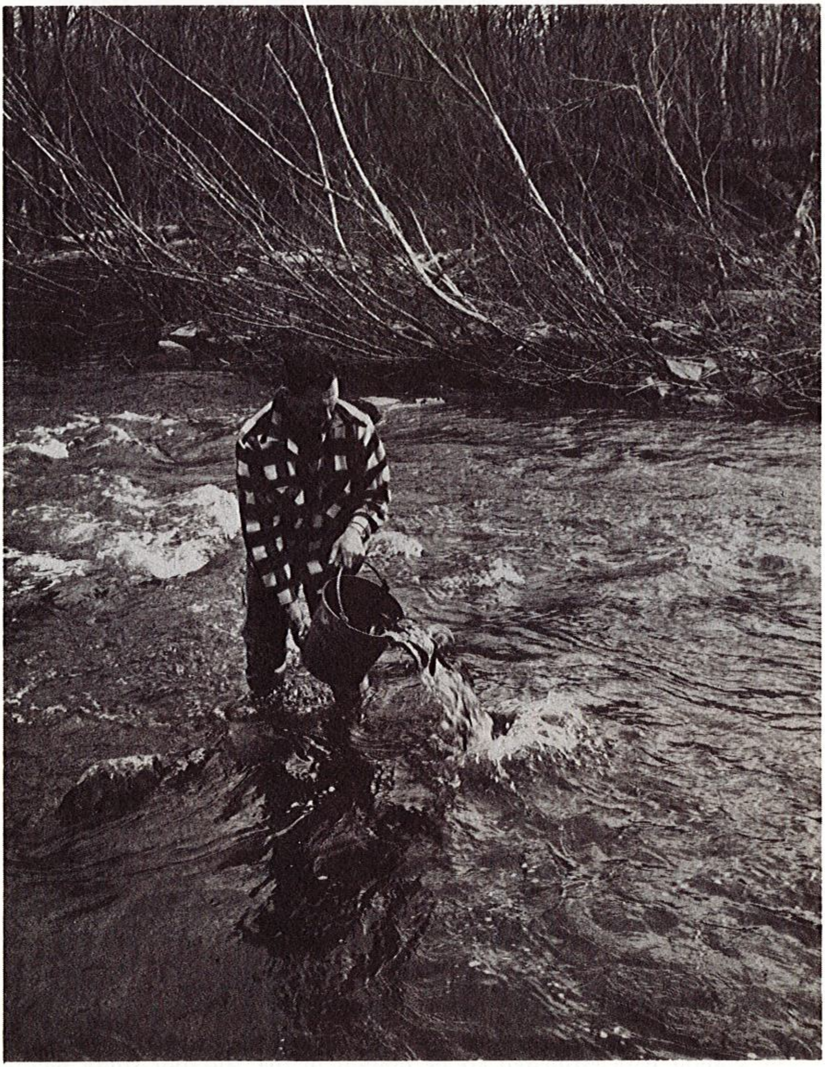
Annual estimates of salmon production were made in eight Sebago

Lake tributaries by electrofishing several sample sections. Because salmon production was so insignificant in the smaller streams, all reference to salmon production in Sebago Lake tributaries will be confined to the Crooked River, Northwest River, and Mile Brook.



Marking crew finclipping salmon for future identification

Salmon production estimates were computed by means of electrofishing 500 to 1,000 feet of stream and applying the mark and recapture method of Schnabel. Estimates were made annually from 1962 to 1970 in the same stream study sections, and from that time on, estimates were made very other year.



Biologist DeRoche stocking yearling salmon in the Crooked River

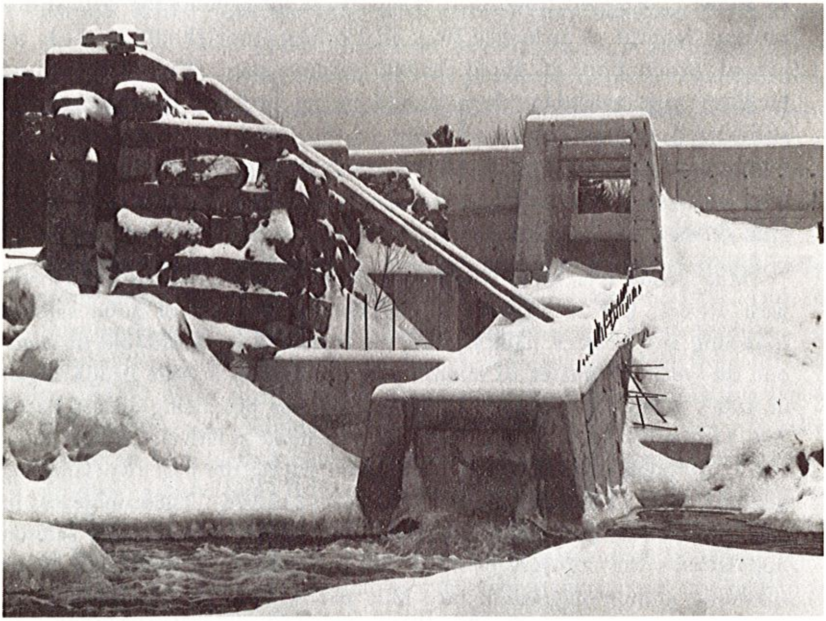
Population studies in Crooked River

Findings:

Crooked River:

Population estimates of salmon parr were made each year from 1963 to 1973 below the Scribner's Mill Dam, where the major concentration of salmon spawning occurred prior to the installation of fish passage facilities. From these data, it became apparent that spawning runs of salmon in the Crooked River increased considerably as a result of the river-stocking program that began in 1962. In 1963, the number of salmon parr estimated to be present in the 500-foot study section below Scribner's Dam was 83 (57-124) with 95% confidence limits. By

1966, salmon parr production in this tudy section had increased to 132 (89-195). The production of salmon parr in this study section has continued to increase as evidenced by the following data: 1970, 375 (282-499); 1972, 409 (310-540); and 1973, 521 (375-698). If similar increases can be attained in the entire Crooked River, which contains about 10 miles of suitable salmon spawning habitat, it can be predicted that the Crooked River is capable of raising 55,000 salmon parr annually.



Fishway in Shute's Dam on Northwest River

Northwest River

The Northwest River has responded well to efforts made to restore salmon spawning runs. In 1963, salmon parr production in a 500-foot study section in this river was estimated to be 22 (16-45). By 1967, numbers of salmon parr in this study section were estimated at 106 (63-177); in 1972, 130 (93-181); and in 1973, 185 (133-257). The increase in parr production in the Northwest River was due to the physical transfers of spawning adult salmon over a natural ledge barrier to up-river spawning habitat. These transfers began in 1966 and continued until 1973, at which time a fishway was completed over this barrier, allowing fish free passage to upstream spawning facilities.

Salmon parr production in the Northwest River study area is well below that in the Crooked River, primarily because of low river flow during July, August and September, which reduces the parr production capabilities of the available habitat. The problem of low river flow is expected to be solved in the near future with the construction of a water control dam that will be located upstream from a 4-mile section of excellent salmon spawning and nursery habitat. The dam is designed to allow a sustained flow of at least 10 cfs throughout the critical dry summer months. A sustained flow of this magnitude should result in an annual production of about 15,000 salmon parr. With fish passage facilities now available, there should be no problem in attaining the anticipated salmon parr production in the Northwest River once the numbers of spawning adult salmon reach maximum anticipated levels.

Mile Brook

Mile Brook is a small stream compared to the Crooked and Northwest Rivers, but it contains a considerable amount of good salmon spawning and nursery habitat, and the stream flow is suitable throughout the year. Estimates of salmon parr production in Mile Brook began in 1967, when the 500-foot study section was producing an estimated 234 (127-430) parr. Production has remained relatively stable since 1967, although some increases were noted during the past two sampling periods: 1971, 296 (252-350); 1973, 367 (235-576). These increases in parr production were unquestionably due to the Sebago Lake salmon population's full recovery by 1969 and the subsequent increase in adult spawning salmon migrations into Mile Brook. It is anticipated that no more than minor, periodic fluctuations in salmon parr production will occur in Mile Brook and that they will be influenced by the density of the adult salmon population in Sebago Lake. With this in mind, it can be estimated that Mile Brook is capable of producing about 4,000 salmon parr annually.

