ROSS LAKE: THE FISH AND FISHERIES

By

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INTRODUCTION

General Ross Lake Fishery Concerns

In recent years many Ross Lake anglers have expressed the opinion that there has been a decrease in the number of fish caught per day and the size of those fish. Most contend that this decline in fishing success and quality has occurred since the late 1960's or early 1970's.

These angler concerns, if correct, could indicate biological problems related to management of the Ross Lake trout fishery. The need to 1) verify the current status of the lake fishery, 2) verify the adequacy of existing fishing regulations to protect the fish population from over-harvest, 3) fill in gaps in our knowledge of the life history and biological/habitat requirements of the trout population, and, 4) collate related historical studies' data, led the Washington State Department of Wildlife (formerly Department of Game) to initiate this study.

The study was partially funded by the Skagit Environmental Endowment Commission.

Study Area: Ross Lake/Canadian Skagit River

Ross Lake (Reservoir) is located in the northeastern portion of Whatcom County, Washington State (Figure 1). It was formed by the building of Ross Dam on the Skagit River. Construction of the dam began in 1937 and was completed 1949. Ross Lake has a surface area, at maximum level, of 11,200 acres in Washington and 480 acres in British Columbia. It is 22 miles in length and extends approximately one mile into British Columbia when at full pool (Figure 2).

The total Skagit River drainage basin comprises 3,140 square miles (Whately, 1970). Approximately 1000 square miles lie upstream from Ross Dam (Anonymous, 1972b). The Canadian portion of the Skagit River begins near Allison Pass in Manning Provincial Park, British Columbia, and flows approximately 32 miles before entering Ross Lake. In Canada the river has an approximate drainage area of 389 square miles (Whately, 1970).

This study, as well as early 1970's fisheries studies associated with Ross Lake and its tributaries, concentrated on data collection from the reservoir, and its U.S. tributaries. The Canadian Skagit River has been the subject of past research and an ongoing study by the Fisheries Branch of the B.C. Ministry of Environment.

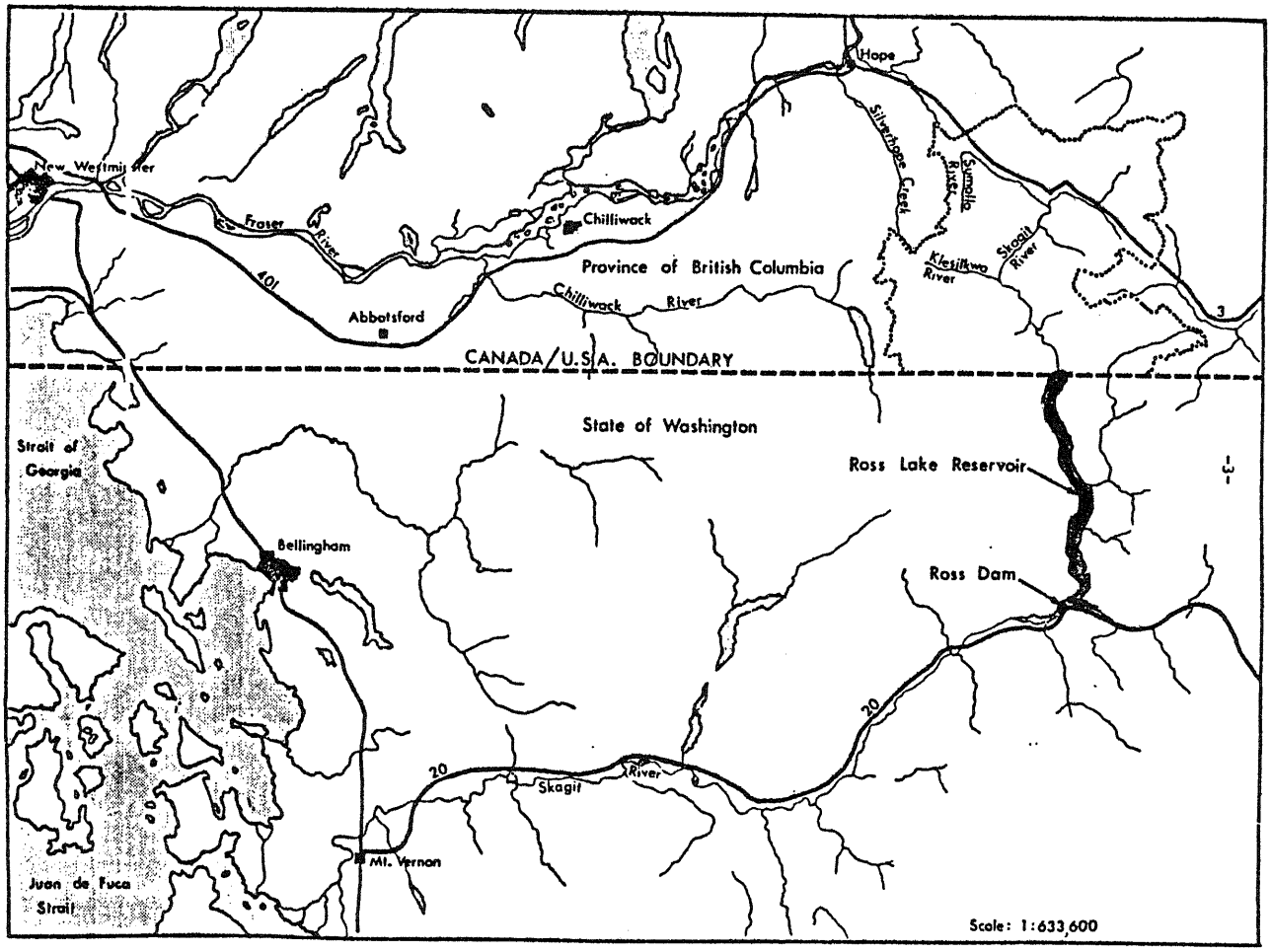

FIGURE 1. Geographic location of Ross Lake in NW Washington.