Jordan River

The number of spawning salmon returning to the Jordan River has increased since 1970, from an average run of 450 fish prior to 1969 to an average of about 750 thereafter. It is strongly felt that this increase is due to a river stocking program that began in 1968 with the annual stocking of 2,500 spring yearlings and 2,500 fall yearling salmon. These salmon were marked by fin-clipping in order that their return to the river could be monitored.

Summation:

The results obtained from studies on the tributaries of Sebago Lake indicate that beyond all doubt, spawning runs of salmon have been increased in the two major tributaries by stocking yearling salmon directly into these rivers. In the case of the Northwest River, salmon runs were obviously increased by transporting spawning salmon above a natural barrier and liberating them into up-river locations. When these rivers reach their peaks in salmon production, it is anticipated that about 74,000 yearling salmon will be produced in them. This contribution should have a considerable impact on the Sebago Lake sport fishery, and it could quite possibly mean that all stocking of hatchery-reared salmon could be curtailed. Present indications demonstrate this, because even though the Northwest and Crooked Rivers are still far below their full salmon parr producing capabilities, the anglers' catch of naturally produced salmon in Sebago Lake has increased significantly from about 4% of the catch in 1963, to nearly 28% in 1974. Due to this increase in naturally produced salmon it has been necessary to reduce the numbers of salmon that are annually stocked from 60,000 to 25,000. With this in mind, therefore, it is quite probable that when full salmon parr production is reached, the recruitment of naturally produced salmon into Sebago Lake will exceed the number required to produce satisfactory fishing. Therefore it is quite conceivable that numbers of adult salmon migrating up these rivers to spawn will have to be regulated. Excessive numbers of adult salmon can be removed by trapping and used to provide salmon eggs required for implementing salmon management programs at other Maine lakes.

Smaller Tributaries

Nason Brook and Bachelder Brook are small streams that flow into Sebago Lake. They are about 5 to 6 feet wide, a few inches to 2 feet in depth, and with flows ranging from 10-20 cfs in the spring and late fall to less than 1 cfs during the summertime. They are not considered typical salmon spawning streams, but there are sporadic runs of salmon in them when fall rains are timely enough to produce high flows during the peak period of salmon spawning activity. Population estimates of salmon parr in these two streams have yielded information on what small lake tributaries can contribute to a lake fishery, Estimates of the number of fingerling (0+) and yearling (I+) salmon produced in these streams varies considerably from year to year depending upon the time and amounts of fall rainfall, but generally they produce about 8-12 salmon parr in each 500-foot section where suitable habitat is found, or about 90-100 salmon parr in each of the two small streams. The number of fingerling salmon estimated to be present in these small streams was about 1,500. It is apparent from these estimates that high mortalities of young salmon occur from one year to the next, and that probably these mortalities are due to low flows that occur during most summers. There is a possibility, of course, that as the water flows in the streams decrease, fingerling salmon move out into the lake, but if this is true there is a question of how successful their existence in the lake will be at this stage in their life cycle.

Perhaps salmon production in small streams of this magnitude could be increased if water control structures were built to provide adequate and sustained summertime flows. However, Havey (1974) failed to show significant increases in salmon parr production in Barrows Stream in Washington County, Maine after a water control structure was built. Whether or not the expense involved in building and maintaining a water control structure is justified from a cost-benefit standpoint is debatable. It was interesting to learn, however, that spawning salmon do utilize small streams and that the density of fingerlings produced in the riffle areas was comparable to the production rates attained in some of the larger tributaries.

3. *Migration and Homing*

Methods and Procedures:

In order to study the migration and homing tendencies of salmon in Sebago Lake it was necessary to fin-clip all salmon prior to stocking. Each group of hatchery-reared salmon was marked with a different combination of fin clips depending upon the time of year stocked and stocking location. For example:

1963	Spring	Sebago Lake	21,500	3 & 4[a]
	Spring	Crooked River	21,500	4[a]
	Fall	Sebago Lkae	21,500	1 & 4[a]
	Fall	Crooked River	21,500	1 & 5[a]
1964	Spring	Sebago Lake	17,500	3 & 5[a]
	Spring	Crooked River	17,500	3, 4, & 5[a]
	Fall	Sebago Lake	17,500	2, 4, & 5[a]
	Fall	Crooked River	17,500	2 & 4[a]

a. Fins numbered: 1 = dorsal, 2 = adipose, 3 = anal, 4 = right ventral, 5 = left ventral.

The program of fin clipping all salmon stocked in Sebago Lake and its tributaries started in 1962 and continued through the entire project. Recaptures of these marked salmon were obtained from creel censuses, gillnetting, trapnetting, electrofishing, and trapping the Bolster's Mill fishway on the Crooked River.

Findings:

This phase of the 12-year study has provided unquestionable evidence that salmon have strong tendencies to home back to "parent" streams at spawning time whether they were produced naturally there or stocked directly into the streams as yearlings. In the Crooked River, not one single *adult* salmon was taken during the 12-year study which was stocked in an area other than the Crooked River. In the summer of 1974, two *immature* female salmon were captured in the Bolster's Mill fishway trap that has been stocked in the Jordan River in the spring of 1972 as yearlings. Until that time, all salmon captured in the Crooked River were either marked fish that had been stocked there, or unmarked, naturally produced salmon presumed to have been produced in the Crooked River. *No salmon stocked directly into Sebago Lake were ever taken in the Crooked River during the 12-year study.*

Salmon also appear to return to the general area in the stream where they were stocked or naturally produced. This became apparent recently when electrofishing data taken from several sections in the Crooked River above the Scribner's and Bolster's Mill dams indicated that salmon have been reluctant to move up-river at spawning time in spite of the fact that it has been 3 years since fish passage facilities were provided in these two dams. For example, the Bolster's Mill fishway passed only 84 adult salmon during the entire summer and fall of 1974, while observations made below Scribner's dam in the fall of 1974 showed that there were hundreds of spawning salmon present there during October and November. All adult salmon captured in the Bolster's Mill fishway trap in 1974 were unmarked, indicating that they were probably naturally produced salmon homing back to the general area in the river where they were produced by either adult salmon living in the river or from adult salmon previously stocked as yearlings in up-river areas in preceding years. It is also possible that these occurrences of unmarked salmon in the trap could be from normal "back-and-forth" movement of river dwelling salmon. It is overwhelmingly clear that the abundance of spawning salmon observed during the fall of 1974 below the Scribner's Mill dam and the presence of only a few salmon below the Bolster's Mill dam during the same time period was due to the reluctance of spawning salmon to venture farther upstream than they have been accustomed to in previous years when the Scribner's Mill dam was impassable to upstream fish movement.

Electrofishing below the Bolster's Mill dam in recent years has produced some increases in the numbers of salmon parr produced there. This indicates that the fish passage facilities in the Scribner's Mill dam are adequate. However, the increase in salmon parr production in this section of the river has not been of the magnitude expected. Spawning and nursery areas located up-river from Bolster's Mill have likewise not shown significant increases in salmon production in the 2 years since fishway construction in the Bolster's Mill dam. These findings tend to substantiate the author's opinion that spawning salmon from Sebago Lake return to the areas in the Crooked River where they were reared naturally or stocked. Salmon have been denied free access to up-river spawning facilities for many years by impassable dams and they do not have the instinct to move farther upstream in search of suitable spawning facilities. On the basis of this assumption, a stocking program was started in 1974, whereby spring yearling salmon were stocked in several locations up-river from the Bolster's Mill dam. Hopefully, these salmon will move downstream into Sebago Lake where they will grow and reach maturity, and then return to the general areas in the Crooked River where they were stocked, thus making it possible for the Crooked River to ultimately reach its full capability to produce salmon parr.