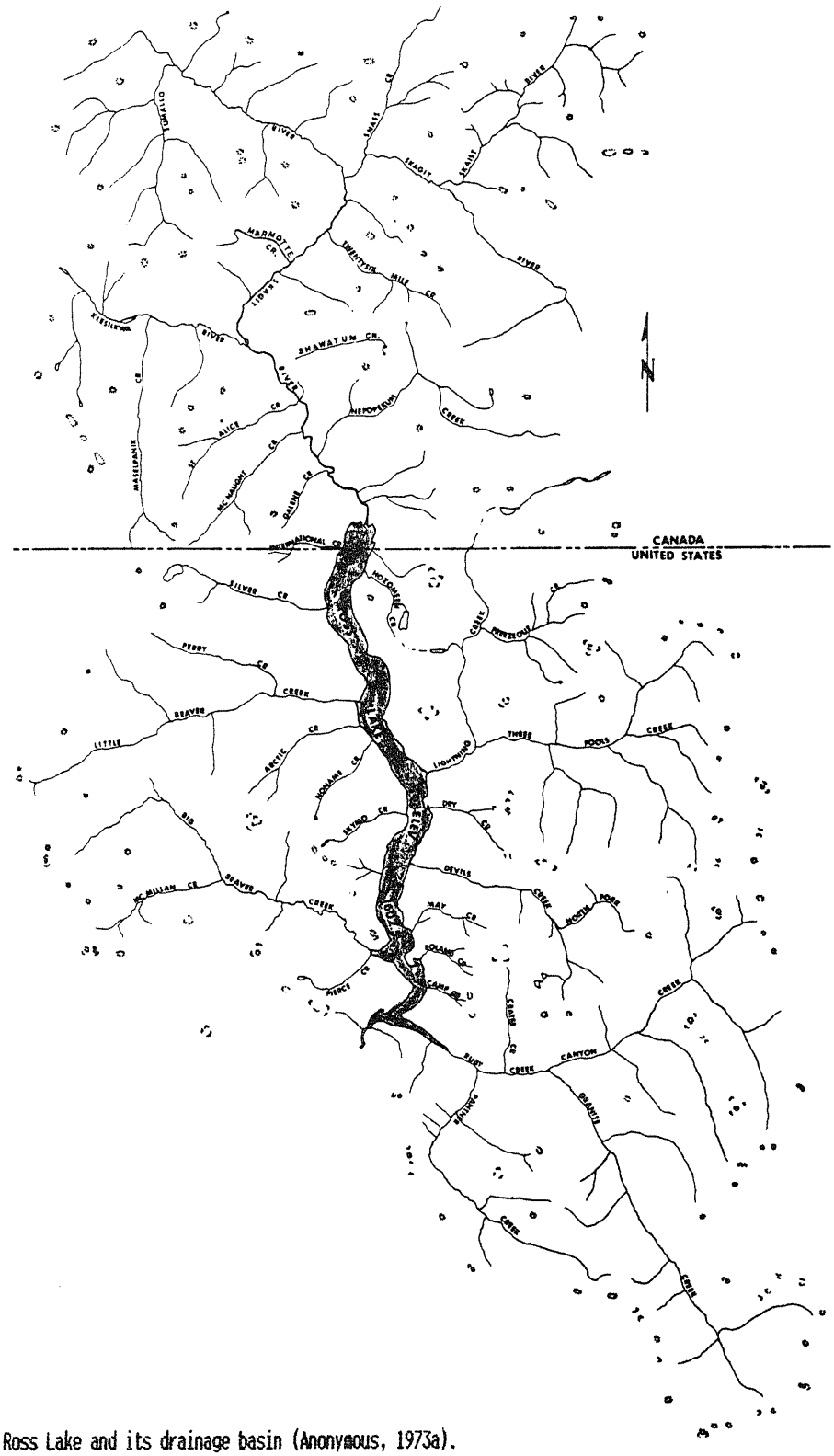

FIGURE 2. Ross Lake and its drainage basin (Anonymous, 1973a).

Study Objectives

Current Fish Harvest Related to Historical Data

One of the objectives of this study was to determine whether current (1985-1988) harvest related data (catch per unit effort (CPUE), annual harvest, age of catch, length of catch, sexual maturity of catch, location of harvest, etc.) differ from historical harvest data. If significant differences exist that threaten the ability of the native trout populations to sustain themselves at historical levels, an attendant objective was to determine if current fishery regulations and/or reservoir operations are responsible and in need of modification.

Rainbow Trout Life History and Migration Patterns

Another study objective was to develop a more clear understanding of Ross Lake rainbow trout life history and migration patterns. Areas of concern include; age distribution, age class strength, age versus length, age versus sexual maturity, migrations between lake and tributaries, diet, length at sexual maturity, fecundity, spawning time, spawning locations, fry emergence timing, fry outmigration timing, fry contribution by tributaries, and population size. Much of the data on life history and migrations are available in prior research documents and field notes, however, the information from over 45 documents has never been assembled to assist in developing a more clear life history portrait. An objective of this study was to assemble those documents, look for gaps or conflicting data, and attempt to complete the life history picture.

Other Recreational Impacts Upon Fishery Resource

One objective of this study was to determine whether recreational gold dredging, primarily in the Ruby Creek drainage, had the potential to harm fish populations that migrated to that watershed from Ross Lake for spawning. If so, then standarized hydraulic permit provisions to protect spawners and progeny through to emergence needed to be developed.

Another objective was to determine if current and long range recreational site development by B.C. Parks and North Cascades National Park, funded in part by the Skagit Environmental Endowment Commission, will have potential negative impacts upon the fishery resources of Ross Lake, through increased fishing pressure brought about by easier access, camping, and boat launching.

If significant increased fishing pressure appears likely then fishing regulations will need to be developed that ensure Ross Lake fish populations are maintained.

Mitigation Needs

The operation of Ross Dam to provide power and flood water storage results in large fluctuations of Ross Lake water levels. An objective of this study was to determine whether the fluctuations have had an impact upon the fishery resource and, if so, what mitigation from Seattle City Light for identified negative impacts should be requested.

Develop Long Range Management Plans

The last objective of this study was to provide data and analysis that will assist in the development of a long range fisheries management plan for Ross Lake, managed co-operatively by Washington Department of Wildlife, North Cascades National Park, and B.C. Ministry of Environment, and the Canadian portion of the Skagit River, managed by B.C. Ministry of Environment. The fisheries resource of the Ross Lake/Canadian Skagit River freely migrate back and forth across the U.S./Canadian International Border, necessitating coordinated, complimentary management goals and objectives.

METHODS

1985 WDW/B.C. MOE Study

The 1985 Washington Department of Wildlife (WDW) and B.C. Ministry of Environment (MOE) Ross Lake harvest survey design and method of data analysis are described in Scott and Peterson, 1986. The creel census was started that year on opening day of the fishing season (June 15 - October 31) at the north end of Ross Lake by the Washington Department of Wildlife. The MOE study, conducted by H. Paish consultants, began immediately after opening day. WDW, however, did not receive funding to add survey personnel until July 17, and as a result the south end of Ross Lake was not sampled until July 21. The Department of Wildlife continued the survey until October 31, after the B.C. survey ended on September 30, 1985. The sampling days were stratified into weekdays and holidays, and surveys were conducted a total of 44 days.

On-site access point surveys at the resort at the south end of Ross Lake and at the main NCNP boat launch (Hozomeen) at the north end of the lake were the primary data collection sites (Figure 3). Interviews of anglers were conducted as they returned to these launching sites. Interview questions included; number of anglers per boat, hours fished, number of fish caught, number of fish released, fishing location, tagging data, fishing method, and whether they had completed fishing for the day. Biological data gathered from the catches included species of fish, fish length, scales for aging, and sexual maturity information.

To assess angling effort, the MOE consultant's survey crew conducted two angler counts (AM and PM) on randomly chosen days between June 15 and July 16 north of Lightning Creek. No counts of anglers were conducted south of Lightning Creek during this time period. From July 17 to September 30, WDW conducted boat counts on all of Ross Lake on each sampling day. The counts were conducted in the AM and PM. During the month of October angler effort was low and it was assumed that total angler counts could be obtained during the take-out point interviews, consequently lake boat counts were discontinued.

Statistical analysis of the data included development of; total angler effort and variance estimates, point estimate of total angler days, estimate of catch per hour, and estimate of total catch and variance.

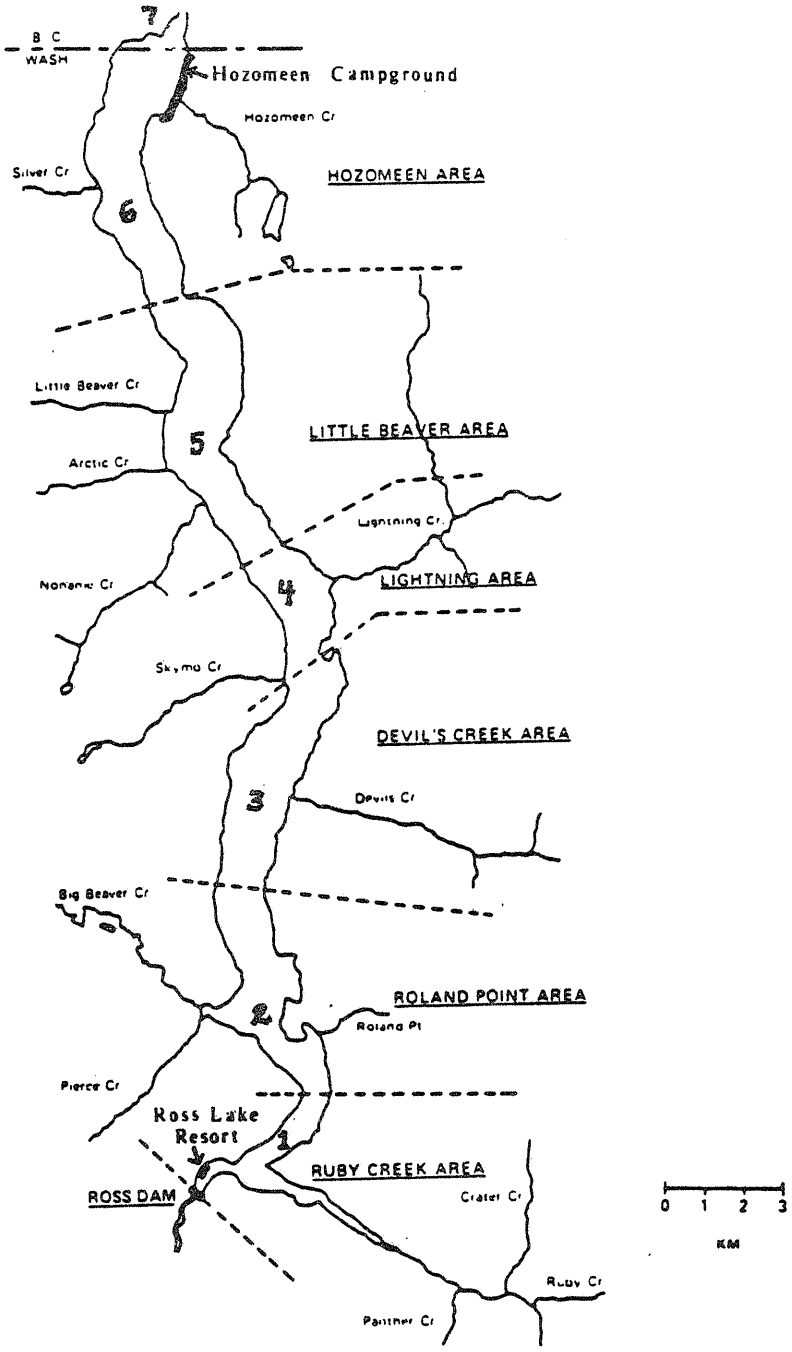

FIGURE 3. Creel census sampling sites and lake survey zones (1 - 7).

Rainbow trout scale and otolith samples, collected during angler interviews, were taken from an area formed by an imaginary line drawn from the rear insertion of the dorsal fin and front insertion of the anal fin and just above the lateral line. Scales were examined under a binocular microscope and two good scales (scales without regenerated areas) were cleaned and mounted sculptured side up on gummed cards. Acetate impressions were made from the mounted scales and photocopies were taken using a 3M "500" reader-printer, which produced photocopies of the scales enlarged 35 times. The scale images were read a minimum of two times to check for precision of the reader. If the two readings agreed, then the scale was considered read, if the two readings did not agree a third reading was done. The sample was discarded as being unreadable if the third examination was not definitive. A sub-sample of otoliths, with scales from the same fish, were read to cross check scale reading accuracy.

1986 WDW Study

Washington Department of Wildlife work on Ross Lake in 1986 included, (1) a season-long creel census on the U.S. and Canadian sides of the reservoir at five separate angler take-out sites, (2) tagging of mature rainbow trout during their spawning run to 7 tributary streams and recording recapture sites in the lake, (3) a biological survey of Big Beaver Creek to look at production potential for rainbow trout, (4) Construction of a temporary channel in Roland Creek around a trout migration barrier at its mouth, and (5) investigation of gold dredging impacts on trout in Ruby Creek drainage.

The creel survey design developed by Western Renewable Resources (Lewynsky, 1986) was followed to estimate the 1986 rainbow trout harvest (Appendix 1). In 1986 the creel surveys took a total of 49 days. The effort data for each site and day type (weekend days and weekday days) were used with the catch data to estimate the total catch for each location during each time period. The fishing season was divided into three time periods (June 14 through July 11, July 12 through August 30, and August 30 through October 31). Five major access areas were scheduled to be sampled four times each period; twice on weekdays and twice on weekends. The locations sampled were: the British Columbia campground (site A), the North Cascades National Park campground and boat launch site (site B1), the middle boat launch at the north end located near the NCNP dock facilities (site B2), the landing (Site C) located at the south end of the Hozomeen NCNP camping facility, and the Ross Lake Resort located at the south end of the lake (site D).

The sampling schedule is given in Appendix 2. The person conducting the survey was to count each boat returning to the sample site during the day and to interview as many fishermen as possible to obtain catch and other data. The effort data for each site and day type (weekend days and weekdays) were used with the catch data to estimate the total catch for each location during each time period. The effort was estimated by multiplying the average number of fishing trips counted on sample days times the number of days in the sample period. The estimated harvest was derived by multiplying the sampled catch per trip times the number of trips. Other data collected included information about party size and composition, length of time fished, type and location of fishing, and species and length of fish captured. A copy of the angler survey form used to record data is shown in Appendix 3.

Rainbow trout scale samples were collected, processed and read following the methods outlined in the 1985 Methods section.

Spawning rainbow trout were captured by hook and line and tagged with numbered Floy anchor tags, between May 22 and June 11, 1986, as they congregated off the mouths of seven Ross Lake tributary streams. At the time of capture the fish were anesthetized, measured, sexed, and scale samples taken before being tagged and released.

A preliminary survey of the lower 4.5 miles of Big Beaver Creek was conducted on October 9, 1986. The survey was accomplished by hiking up the Big Beaver Creek trail to a point approximately 3.5 trail-miles from the stream's confluence with Ross Lake, then floating the stream in rubber rafts back to the lake. During the float trip observations were made on the quality of fish habitat including stream depth, instream cover in the form of organic debris and vegetation, potential spawning gravel, log jams, riparian vegetation, and quality of tributaries for spawning or as sources of spawning gravel.

1987-1988 WDW Studies

In 1987 and 1988 anglers and fish from Ross Lake were sampled only on the opening day of the fishing season. Sampling occurred at the north end at the Hozomeen Campground boat launch (site B1), and at the south end of the lake (Ross Lake Resort). Data collected included number of anglers per boat, method of fishing, fishing duration (completed and incompleted trip anglers), number of fish caught by species, length of fish by species, sexual maturity of catch, and scales for aging.

RESULTS

1985 WDW/B.C. MOE Study

1985 Lake Levels and Access

In 1985 the lowest lake level occurred in the spring and the maximum occurred in the summer. The reservoir reached a minimum level of 1491.45 feet above mean sea level (msl) on April 6, 1985 and a maximum of 1602.16 feet above msl on July 5, 1985. The opening day reservoir level was 1589.43 feet above msl on June 15, 1985; 13 feet below full pool. The 1985 level had significant impact on the opening day fishery in that there was very little reservoir in the Canadian portion of the reservoir and it was difficult for most fishermen to launch and retrieve their boats. The full pool lake level was maintained from June 29 through July 26, 1985. The lake level then receded steadily to 13.5 feet below full pool by the end of the fishing season (October 31, 1985).

Angler access to, and usage of Ross Lake were also impacted by fire closures in Canada from July 23 to August 7, 1985. However, the road to Ross Lake and two B.C. campsites remained open as did the North Cascades National Park campsites.