Speculation developed during this phase of the Sebago Lake study concerning how far hatchery-reared salmon yearlings travel following stocking directly into the lake and whether or not they remain in the general stocking area for long periods of time. It was also not known where lake-stocked salmon travel when they reach maturity and begin their annual spawning migrations. In order to answer these questions, a special 3-year marking, stocking and recapture program was started in 1971. During this period of time, 85,000 yearling salmon were fin-clipped and stocked in four stocking locations in Sebago Lake and another 10,000 in the Jordan River. Returns from anglers and gillnetting results showed conclusively that lake-stocked, hatchery-reared salmon move about Sebago Lake quite freely, and do not remain within the immediate stocking area (Figure 1, Tables 11 and 12).

Of the 512 specially marked salmon that were recaptured, 91% were captured *outside* the general area where they were stocked. It should be mentioned, however, that areas of capture *adjacent to the*

Figure 1. Sebago Lake Map

Stocking Areas *
Fishing Areas - - - - - - - -
Spawning Rivers **

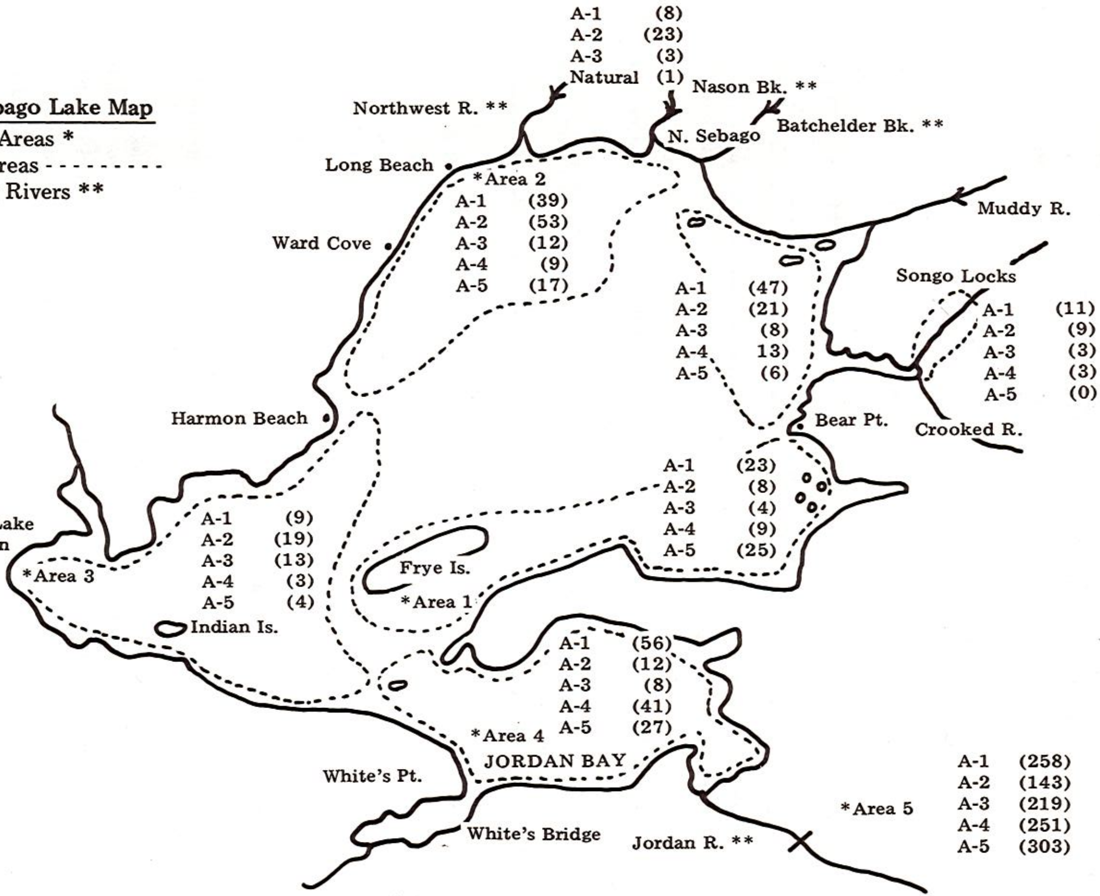


Table 11. Angler returns of marked salmon from six fishing areas in Sebago Lake.[a]

Fishing Areas	Stocking Areas 1	2	3	4	5	Total	Percent
Area #1	23	8	4	9	25	69	13.5
Songo River	47	21	8	13	6	95	18.6
Songo Locks	11	9	3	3	0	26	5.0
Area #2	39	53	12	9	17	130	25.4
Area #3	9	19	13	3	4	48	9.4
Area #4	56	12	8	41	27	144	28.1
Totals	185	122	48	78	79	512	
Percent	36	24	9	15	16		

a. Figure 1 for Sebago Lake map of fishing and stocking areas.

Table 12. Angler returns of marked salmon from all stocking areas in Sebago Lake.[a]

Stocking Areas	Total Caught Number	Percent	Caught Outside Stocking Area Number	Percent
1	185	36.2	162	87.5
2	122	23.8	114	93.4
3	48	9.4	44	91.7
4	78	15.2	69	88.5
5	79	15.4	79	100.0
	512		468	91.4

a. Figure 1 for Sebago Lake map of stocking areas.

stocking location contributed the greatest returns of salmon caught *outside of the stocking area.*

Returns from anglers at the Songo Locks showed that *no* Jordan River stocked salmon were caught there (Figure 1 and Table 11). This confirms an earlier statement in this report regarding the origin of spawning salmon captured in the major Sebago Lake tributaries, and it emphasizes again the strong tendency for salmon to return to the parent stream at spawning time, (in this sense, the word "parent" means either from direct stocking or from natural reproduction).

Returns of spawning salmon in the Jordan River were made up of salmon stocked in all five locations. Generally, the heaviest returns were from the stocking sites nearest the Jordan River (Table 13 and Figure 1). Salmon stocked directly into the Jordan River, returned there in remarkably high numbers when we consider that *only 10% of all salmon stocked during this special study were stocked in the Jordan River*; yet, 26% of all salmon recaptured in the Jordan River spawning runs were salmon that had been stocked there (Table 13).

Table 13. Returns of marked salmon from two spawning rivers.

	Stocking Areas				
Spawning Rivers	**1**	**2**	**3**	**4**	**5**
Jordan River	258	143	219	251	303
	22%	12%	19%	21%	26%
Northwest River	8	23	3	—	—
	23%	68%	9%	—	—

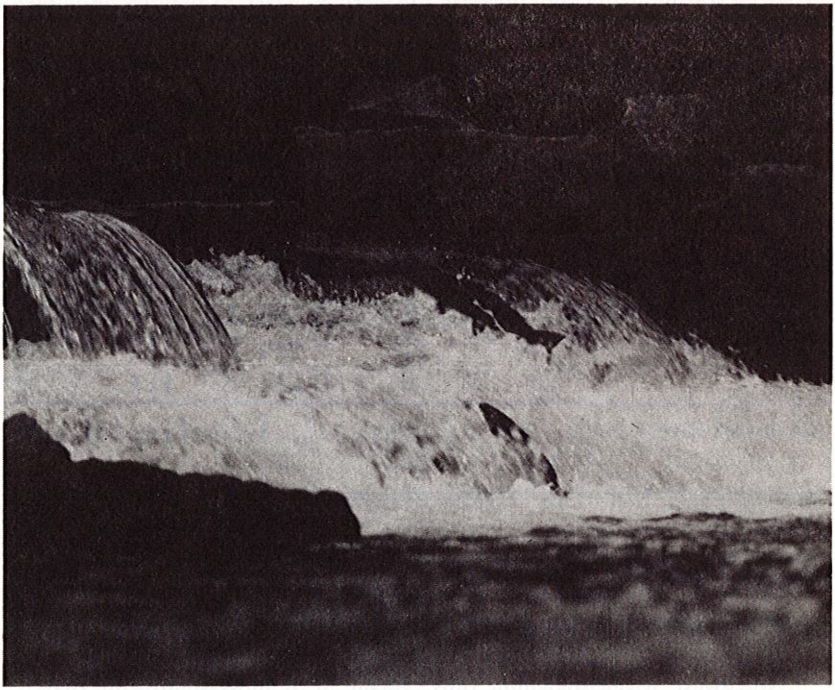
Returns of spawning salmon in the Northwest River were predominantly salmon that had been stocked in Area 2, literally at the mouth of the river. No salmon that were stocked in Areas 4 and 5 (farthest away from the mouth of the Northwest River) were taken in the Northwest River spawning runs. Again, it is most significant that *NO* Jordan River stocked salmon were captured in the Northwest River. It is of special significance that 24% of the Northwest River catch was made up of naturally produced salmon, especially since at the present time the Northwest River is far below its capacity to produce salmon parr. From these data it seems quite possible that the survival of naturally produced salmon yearlings may far exceed the survival of hatchery-reared salmon yearlings following stocking in the lake or its tributary streams.