1985 Creel Census Effort

In 1985 during the 44 day creel census, a total of 1067 anglers were interviewed. During the interviews 2119 fish were sampled.

1985 Angling Effort

Angler effort estimates for Ross Lake in 1985 are shown in Table 1 (from Scott and Peterson, 1986). Angler effort was estimated to be 65,673 hours (14,550 days) from June 15 to October 31, 1985. Angling effort was greatest between the opening day and the July 4th weekend (57%). Effort was distributed on the lake as follows: Canadian Zone 7 (12%), Hozomeen Zone 6 (25%), Little Beaver Creek Zone 5 (13%), Lightning Creek Zone 4 (7%), Devils Creek Zone 3 (10%), Roland Point Zone 2 (21%), and Ruby Creek Zone 1 (12%).

TABLE 1. Estimated angler effort on Ross Lake from June 15 to October 31, 1985.

Period	Reservoir Zones	Angler Hours Midweek	Weekend	Total (S.E.)	Angler Days Total
June-July	7	1675	1976	3651 (654.1)	857
	6	5676	4822	10498 (2812.4)	2464
	5	2978	2803	5782 (1317.6)	1357
	4	1303	1458	2761 (649.5)	648
	3	2512	1527	4040 (1331.5)	948
	2	4467	1874	6341 (1665.3)	1488
	1	2373	1041	3414 (1022.7)	801
Reservoir Total		20984	15502	36487 (4010.9)	8565
August-September	7	2130	2079	4209 (724.6)	871
	6	3263	1906	5169 (949.6)	1070
	5	1087	1612	2699 (425.2)	559
	4	816	702	1518 (328.2)	314
	3	993	1162	2154 (314.8)	446
	2	3823	3028	6851 (836.6)	1418
	1	3029	1437	4466 (605.0)	925
Reservoir Total		15141	11926	27067 (1697.1)	5604
June-September	7	3805	4055	7860	1728
	6	8939	6728	15667	3534
	5	4065	4415	8480	1916
	4	2119	2160	4279	962
	3	3505	2689	6194	1394
	2	8290	4902	13192	2906
	1	5402	2478	7880	1726
Four Month Reservoir Total		36125	27428	63553 (4355.2)	14169
October (All)		795	1325	2120	381
Five Month Reservoir Total		36920	28753	65673	14550

1985 Catch Per Unit Of Effort (CPUE)

Angler catch rates for rainbow trout were highest in June, September and October (Table 2, from Scott and Peterson, 1986). During the mid-summer catch rates for rainbow trout declined. The overall season average CPUE for harvested rainbow only was 0.30 fish per hour (for all species CPUE was 0.33). The B.C. study did not include the June opener at the north or south ends of the lake, nor the south end of the lake prior to WDW initiating its survey on July, 21. Therefore the CPUE figures are low for the month of June in particular. For example, although not used in the MOE consultant's report (Scott and Peterson 1986), the opener on June 15 and 16, 1985, checked at the north end by WDW, showed an opening day harvest catch per hour of 0.83 for all species and 0.81 for rainbow. Harvest rates were also low at the north end in October due to falling water levels and associated boat launching problems.

The rainbow trout harvest rates for the season started out high on the opener, declined in June to 0.39 fish per hour and in July to 0.18, and then began to increase in August (0.24), September (0.37) and October (0.45).

Angler harvest rates for other species were: dolly varden char (0.024 fish per hour, see Table 3 from Scott and Peterson, 1986), eastern brook (0.003), and cutthroat (0.001). These harvest rates when added to the rainbow harvest rates gave all-species harvest rates by month of: June (0.47), July (0.21), August (0.27), September (0.37) and October (0.45). The overall seasonal harvest CPUE for all species combined was 0.33 fish per hour.

TABLE 2. Estimated angler catch rates for rainbow trout from Ross Lake, June 15 to October 31, 1985.

	Number of Anglers Interviewed		Mean Catch per Hour							
			Rainbow Trout Harvested			Rainbow Trout Released			Rainbow Trout Catch	
Period	Midweek	Weekend	Midweek	Weekend	Total(S.E.)	Midweek	Weekend	Total(S.E.)	Catch/Hr	Catch/Day
June	31	274	.192	.407	.385 (.037)	.023	.029	.028 (.011)		
July	172	255	.159	.195	.18 (.015)	.016	.053	.038 (.008)		
Total	203	529	.164	.305	.266 (.018)	.017	.04	.034 (.006)	.25	1.068
August	241	297	.235	.251	.244 (.015)	.062	.047	.054 (.008)		
September	171	245	.451	.306	.366 (.019)	.152	.129	.138 (.014)		
Total	412	542	.325	.276	.297 (.012)	.099	.084	.09 (.008)	.396	1.912
October	62	94	.265	.571	.449 (.030)	.199	.081	.128 (.036)	.58	3.3
Five Month Season	677	1165	.271	.313	.298 (.010)	.084	.064	.071(.006)	.335	1.51

TABLE 3. Angler catch rates for dolly varden char from Ross Lake, June 15 to October 31, 1985.

Period	Number of Anglers Interviewed		Mean Catch per Hour							
			Dolly Varden Harvested			Dolly Varden Released			Dolly Varden Catch	
	Midweek	Weekend	Midweek	Weekend	Total(S.E.)	Midweek	Weekend	Total(S.E.)	Catch/Hr	Catch/Day
June	31	274	.064	.084	.082 (.019)	0	.001	.001 (.0008)		
July	172	255	.047	.022	.032 (.010)	0	.002	.001 (.0012)		
Total	203	529	.05	.054	.053 (.010)	0	.002	.001 (.0003)	.053	.224
August	241	297	.014	.007	.01 (.003)	.001	0	0 (.0005)		
September	171	245	0	0	0	0	0	0		
Total	412	542	.008	.004	.006 (.002)	.001	0	0 (.0002)	.007	.033
October	62	94	0	0	0	0	0	0	0	0
Five Month Season	677	1165	.02	.026	.024 (.004)	.001	.001	.001 (.0001)	.031	.142

1985 Catch and Harvest Estimates

Rainbow trout comprised 89.0 percent of the harvested fish from Ross Lake in 1985. Dolly varden made up 10 percent of the harvest, and cutthroat and eastern brook the remaining 1 percent.

The 1985 estimate of rainbow trout harvest was 18,503 fish (Table 4, from Scott and Peterson, 1986). In addition, 2101 dolly varden char were caught and 98% (2055) of these fish were retained. Most released fish were either small, in some cases below the minimum size limit (6 inches in U.S., and 8 inches in B.C.), or were sexually mature fish. Other species harvested included 421 eastern brook char and 24 cutthroat. The total harvest for 1985, for all species, was estimated to be 21,007 fish.

TABLE 4. Estimated total numbers of trout and char harvested and released, Ross Lake, June to October, 1985.

Period	Harvested			Released			Total Catch		
	Midweek	Weekend	Total(S.E.)	Midweek	Weekend	Total(S.E.)	Midweek	Weekend	Total
			Rainbow Trout						
June-July	3441	4728	8170 (1257.6)	357	620	977 (272.3)	3798	5348	9146
August-September	4921	3291	8212 (600.4)	1499	1002	2501 (258.2)	6420	4293	10713
June-September	8362	8019	16382	1856	1622	3478	10218	9641	19859
October									2120
			Dolly Varden						
June-July	1049	837	1886 (415.8)	0	31	31 (12.9)	1049	868	1917
August-September	121	48	169 (43.2)	15	0	15 (4.1)	136	48	184
June-September	1170	885	2055	15	31	46	1185	916	2065
October									0
			Brook Trout						
June-July	336	47	382 (156.5)						
August-September	15	24	39 (21.9)						
June-September	351	71	421						
October			0						
			Cutthroat Trout						
June-July	0	0	0						
August-September	0	24	24 (16.3)						
June-September	0	24	24						
October			0						

1985 Age of Catch

The age of the rainbow trout in the sport catch in 1985 ranged from age 1 to age 6 (Table 5) based on the reading of 538 randomly collected scale samples. Age 1 fish comprised 17.5% of the harvest, age 2 (36.4%), age 3 (28.5%), age 4 (12.8%), age 5 (4.0%) and age 6 (0.8%). The season's most abundant age class in the fishery (age 2) was not always the dominant fish each month.

Age 3 rainbow were dominant in June, then declined in abundance through the summer months but increased slightly in September and October. Age two fish increased in contribution to the catch in July and August. Age 1 trout, absent from the fishery in June, increased in numbers caught as summer progressed and on into the fall. Age 5 fish maintained a relatively constant low contribution to the catch during the fishing season, but with a slight increase in late summer and fall. Age 6 rainbow contributed to the fishery only in September and October, primarily at the north end of the lake.

TABLE 5. Percent age composition of Ross Lake angler catch, rainbow trout, by month, 1985.

	JUNE		JULY		AUG		SEPT		OCT		TOTALS	
AGE	n	%	n	%	n	%	n	%	n	%	n	%
ONE	0	0	3	4.1	22	17.2	44	23.7	35	22.9	104	17.5
TWO	15	27.8	42	57.5	53	41.4	56	30.1	50	32.7	216	36.4
THREE	26	48.1	21	28.8	30	23.4	51	27.4	41	26.8	169	28.5
FOUR	9	16.7	6	8.2	17	13.3	26	14.0	18	11.8	76	12.8
FIVE	4	7.4	1	1.4	6	4.7	6	3.2	7	4.6	24	4.0
SIX	0	0	0	0	0	0	3	1.6	2	1.3	5	0.8

1985 Length of Catch

The 1985 average fork length of rainbow trout, derived from 1469 randomly sampled sport caught fish, was 275.4 mm, or 10.8 inches. Age 1 fish averaged 220.7 mm fork length (8.7 inches), age 2 averaged 259.6 mm (10.2 inches), age 3 averaged 302 mm (11.9 inches), age 4 fish averaged 334.3 mm (13.2 inches), age 5 fish averaged 346.9 mm (13.7 inches), and age 6 fish averaged 393.6 mm (15.5 inches). These data, and the size range for each age class are shown in Table 6.

TABLE 6. Ross Lake rainbow trout ages from creel census samples, June 15 to October 31, 1985.

			LENGTH (MM)		
AGE	NUMBER	PERCENT	AVG	RANGE	
0	0	0.0	--	--	--
1	104	17.5	220.7	158	272
2	216	36.4	259.6	183	337
3	169	28.5	302.0	207	369
4	76	12.8	334.3	275	378
5	23	3.9	346.9	307	384
6	5	0.8	393.6	374	424
TOTAL	593	100.0			

The range in size for any one age class can, in part, be attributed to the span of the sampling season. For example, the age 3 fish averaged 285.4 mm in June and grew to an average size of 310.4 mm by October as seen in Table 7. Other age classes, such as age 4 grew very little over the summer months, which is not uncommon for older fish, particularly those that have spawned at the beginning of summer. Although the age 1 and 2 rainbow trout appear not to have grown over the summer, and even decline in size (Figure 4), this is a data artifice caused by increasing numbers of small fish entering the fishery from the streams and near shore rearing areas. Their small size kept the average size down and contributed to the wide size range for those two age groups. Another reason the size range for any one age group was broad was due to length of stream residency prior to entry into the lake. The pattern of stream growth was detectable on some scales (fewer and more closely spaced circuli before the annulus for stream compared to lake residency) and those fish were generally smaller at a given age than a fish that was reared the same period of time in the lake only.

TABLE 7. Ross Lake rainbow trout lengths (mm), by age class, by month, for 1985 Ross Lake angler catches.

	AGE											
	ONE		TWO		THREE		FOUR		FIVE		SIX	
MONTH	n	AVG	n	AVG	n	AVG	n	AVG	n	AVG	n	AVG
JUN	0		2	269.9	26	285.4	9	324.9	4	354.0	0	
JUL	3	218.0	42	254.5	21	302.0	6	341.7	1	360.0	0	
AUG	22	213.0	53	252.0	30	295.9	17	339.8	6	358.2	0	
SEP	44	219.4	56	260.3	51	307.2	26	329.3	6	325.8	3	389.0
OCT	35	227.5	50	268.2	41	310.4	18	338.4	7	335.3	2	400.5
SEASON	104	220.7	203	259.0	169	302.0	76	334.3	24	342.8	5	393.6

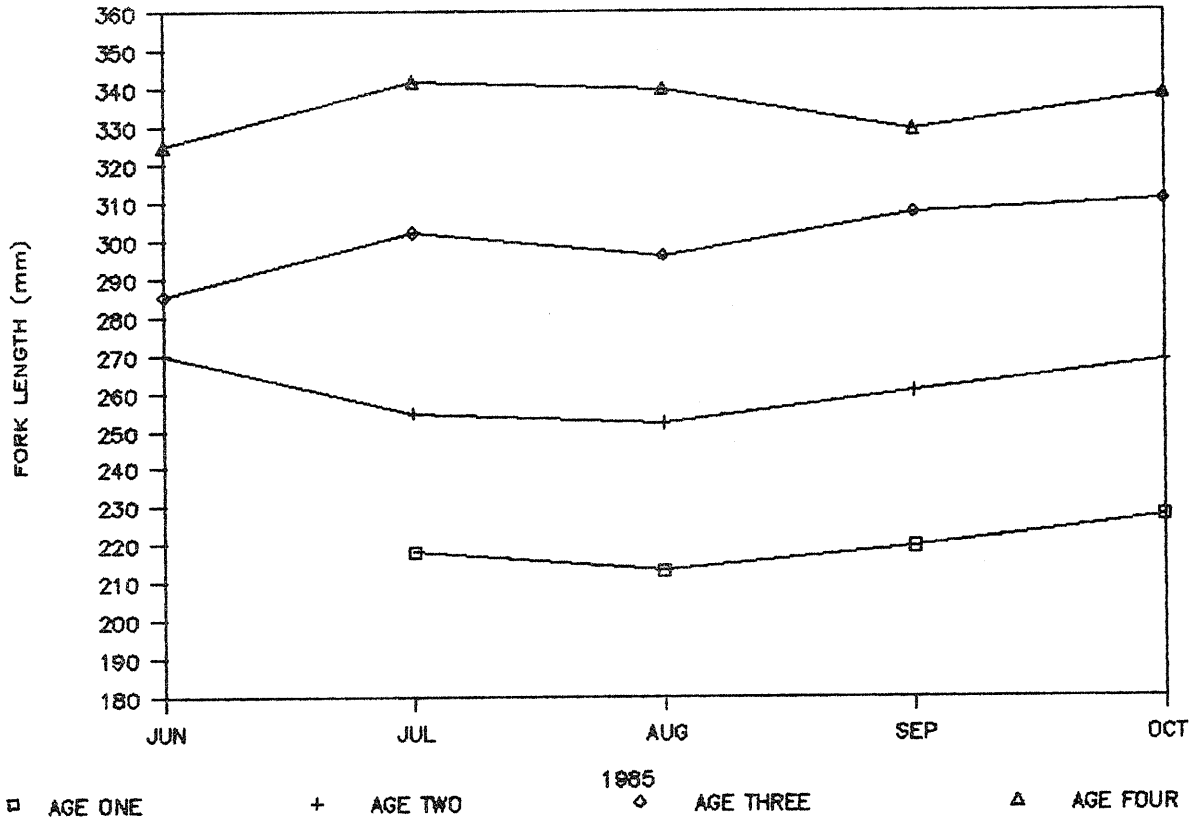

FIGURE 4. Average sizes of age 1 through 4 rainbow trout as they entered the catch, June to October, 1985.