4. *Evaluation of Salmon Stocking*

Methods and Procedures:

Throughout this entire study, *ALL* salmon that were stocked in Sebago Lake and its tributaries were fin-clipped in various ways so as to identify them properly when they were subsequently recaptured.

When this study began in 1962, approximately the same number of salmon were stocked that had been stocked in previous years. However, to re-establish a significant spawning run of salmon in the Crooked River, one-half of the annual allotment was stocked at various locations



Adult salmon ascending Edes Falls on Crooked River to reach upstream spawning areas

in the Crooked River from its headwaters in Waterford to Edes Falls, the lowermost riffle area before it empties into Sebago Lake. Stocking the Crooked River was discontinued in 1968 because it was felt that 6 years of river stocking was sufficient to establish a salmon spawning run. As stated previously, this objective was satisfactorily accomplished.

Numbers of salmon stocked annually in Sebago Lake and tributaries was reduced from 86,000 in 1962 and 1963 to 30,000 by 1968 and 1969. Beginning in 1968, and continuing through 1974 about 5,000 salmon were stocked annually in the Jordan River in an attempt to increase the spawning run in the river. In 1974, 40,000 salmon were stocked directly into Sebago Lake, and 10,000 were stocked in the Crooked River at three locations above the Bolster's Mill dam to increase the number of spawning salmon migrating into areas of the river which had been blocked to salmon migrations by impassable dams for 100 years or more.

Spring yearling salmon were stocked in May and fall yearlings in

October. By stocking two groups of specially marked salmon, evaluation could be made of their relative contributions to the sport fishery. From 1962 to 1967, lake-stocked salmon were stocked by boat at three locations and from shore in one location which is in close proximity to deep water.

Returns of marked salmon were obtained from creel census, voluntary angler reports, gillnetting, and by trapping spawning migrations. Because returns of spring- and fall-stocked salmon were almost identical from all recapture methods, it seems necessary to only report returns from one recapture method. Therefore, returns from anglers have been used because all age groups from II+ and VIII+ are fully represented.

Findings:

There were annual variations in the returns of spring- and fall-stocked salmon, but generally 11 years of data indicate that spring- and fall-stocked salmon contributed about equally in returns to anglers (Table 14).

Table 14. Angler returns of spring and fall yearling salmon stocked in Sebago Lake during the spring and the fall of each year from 1962 until 1973, in numbers, percent and ratio.

Year Caught	Spring Stocked		Fall Stocked		
	Number	Percent	Number	Percent	Ratio
1964	61	31	136	69	1:2.2
1965	115	44	146	56	1:1.3
1966	95	38	158	62	1:1.7
1967	192	55	156	45	1.2:1
1968	377	73	141	27	2.7:1
1969	212	42	294	58	1:1.4
1970	271	51	259	49	1.1:1
1971	348	47	387	53	1:1.1
1972	221	50	221	50	1:1
1973	214	50	212	50	1:1
1974[a]	170	63	100	37	1.7:1
Totals	2,276	51	2,210	49	1.03:1

a. Biased somewhat by a 17" length limit.

Catch data in the above table show that variations in the return of spring- and fall-stocked salmon occurred occasionally throughout the study. For example, in 1964 and 1966, *fall yearlings* made up 69 and 62% of the catch, but in 1968 and 1974, *spring yearlings* dominated the catch by 73 and 63%. These variations can only be considered as chance occurrences, probably due to various physical and biological conditions existing at the time of stocking that led to higher-than-normal mortalities following stocking. It is also quite possible that annual variations in the quality of yearling salmon raised at the Casco Hatchery could be responsible for "unusual" and "occasional" variations in returns of spring- and fall-stocked salmon. Generally, however, the ratios of recaptured spring- and fall-stocked yearling salmon were about 1 to 1 over the 11-year study. Of 4,486 recaptures from anglers, 2,276 (51%) were spring-stocked yearlings, and 2,210 (49%) were from fall-stocked yearlings (Table 14). Total returns of adult salmon on the Jordan River spawning runs during the same period agreed exactly with angler returns (51 and 49%).

The age composition of the Sebago Lake salmon population will be covered fully in a later segment of this report, but for clarity it seems appropriate to mention here the age composition of spring- and fall-stocked salmon that were taken in the Jordan River spawning runs (Table 15).

Table 15. Numbers (%) of spring and fall stocked salmon by age groups in the Jordan River spawning runs, 1970-1974.

Stock[a]	II+	III+	IV+	V+	VI+	VII+	VIII+	Totals
SY	191(61%)	465(48%)	194(33%)	182(66%)	103(74%)	9(43%)	1(25%)	1,145(50%)
FY	121(39%)	498(52%)	391(67%)	96(34%)	37(26%)	12(57%)	3(75%)	1,158(50%)

a. Spring yearling, Fall yearling

Although the data during the study indicated no difference between the returns of spring- and fall-stocked salmon, there were differences in returns among the various age groups represented in the catch. Spring yearlings in age groups II+, V+, and VI+ contributed significantly higher returns than fall yearlings, but in age groups IV+, VII+, and VIII+, fall yearlings dominated the catch (there was little real difference in returns of age III+ salmon). One may conclude from these data that fall-stocked salmon probably contribute the most returns to a salmon fishery, because age groups III+ and IV+ are probably the most desirable in terms of size and abundance. Spring yearlings, however, provided the greatest returns of age II+ fish soon after stocking, and they provided the best returns of large salmon in ages V+ and VI+. From the

Sebago Lake findings, it appears most desirable to stock both spring and fall yearling salmon because of the advantages that both offer in terms of returns to the angler. Spring yearlings, enter the fishery as age II+ fish, providing a significant part of the lake fishery during the spring and summer the year following stocking. Fall yearlings enter the fishery in late summer the year following stocking, becoming fully vulnerable the following year and producing the greatest returns as age III+ fish, and contribute the following year at age IV+. Spring yearlings make the greatest contribution to anglers of larger salmon at ages V+ and VI+. Fall yearlings contribute the majority of the largest and older salmon as ages VI+ and VIII+, but their numbers are so limited that their contribution to the fishery or to the spawning population is relatively insignificant. In the future, especially in Sebago Lake, if it becomes important to stock for quality-sized salmon only, it would be wisest to stock spring yearlings.

Angler returns of river-stocked salmon made up only 36% of the total catch during the entire study; therefore, tributary stocking of salmon would not be the best course to pursue in managing a lake fishery. However, the contribution that these fish made to the restoration of the Crooked River spawning runs was well worth the effort. It became clear, however, that it is not necessary to stock as many salmon as were stocked in the Crooked River in the early and late 1960's to increase significantly the spawning runs. Perhaps only 1/3 as many stocked fish would have been sufficient. It is important to continue a river stocking program for at least 4 or 5 years to insure widespread representation of age groups in future spawning migrations.

Results obtained from stocking specially marked salmon in various locations around Sebago Lake are conclusive in showing that the best returns came from scatter-plantings of salmon, boated over deep water, or from plantings along sandy shores in close proximity to deep water where predator species are scarce. Studies on several Maine lakes have shown that predation on newly stocked salmon can be significant when they are stocked in areas that are frequented by predator fish. Maine's salmon stocking policy is now based on findings from this and related studies.

5. *Age and Growth*

Methods and Procedures:

All age and growth analysis associated with this study are based on adult salmon captured on the Jordan River spawning runs from 1960 to

1974. Growth comparisons were made between adult salmon captured on the Crooked River and the Northwest River spawning runs, from anglers' creels, and from salmon gillnetted in Sebago Lake. Annual comparisons of growth were made exclusively from known-age, hatchery-reared salmon that had been stocked in Sebago Lake throughout the project. A pilot study early in the project confirmed that growth of stocked and naturally produced salmon were comparable, thus justifying the use of only known-age, hatchery-reared salmon for this segment of the study.

In the fall of 1957, a sample of spawning salmon was taken in the Jordan River in association with a salmon study that was being conducted at the Fish River Chain of Lakes in Northern Maine (Warner, 1962). This was most fortunate because at that point in time salmon growth in Sebago Lake was considered normal; therefore, the 1957 sample served throughout the Sebago Lake Study as a basis for determining when Sebago Lake salmon growth had been restored to normal levels.

The average weights of salmon in these analyses are somewhat biased due to the fact that they are taken from salmon that had been stripped of their eggs and sperm prior to weighing; however, for annual growth comparisons these data seem appropriate. The annual comparisons of growth were made on Age IV+ salmon, because this age salmon is most vulnerable to anglers, present in greatest number on the spawning runs, and age IV+ salmon seem to epitomize the general characteristics of a typically healthy landlocked salmon.

Findings:

Sebago Lake salmon made a spectacular recovery in growth following the cessation of DDT spraying and the recovery of the smelt population. In 1957, when salmon growth was considered normal in Sebago Lake, age IV+ salmon averaged 18.7 inches in length and weighed 32 ounces. As the full impact of the high concentrations of DDT in the Sebago Lake ecosystem was felt in terms of high mortalities of smelts and the deterioration of the general health and survival of salmon, growth of salmon decreased markedly from 1960 to 1964 (Table 16).

The poorest year for salmon growth in Sebago Lake was 1964, when the average age IV+ salmon was 14.9 inches long and weighed only 15 ounces—a "far cry" from the growth of age IV+ salmon in 1957. As the smelts recovered and the amounts of DDT in the ecosystem decreased, a steady improvement in growth occurred, and by

Table 16. Average length in inches and (weight in ounces) of known-age salmon taken in the Jordan River spawning migrations from 1957 to 1974.

Year	Number	II+	III+	IV+	V+	VI+	VII+	VIII+
1957	230	—	17.6(27)	18.7(32)	19.6(37)	20.6(45)	—	—
1960	501	—	14.5(14)	16.0(19)	17.6(25)	19.9(35)	—	—
1961	158	—	14.4(12)	15.4(15)	17.0(21)	17.8(25)	—	—
1962	508	—	13.7(11)	15.1(13)	16.6(18)	17.6(23)	—	—
1963	524	—	13.6(10)	15.6(16)	16.4(19)	18.1(27)	—	—
1964	672	—	13.7(11)	14.9(15)	16.9(23)	18.4(30)	—	—
1965	920	—	16.4(21)	17.0(24)	18.4(30)	20.3(41)	—	—
1966	913	—	16.1(18)	17.4(23)	17.9(25)	18.4(30)	—	—
1967	509	—	15.6(17)	17.4(21)	18.5(26)	18.3(26)	—	—
1968	432	—	16.4(22)	18.4(31)	19.3(36)	18.5(32)	—	—
1969	461	—	17.1(24)	19.3(34)	20.0(37)	20.2(35)	—	—
1970	449	16.4(26)	17.9(33)	20.2(45)	20.6(50)	22.8(67)	21.8(65)	23.9(78)
1971	722	15.5(17)	18.2(27)	20.0(36)	20.8(40)	21.9(53)	21.6(42)	25.5(58)
1972	715	14.8(16)	16.8(23)	19.1(33)	20.2(38)	21.7(48)	22.4(49)	—
1973	453	13.6(11)	15.9(17)	18.2(26)	19.8(33)	20.5(34)	21.0(40)	23.1(48)
1974	1,030	14.7(11)	15.5(14)	18.1(23)	20.5(34)	20.5(31)	—	—

1969, salmon had actually surpassed the 1957 growth levels. By 1970, salmon growth had reached an all-time high when the average age IV+ salmon was 20.2 inches long and weighed 45 ounces. This level of growth not only surpassed what is considered normal for Sebago Lake salmon, but also it is well above the average of most Maine salmon lakes. As the data indicate, above-average growth was prevalent in all age groups; therefore, 1970 can be considered the very best year for salmon during the 15-year study.

Between 1970 and 1974, salmon growth declined to a point where an average age IV+ salmon was 18.1 inches long and weighed only 23 ounces. The same observations can be made for all age groups represented in the Jordan River spawning runs. Growth did not decline to the low levels that were experienced during the period from 1960 to 1964, however. There are some reasonable explanations for the decline in growth experienced during this period of the project. In an attempt to provide as many acceptable-sized salmon as possible to satisfy the angler, the number of salmon stocked into Sebago Lake was increased from 30,000 in the mid-60's to 60,000 by 1973. At the same time, resulting from increases in the salmon spawning runs in the Crooked and Northwest Rivers, the number of naturally produced fish in anglers' creels increased from about 5% in 1964, to 28% in 1974. Concomitant with the increases in the number of salmon stocked and natural recruitment of salmon into Sebago Lake, there was a decline in numbers of smelts in the Crooked and Songo Rivers during smelt spawning migrations. The combination of these three factors, created a situation where there were too many salmon in Sebago Lake for the amount of food available for them. It now appears that to provide a satisfactory salmon fishery in Sebago Lake in terms of good growth and satisfactory angler success, about 20,000 yearling salmon should be stocked annually. Adjustments in these numbers will be contingent upon the recruitment of naturally produced salmon into the lake.

Perhaps of more significance to the Sebago Lake salmon population and the success of the sport fishery, is the steady decline in the numbers of older salmon in the population (Table 17).

In 1957, 66% of the Jordan River spawning salmon consisted of age V+ to VII+ fish. Even during the "bad" years (1960-1964), these same age groups averaged about 36% of the runs. A most drastic decline in older salmon occurred from 1970 to 1974 to a point where they made up only 2% of the 1974 Jordan River spawning run. Reasons for the decline in older salmon are obvious. As Sebago Lake recovered from

Table 17. **Percentage of known-age salmon represented in the Jordan River spawning migrations, 1957-1974.**

Year	II+	III+	IV+	V+	VI+	VII+	VIII+
1957	0	8	26	48	16	2	0
1960	0	20	54	20	4	2	0
1961	3	20	28	24	21	5	0
1962	4	22	32	26	10	15	0
1963	17	27	32	25	8	1	0
1964	5	46	34	11	6	2	0
1965	1	14	76	7	1	1	0
1966	6	45	28	19	2	0	0
1967	10	33	45	7	5	0	0
1968	4	47	31	12	1	5	0
1969	2	8	69	11	2	7	1
1970	18	13	33	26	7	2	1
1971	9	59	18	5	9	0.5	0.5
1972	12	48	28	5	4	3	0
1973	26	37	25	9	2	0.5	0.5
1974	21	67	10	1	0.5	0.5	0
1975[a]	18	38	29	10	3	2	0

a. Data made available for clarity and support of the 17-inch legal length limit.

the effects of DDT, fishing pressure increased tremendously. By 1969 and 1970, when the ultimate in terms of growth and general health of salmon had been reached, the number of people fishing Sebago Lake reached exceedingly great proportions. Because of this tremendous increase in fishing pressure, an over-harvest of age II+ and III+ salmon occurred, thus dangerously reducing the number of salmon being recruited into the older age groups. By 1973, the situation had reached a point where fishermen were removing salmon about as fast as they reached the legal length (14 inches). To halt this over-harvest, a 17-inch length limit was imposed in 1974 in an attempt to increase the number of young salmon in the lake population to a degree where significant recruitment into the older age classes would occur. After two fishing seasons, the 17-inch regulation was responsible for a significant increase in the number of ages III+ and IV+ salmon in the 1974 and 1975 Jordan River runs (Table 17). Some age II+ salmon are not mature and therefore, their numbers in the Jordan River runs are not representative of this age class. The continuation of the 17-inch length limit at Sebago Lake would be justified had it not been for a noticeable decline in the smelts in Sebago Lake during the past 3 or 4 years. Considering these events, it is necessary to return to a 14-inch salmon length limit for a period of time. This will allow a greater harvest of salmon, and reduce predation upon smelts, thereby allowing the smelt population to recover more rapidly.