The length-frequency distribution of rainbow trout caught on opening day, June 15, 1985, at the north end of Ross Lake is shown in Figure 5. The length-frequency distribution for all harvested rainbow trout in 1985, with the length-frequency distribution by month, from June to October, are shown in Figure 6.

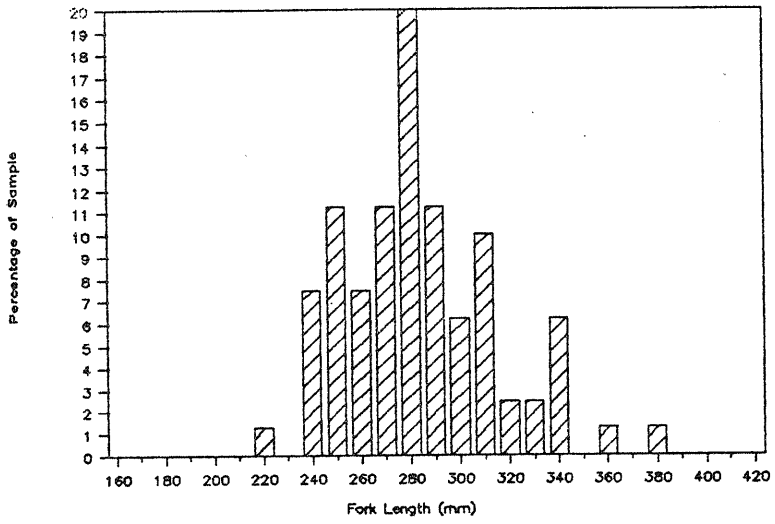

FIGURE 5. Length-frequency distribution, rainbow trout, north end Ross Lake, opening day, 1985.

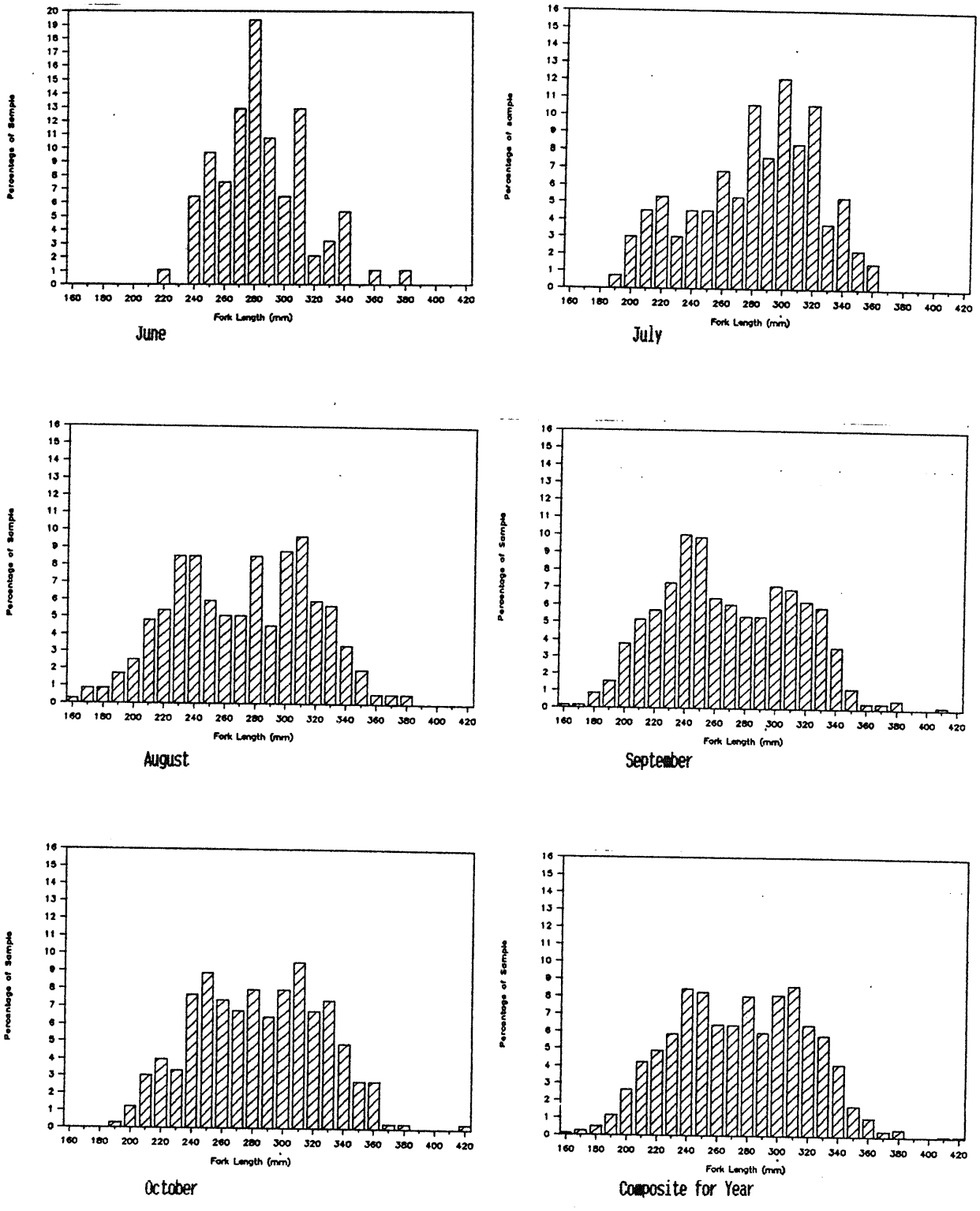

FIGURE 6. Length-frequency distribution, rainbow trout, by month, 1985.

The dominance of the larger, age 3 fish early in the season, and their decline in relative percent contribution can be seen as well as the large increase in relative contribution of the smaller age 1 and 2 fish (<249 mm) in July and August.

1985 Location of Catch

Not unexpectedly, most of the rainbow trout catch was from the two zones of the lake which experienced the greatest fishing pressure; the Hozomeen (Zone 6) and Roland Point (Zone 2). Figure 7, from Scott and Peterson, 1986, displays actual, not expanded, catch data.

Approximately 12 percent of the angler effort occurred on the Canadian portion of Ross Lake and 88 percent on the U.S. side of the International Border. In 1985, 57 percent of the angling effort occurred from Lightning Creek north to the mouth of the Canadian Skagit River and 43 percent south of that area: Canadian Zone (12%), Hozomeen Zone (25%), Little Beaver Zone (13%), Lightning Creek Zone (7%), Devils Creek Zone (10%), Roland Point Zone (21%), and Ruby Creek Zone (12%).

No data was collected from the zones of the lake south of Lightning Creek between June 15 and July 21. Had that data been collected, a higher portion of the catch would have been recorded for the south end of the lake zones (1-3).