There were differences in growth between spring- and fall-stocked yearling salmon (Table 18). Spring-stocked salmon experienced better growth than fall-stocked yearlings, but beyond age IV+, growth between the two groups was similar.

Table 18. Age and growth of fall yearlings (FY) and spring yearlings (SY) in the Jordan River salmon spawning migrations, length in inches, (weight in ounces).

Year	Stock	II+	III+	IV+	V+	VI+	VII+	VIII+
1971	FY	15.0(15)	17.6(15)	20.3(38)	20.8(38)	21.8(47)	—	—
	SY	15.4(18)	18.6(29)	19.7(33)	20.6(40)	21.8(48)	—	—
1972	FY	15.1(16)	16.4(21)	19.3(33)	20.6(39)	21.6(48)	21.8(48)	—
	SY	14.7(16)	17.9(27)	19.4(33)	19.7(35)	21.8(47)	22.5(49)	—
1973	FY	13.2(10)	15.5(15)	18.1(25)	19.3(31)	20.0(29)	20.4(40)	—
	SY	14.2(11)	16.2(17)	18.8(28)	20.8(37)	20.7(36)	—	23.1(48)
1974	FY	14.5(12)	15.3(13)	17.3(20)	19.0(27)	—	—	—
	SY	14.5(12)	15.2(13)	18.0(24)	21.7(43)	—	—	—

One can also see the effects of the decline in smelts in reducing salmon growth in all age groups of salmon represented in the Jordan River runs in 1973 and 1974.

There were vast differences in the condition (K) of salmon taken in July and August and those captured on the spawning gorunds in November:

K Factors for 17" and 17.9" Sebago Lake Salmon

Month	1969	1970	1973	1974
July	0.838	0.771	0.834	0.810
November	0.703	0.627	0.637	0.680

These data for July-August show little evidence to support belief among anglers that Sebago Lake salmon are not as fat as they were in

1969 and 1970. These data also raise the question of the validity of using growth data from spawning salmon to make statements relative to the general condition of salmon in a particular lake. A more meaningful and unbiased assessment of salmon condition can be made from those captured during the peak of the growing season in July and August.

Throughout much of this study there has been a question among biologists and anglers as to whether or not growth was adversely affected by the presence of the tapeworm *Diphyllobothrium sebago* (Ward, 1910). To evaluate possible effects, all salmon gillnetted in 1969, 1971 and 1973 were separated into two groups: those that were moderately to heavily infested with tapeworms, and those with relatively few or no tapeworms in their viscera. The condition of the two groups of fish were compared:

1969		1971		1973	
With	Without	With	Without	With	Without
0.834	0.841	0.774	0.757	0.835	0.833

With = with tapeworms, Without = without tapeworms

The above comparisons strongly indicate that there is little difference in the condition of these two groups of salmon. Some comparisons of individual fish, however, revealed that when salmon became 6 or 7 years old and were heavily infested with tapeworms, condition declined rapidly; this was not apparent in younger salmon from 2 to 4 years old.

6. *Angling*

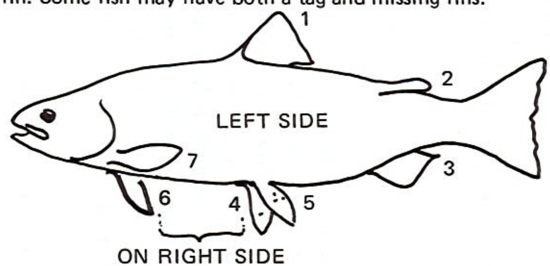
Methods and Procedures:

No concentrated effort was made during this study to measure total angler harvest or total fishing pressure on Sebago Lake, but partial creel censuses by Department personnel allowed for reasonable estimates of these parameters. In addition, a large volume of catch data was obtained from anglers who kept annual fishing records. Creel census clerks and volunteer anglers kept records of: fins removed, length, weight, and location in the lake where salmon were caught, the number of hours fished and the number of anglers (successful and unsuccessful) in the party (Figures 2 and 3).

Census clerks collected information annually, providing data for determing what was actually happening to the salmon fishery in terms

Figure 2

MISSING FINS: Most of the fish marking is done by removing one or more fins. Check your fish carefully for missing fins. If your fish has one or more missing fins place the fish in the same position as the one on the diagrma below, and determine which number or numbers correspond to the missing fins. Record these numbers by encircling the appropriate number or numbers in the column under "missing fins." If a fin is very small or distorted, record it as a missing fin. Some fish may have both a tag and missing fins.



FISH RELEASED: Check fish to be released for tags or missing fins. If you release short or legal-sized fish please note the species and approximate lengths as well as the number of fish released at the bottom of the page. These should not be held long enough to measure or weigh them.

IMPORTANT: **Please make an entry in your book for each trip whether you caught any fish or not. It is important for us to learn about trips where no fish were caught as well as successful trips.**

At the end of the fishing season return booklet to:

After we have recorded the information your booklet will be returned to you for your own records. We sincerely appreciate your cooperation for better fishing in Maine.

Figure 3

Date June 10, 1969 Lake or stream Sebago Lake

Time at start of fishing 7:30 am Time at end of fishing 3:00 pm

Number of fishermen covered by report 4-2

RECORD OF FISH CAUGHT				
Species	Length	Weight	Tag No.	Missing Fins
Salmon	17¼	1½ lb.	A-302	1 2 3 4 5 6 7
"	18¾	3 lb.		1 2 3 ④ ⑤ 6 7
"	15½	1 lb.		1 2 3 4 5 6 7
Togue	20¼	3½ lb.		1 2 3 4 5 6 7
"	18½	2 lb.		1 2 3 ④ 5 6 7
Trout	14			1 2 3 4 5 6 7
				1 2 3 4 5 6 7
				1 2 3 4 5 6 7
				1 2 3 4 5 6 7

Fish Released (Number and Approximate Lengths)
3 Salmon —10 to 13 inches
1 Togue —12 inches

Remarks: One of the salmon released had number 5 fin missing. Fishing mainly for togue.

of catch-per-hour, rates of angler success, returns of spring- and fall-stocked yearlings, and the location in the lake where the fish were caught.

Volunteer creel census booklets were kept by guides, "better-than-average" anglers and "average" salmon fishermen. Fishing results from these three groups were compared annually so that trends in fishing quality and success could be established. These data gave an excellent opportunity to check the validity of volunteer records against data gathered by trained creel census clerks.

Findings:

The quality of salmon fishing in Sebago Lake increased significantly as fishery management measures took effect (Table 19).

Table 19. Fishing results from two groups of fishermen who fish Sebago Lake.

Year	Group A[a]		Group B[b]		Combined Catch/hr.
	% Success	Catch/hr.	% Success	Catch/hr.	
1962	—	0.270	3	0.130	—
1967	—	0.454	20	0.250	—
1969	75	0.404	38	0.275	—
1970	81	0.460	65	0.284	—
1971	77	0.568	69	0.280	0.367
1972	86	0.571	35	0.290	0.449
1973	87	0.476	65	0.314	0.324
1974	—	0.520	—	0.310	0.379

a. Group A—Guides and better-than-average salmon anglers.
b. Group B—Average successful salmon anglers.

Salmon fishing was so poor from 1962 to 1966 that it took an "average" salmon angler (Group B) nearly *eight* hours to catch *one* legal salmon. These anglers were successful in catching a legal salmon on only 3% of their angling trips. The "better-than-average" fishermen (Group A), caught a legal salmon about every *four* hours of fishing. By 1967, as the salmon population began to show signs of recovery, fishing results began to improve, and good fishing quality became well re-established by 1970-1973. During this period, anglers caught a legal salmon about every *three and one-half* hours and were successful on about 50-60% of their trips. Guides and "better-than-average" salmon anglers were significantly more successful, being successful on about 80% of their trips and catching *one* legal salmon every *two* hours.

The length class structure of salmon taken from Sebago Lake improved noticeably once the lake salmon population recovered (Table 20).

Table 20. Length-class structure of the Sebago Lake salmon population as taken on the Jordan River spawning runs (in percent).

Length Range (Inches)	(percent)							
	1957	1964	1969	1970	1971	1972	1973	1974
13.0-16.9	7	80	10	16	16	16	59	87
17.0-21.9	83	13	83	71	78	78	39	12
22.0-28.9	10	7	7	13	6	6	2	1

In 1957, before pesticide problems occurred, 83% of the salmon caught by anglers were between 17.0" and 21.9" in total length. In the very early 1960's, salmon growth started to deteriorate and by 1964, which was considered the poorest year for salmon growth during the project, only 13% of all salmon caught were between 17.0" and 21.9". From 1969 to 1972, from 71 to 83% of all salmon caught were between 17.0" and 21.9" in total length. This increase in average size of salmon was due to the restoration of the population resulting from the discontinuation fo the use of DDT in the Sebago Lake drainage. Due to the tremendous increase in fishing pressure during the late 1960's, and continuing through the 1970's, an over-harvest of salmon by anglers occurred, resulting in a significant deterioration of the length class structure of fish in the catch. In 1973, for example, the percentage representation of 17.0" and 21.9"-long salmon in the catch decreased to 39%, and by 1974, it had further declined to only 12% of the catch. In an attempt to reduce over-harvest of young salmon in Sebago Lake and thereby increase recruitment of salmon into older age classes, a 17-inch length limit was imposed in 1974. Statements regarding the 17-inch length limit have been made earlier in this report.

It has been well documented throughout this study that Sebago Lake is capable of producing sufficient numbers of desirable-sized salmon, averaging 2.5 to 3.0 pounds. Considering this, Sebago Lake should be managed so that about 80% of the adult salmon population is composed of fish between 17 and 28 inches in total length.

Reference has been made to the current heavy fishing pressure at Sebago Lake. From 1971 creel census records, it is possible to make approximations of fishing pressure and angler harvest. It is doubtful that fishing pressure changed significantly on Sebago Lake from 1971 to 1973. A general census of Sebago Lake anglers was conducted by two creel census clerks from mid-April to June 30 in 1971. During that time interval, 319 salmon were checked and approximately 32% of all anglers interviewed had caught at least one salmon. It was estimated that about 5% of all anglers fishing Sebago Lake during the census period were checked. Based on this assumption, about 6,300 salmon were caught during the period from April 15 to June 30, 1971. From fishing records kept by guides and "better-than-average" anglers, it was found that about 57% of their catches of salmon was made during July, August and September. Their catch per hour did not vary significantly between the early part of the season (mid-April to June 30) and the latter part (July to September): 0.547 in the early season and 0.532 during the late season. The success rate of these two groups of anglers during these two periods were 77% and 75%, respectively. During 1971, it was not difficult to check 50 to 100 boats a day on Sebago Lake during July, August and September. If we assume that these were mostly "better-than-average" salmon fishermen, and that they were successful on 75% of their trips, we estimate that about 5,500 salmon were caught during July, August and September, 1971. Combining both periods of the 1971 fishing season, it appears that approximately 12,000 salmon were caught. This amounts to a harvest of about 0.42 fish per acre, which is somewhat lower than the state-wide average.

Analysis of the angler-catch in terms of numbers of salmon kept by anglers, shows that in 1973, 84% of all successful anglers took home catches of less than three salmon (Table 21).

Table 21. Take-home catches of salmon from the 1973 and 1974 angling seasons.

Year	1 Fish	2 Fish	3 Fish	4 Fish	5 Fish	Anglers	Ave. Catch
1973	484(54%)	267(30%)	77(9%)	36(4%)	25(3%)	889	1.7
1974	106(28%)[a]	104(27%)	59(15%)	60(15%)	61(15%)	390	2.7
1974	163(79%)[b]	41(20%)	2(0.9%)	1(0.1%)	0	207	1.2

a. Salmon 14 inches and over.
b. Salmon 17 inches and over.

In 1974, 54% of all successful anglers took home limits of one to two fish, but more encouraging still, 45% of all successful anglers took home catches of three to five salmon. The 1974 "take-home" catch of fish 17 inches and over indicates that fishing was relatively poor for this size salmon, because 79% of all successful anglers took home only one salmon, 20% took home two, and only 1% took home three or more.

There is strong reason to believe that once the length-age structure of Sebago Lake salmon is restored to near the 1969 to 1972 levels, that more anglers will be taking home two and three salmon of larger size. It is very doubtful, however, that the salmon length-age structure in Sebago Lake can be maintained at a favorable level for very long with heavy fishing pressure exerted with a 14-inch length limit and a bag limit of 5 fish. It seems highly probable that the legal length should ideally be about 16 inches and the daily bag limit at two or three fish.

In October, 1972, a special 31-day, fly-fishing-only season began at Sebago Lake Station at the south end of the lake. Anglers were restricted to fishing from the shore, and only barbless hooks were allowed. It was strictly designed as a "fish-for-fun" experience because all salmon caught had to be released. This special season was adopted so that fishermen who had customarily fly-fished this area of Sebago Lake for years during the last week in September could have an extension of the season. In this area of Sebago Lake, a substantial number of adult salmon congregate in late September, remaining there through November. Their presence is readily apparent by their aerial acrobatics as they jump and splash about, obviously a part of their pre-spawning activity. So spectacular is this annual occurrence that people from miles around come to the "Station" when they hear that the "salmon are in." Believing that no significant harm could result from such a high-quality sport fishery, the Department agreed to this special October season. To monitor the special season, a partial creel census was conducted in 1972 and 1973. In addition to the census clerk, volunteer records were kept by interested anglers, and in most cases these anglers kept records of other anglers who were present when the creel census clerks were absent. Therefore, rather complete records were kept during the first two years of the special season. In 1972, it was estimated that a total of about 230 anglers fished during the special season and caught 120 salmon for a catch-per-hour of 0.101 salmon. All of these salmon were returned to the lake, and insofar as is known only one fish died as a direct result of hooking and playing. In 1973, it was estimated that 240 anglers fished during the special season and caught about 80 salmon for a catch of 0.154 salmon per hour. No reports of dead salmon were received during the 1973 season. Approximately 17% of the anglers were successful in 1972 and 1973. There are no records available for the 1974 season, but conversations with a few of the anglers who routinely fish during this special season indicated that fishing was much poorer in 1974. It is speculated that the poor fishing was due to an unusually warm October, which kept water temperatures relatively high, with salmon avoiding shallow water area where anglers fish.

The popularity of this special season is well documented now and the "fish-for-fun" concept has been very well accepted. After 3 years of this special season, there seems to be no reason to discontinue it.

There is another "success story" in the making at Sebago Lake concerning lake trout which were introduced in 1972 with the stocking of 108,000 spring yearlings. The decision to stock lake trout in Sebago Lake came after 10 years of netting the lake, which revealed that salmon were predominantly found in water depths of 10 to 40 feet, and rarely were they taken in depths greater than 60 feet. Since lake trout need water temperatures ranging from 60°F downward, and water containing amounts of dissolved oxygen in excess of 5 ppm, it seemed that the large volume of suitable lake trout habitat in Sebago Lake would provide excellent conditions for lake trout (Figure 4).