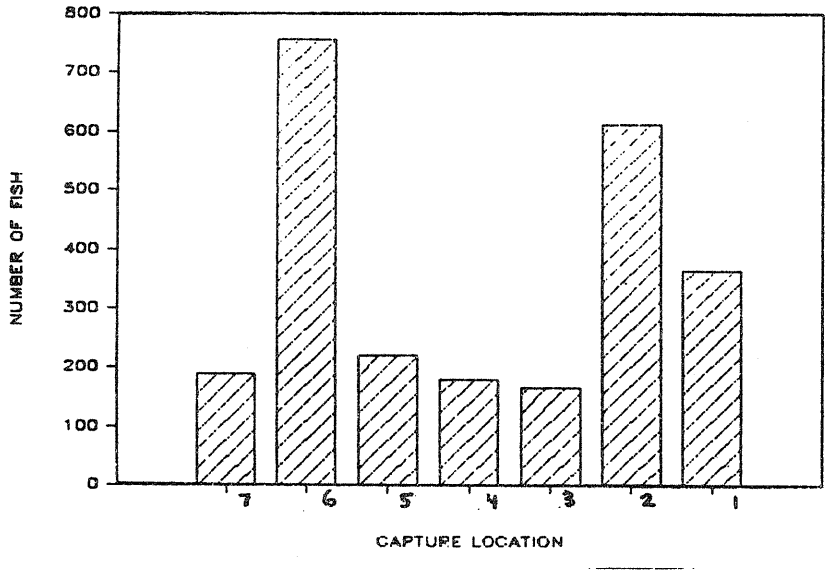

FIGURE 7. Spatial distribution of rainbow trout catch reported by anglers, Ross Lake, 1985.

1985 Angler Profiles

On Ross Lake, 83.6% of the anglers interviewed were from Washington State, 12.8% were from the lower British Columbia mainland, 1.5% other areas of B.C., other Canadian provinces (0.2%) and other states (1.9%). Approximately 80% of the anglers held a Washington fishing license, 12% a B.C. license, and 3% were in possession of both licenses.

Anglers fishing Ross Lake used a variety of techniques but trolling flashers with bait was the most popular (80%). Approximately 16 percent of the anglers chose to still-fish with bait; the majority at the north end.

1986 WDW Study

1986 Lake Levels and Access

The minimum level in 1986 of 1539.40 feet above msl occurred on February 23 and the maximum of 1602.46 feet above msl on July 21. The opening day reservoir level was 1599.02 feet above msl on June 14, 1986; 3 feet below full pool. The reservoir levels in 1986 remained above the 1600 foot level from June 19 through September 10.

1986 Creel Census Effort

Creel Census: In 1986 a total of 1876 anglers were interviewed on 49 days of sampling.

1986 Angling Effort

Table 8 shows angling effort in terms of angling trips, which is not the same as number of anglers. Angler trips, for the 1986 census, was defined as boat trips. A total of 8239 boat trip days was estimated for the 1986 season. The average boat trip lasted 3.63 hours. At an average of 2.2 anglers per boat, the total angler trips was estimated to be 18,125 for 1985. The greatest angling effort (2828 boat trips) was recorded at the Ross Lake Resort (Site D) followed by the Hozomeen boat launch (Site B1) with 2598 boat trips. Significant numbers of boat trips (2140) also originated out of the Canadian campground (Site A).

TABLE 8. Estimated effort and harvest by weekends and weekdays, Ross Lake 1986.

LOC. *		TIME PERIOD ONE JUN 14 - JUL 11 EFFORT	HARVEST	TIME PERIOD TWO JUL 12 - AUG 30 EFFORT	HARVEST	TIME PERIOD THREE AUG 31 - OCT 31 EFFORT	HARVEST
A	1	126	279	252	321	459	566
	2	171	361	525	456	607	793
B1	1	369	1677	357	505	666	1946
	2	190	639	542	766	473	1940
B2	1	90	414	35	99	-	-
	2	95	352	140	140	-	-
C	1	-	-	-	-	136	643
	2	-	-	-	-	176	1264
D	1	201	919	322	713	405	1004
	2	228	891	840	1636	832	4200
TOTALS		1470	5532	3013	4636	3754	12356

* The locations are sampling locations from north to south and the number "1" is for weekend days and "2" is for weekday days.

1986 Catch Per Unit Of Effort (CPUE)

The opening day, June 14, 1986 catch per unit of effort for all species was 0.83 fish per hour at the north end and 0.76 fish per hour at the south end of Ross Lake. The overall CPUE for all species for the total lake declined from June (0.45), through the summer months, July (0.29) and August (0.23), then increased in September (0.37) and October (0.49). The overall season CPUE was 0.41.

1986 Catch and Harvest Estimates

The harvest species composition was (97.7%) rainbow trout, 56 (1.9%) dolly varden, 8 (0.29%) eastern brook, and 1 cutthroat trout.

The estimated rainbow trout harvest in 1986 was 22,524 fish (see Table 9 for estimates by time period, location, and day types). Total harvest of all species was estimated to be 23,054.

TABLE 9. 1986 estimated rainbow trout harvest by location, day type, and time period.

TIME PERIOD ONE JUNE 14 - JULY 11		TIME PERIOD TWO JULY 12 - AUGUST 30		TIME PERIOD THREE AUGUST 31 - OCTOBER 31	
CANADA WEEKENDS	279	CANADA WEEKENDS	321	CANADA WEEKENDS	566
CANADA WEEKDAYS	361	CANADA WEEKDAYS	456	CANADA WEEKDAYS	793
B2 WEEKENDS	414	B2 WEEKENDS	99	C WEEKENDS	643
B2 WEEKDAYS	352	B2 WEEKDAYS	140	C WEEKDAYS	1264
HOZOMEEN WEEKENDS	1677	HOZOMEEN WEEKENDS	505	HOZOMEEN WEEKENDS	1946
HOZOMEEN WEEKDAYS	639	HOZOMEEN WEEKDAYS	766	HOZOMEEN WEEKDAYS	1940
RESORT WEEKENDS	919	RESORT WEEKENDS	713	RESORT WEEKENDS	1004
RESORT WEEKDAYS	891	RESORT WEEKDAYS	1636	RESORT WEEKDAYS	4200
TIME PERIOD ONE ESTIMATED CATCH	5532	TIME PERIOD TWO ESTIMATED CATCH	4636	TIME PERIOD THREE ESTIMATED TOTAL	12356
		1986 ESTIMATED TOTAL RAINBOW TROUT HARVEST			22524

1986 Age of Catch

A total of 730 rainbow trout scale samples from 1986 were read for age determination. Figures 8 through 11 are photocopies (35X) of Ross Lake rainbow trout scales. Various features used to age the scales are noted in the margins. Table 10 shows the age compositions by month, of the aged, sport caught rainbow trout only, for 1986. Like 1985, the 1986 samples show an increasing percentage of age 1 and 2 fish in the sample as the season progressed and a decreasing number and percentage of age 3 fish. Age 3 rainbow were most abundant in the catch (39.8%) followed by age 2 (28.1%), age 4 (19.0%), age 1 (8.3%), age 5 (4.2%), and age 6 (0.6%).

TABLE 10. Percent age composition of Ross Lake angler caught rainbow trout, 1986.