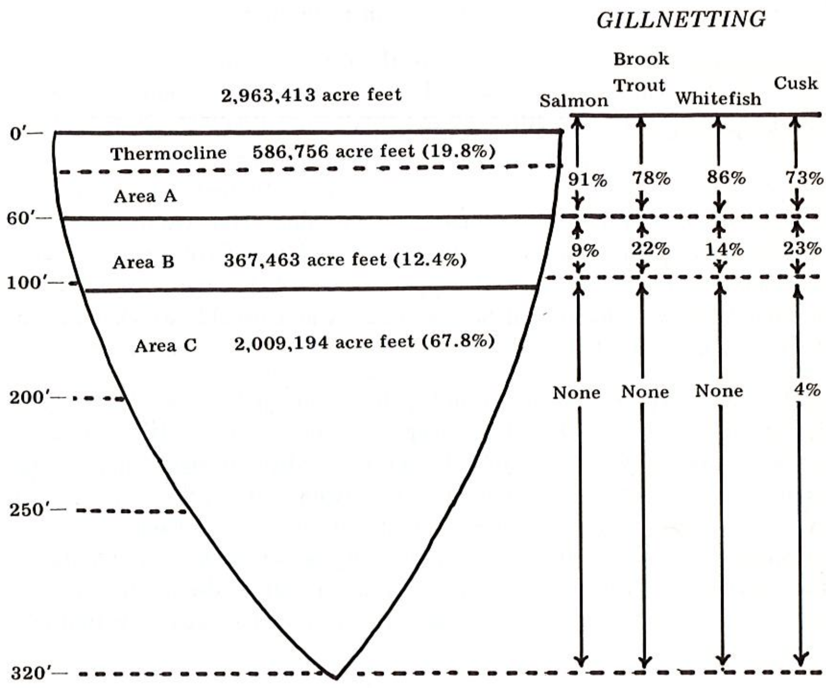
Hoping that lake trout would confine themselves mostly to water depths in excess of 60 feet, a deep-spawning strain of lake trout was procured from New York State's Finger Lakes. In their native habitat, this strain of lake trout is commonly found spawning in depths of 100 to 300 feet. Plans were originally made to stock this strain in Sebago Lake for 5 consecutive years in hopes of establishing a self-sustaining population. These plans have been altered somewhat as a result of the recent reduction in numbers of smelts in Sebago Lake. Togue stocking was terminated after the third stocking in 1975.

In 1974, a spectacular openwater sport fishery developed from the 108,000 spring yearling lake trout that were stocked in 1972. In reports from 307 anglers who fishes for 1,542 hours, 693 lake trout were caught that averaged 16.0" and weighed 20 ounces. These anglers had an hourly catch of 0.449 fish and a catch of 2.2 fish per angler. A mid-summer condition factor (K) was computed on angled lake trout and compared to the mid-summer K of similar-sized salmon. Lake trout had a value of 0.900, while the condition factor for salmon was 0.810. For the most part, lake trout stomachs contained smelts, but yellow perch, whitefish, cusk and various species of aquatic insect larvae and amphipods were frequently found.

Angler reports vary as to the depth at which lake trout were caught,

Figure 4.

SEBAGO LAKE (28,771 Acres)



Area A — 87.3% of *all* fish gillnetted.
Area B — 8.5% of *all* fish gillnetted.
Area C — 4.2% of *all* fish gillnetted.

Net Statistics

23.9 fish/100′ of net in 10′ to 60′
1.1 fish/100′ of net in 60′ to 250′

but judging by these reports it appears that most lake trout were taken in depths of from 40 to 90 feet. Gillnets set in the summer of 1973, failed to take any lake trout at depths less than 80 feet.

DISCUSSION

The Sebago Lake Study has been an interesting and valuable experience in that it has shown what can be done when appropriate and immediate action is taken to restore a salmon fishery in a large lake. The results of this study show beyond all doubt that the use of DDT to control pestilent insects around the shores and tributaries of Sebago Lake was fully responsible for the collapse of the smelt population, which in turn adversely affected the well-being of the landlocked salmon population. Had this practice of using DDT around Sebago Lake continued, salmon fishing would have been destroyed.

Species composition studies showed that nearly all fish species living in Sebago Lake were adversely affected by DDT spraying and only now, 10 years after the cessation of the use of DDT, are these species returning to normal levels. There are strong indications that most minnow species have not recovered, and this is quite probably due to the severe reduction in their numbers during the years when DDT was used around the shores of Sebago Lake. Smallmouth bass, largemouth bass, cusk and suckers which were markedly reduced in numbers, are just now showing signs of complete recovery.

Residues of DDT and its metabolites are now down to levels where they are not considered harmful to fish life in Sebago Lake. This is gratifying because all decreases in pesticide levels in the Sebago Lake ecosystem have come only 10 years following the cessation of the use of DDT. It was originally believed from reading the literature regarding the persistency of DDT that it would take nearly 20 years for DDT to dissipate to levels where it would be harmless to the general health and well-being of the organisms living in the Sebago Lake ecosystem.

The pesticide monitoring study will continue on Sebago Lake by sampling 30 adult male, age III+ salmon every 5 years to ascertain levels of the various pesticides present in their body tissues. A continuation of these assays will shed more light on the absolute persistency of DDT in the environment, especially as it pertains to its delineation in the body tissues following the cessation of its use.

The recoveries in numbers of various species of fish that inhabit Sebago Lake have been gratifying, especially with salmon, bass and cusk. The decline of white perch and yellow perch is probably due to the increase in numbers of smallmouth and largemouth bass which prey upon the perches and compete with them for food and space. It would probably be premature at this time to speculate relative to the change in status that occurred in 1973 in the numbers of whitefish and suckers in the gillnet catches. Possibly this is due to some hidden bias in the 1973 gillnetting results; however, it seems more than coincidence that the 1974-1975 winter catch of whitefish was far below normal levels. Future netting studies will be beneficial in establishing the real significance of the 1973 netting data.

The recovery of Sebago Lake salmon has been remarkable, and it must be emphasized again that had the uncontrolled use of DDT continued around Sebago Lake, there is little doubt that salmon would have continued to decline in numbers and deteriorate in general condition to a point where they would no longer provide a significant fishery. Perhaps the most significant finding of this entire study is the abundantly important role that smelts play in the management of a lake population of salmon. Unless a smelt population is maintained at a reasonably high level, salmon will not provide a satisfactory lake fishery.

The Sebago Lake study has soundly demonstrated that lakes as large as Sebago can be managed successfully. The general public in the Sebago Lake area must be commended for their acceptance of the Maine Fisheries and Wildlife Department's approach to the problems that have existed there for the past 15 years. The application of basic fishery management principles on Sebago Lake has been responsible for the complete recovery of salmon, not only in terms of growth and population abundance, but also in providing a successful sport fishery. Intensive fishery management must continue at Sebago Lake to provide satisfactory salmon fishing in the years ahead.

Recommendations:

The following recommendations are based on knowledge gained from this study and unsolved problems that still exist in Sebago Lake:

1. Under no circumstance should DDT and/or other "hard" pesticides be used in the Sebago Lake drainage.

2. Pesticide assays of Sebago Lake salmon should be made every 5 years as a continuation of the monitoring program to detect increases or decrease of DDT or other pesticides.

3. The trapping of mature salmon should continue on the Jordan River spawning migrations to monitor age and growth status and the general health and well-being of the Sebago Lake salmon population.

4. Partial creel censuses and volunteer fishing records should be continued to evaluate changes in fishing success and fishing quality resulting from current and future fishery management programs.

5. A continuation of production studies in the Northwest River, Crooked River, and Mile Brook is necessary. These studies should be conducted on an alternate year basis to determine the progress made toward reaching full salmon production in these streams.

6. Because of the high intensity of fishing pressure at Sebago Lake, changes in fishing regulations seem necessary. As soon as the present salmon growth problems are solved, a length limit and a bag limit should be established which will assure the maintenance of a healthy salmon population. It appears that the 16-inch, 3-fish bag limit might be appropriate to accomplish this objective.

7. The Bolster's Mill fishway trap on the Crooked River should be operated long enough to determine when and if the spawning runs of salmon in the Crooked River have reached maximum proportions. Quite possibly the trap would serve many services such as providing an additional source of salmon eggs for the hatchery system, determining population abundance of salmon and trout of all ages living in the Crooked River, and as a source of determining the age and growth characteristics of naturally produced salmon. Further knowledge relative to homing tendencies of river-produced salmon are possible by the continuation of this operation.

8. Lake trout stocking in Sebago should be discontinued, at least temporarily, pending restoration of normal smelt abundance. Introductory stockings previously planned for 1976 and 1977 will not be made. To assist in establishing a self-sustaining population of lake trout, a length limit of 18 inches, with a bag limit of 2 or 3 fish should be enacted. This should come following the restoration of the smelt population and the complete recovery of salmon growth. Winter fishing for lake trout should begin in 1977.

9. Continued monitoring of the fish populations in Sebago Lake is necessary to provide the necessary information required for the management of the lake's fishery resources.

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