	MONTH											
	JUN		JUL		AUG		SEP		OCT		TOTALS	
AGE	n	%	n	%	n	%	n	%	n	%	n	%
ONE	0	0	2	2.0	8	20.0	22	18.8	11	31.4	43	8.3
TWO	43	27.6	28	27.5	30	48.2	37	31.6	8	22.9	146	28.1
THREE	74	47.4	50	49.0	44	27.3	29	24.8	10	28.6	207	39.8
FOUR	33	21.2	18	17.6	22	15.5	21	17.9	5	14.3	99	19.0
FIVE	6	3.8	4	3.9	5	5.5	6	5.1	1	2.9	22	4.2
SIX	0	0	0	0	1	0	2	1.7	0	0	3	0.6

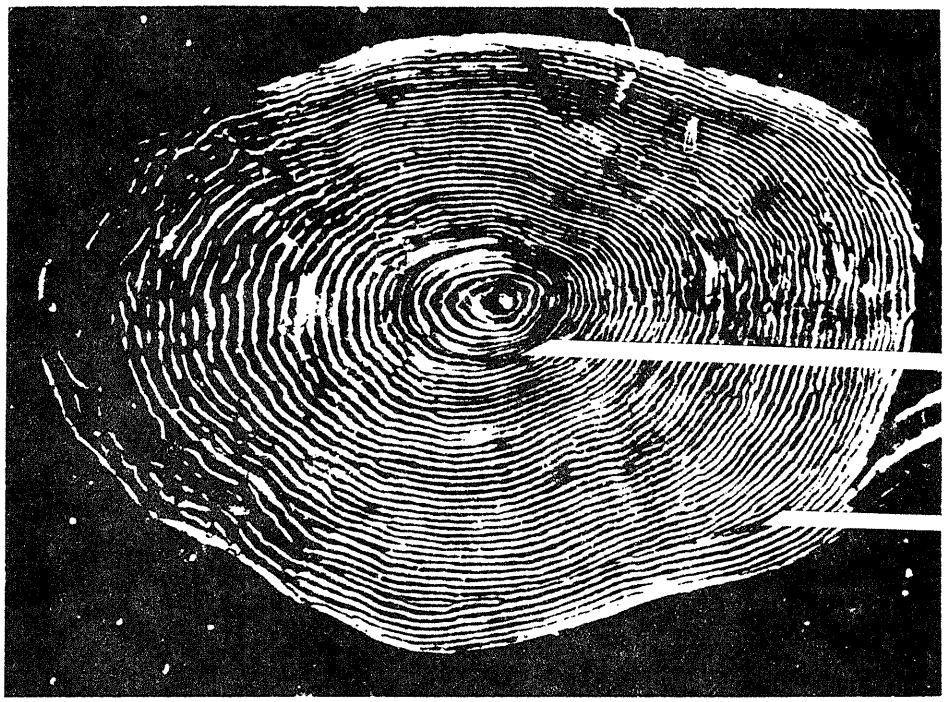

FIGURE 8. Ross Lake rainbow trout scale: age 2, 282 mm, immature female.

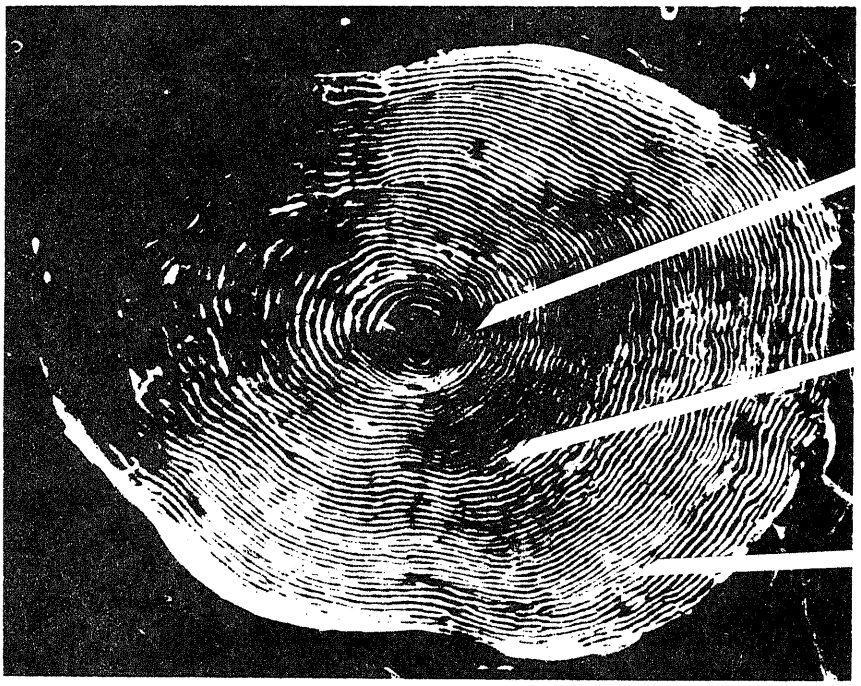

FIGURE 9. Ross Lake rainbow trout scale: age 3, 285 mm, immature female.

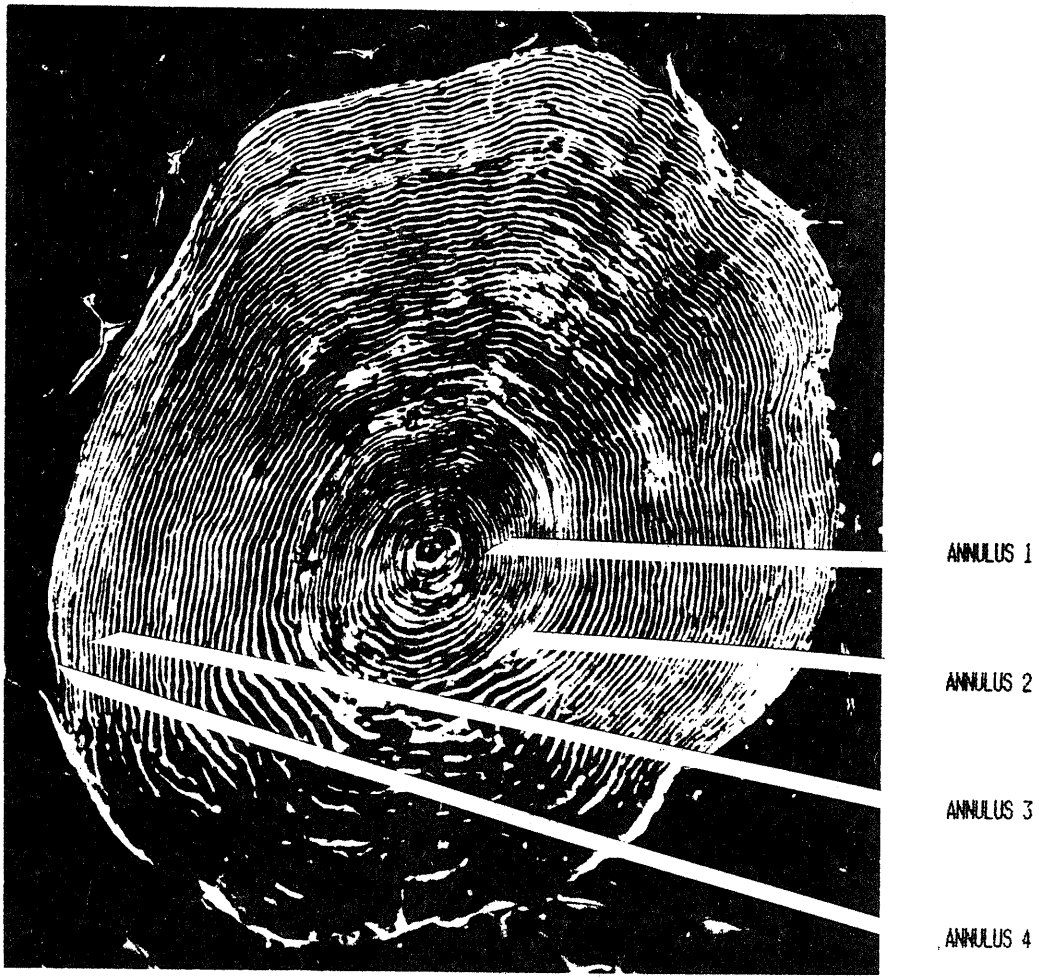

FIGURE 10. Ross Lake rainbow trout scale: age 4, 340 mm, kelt female.

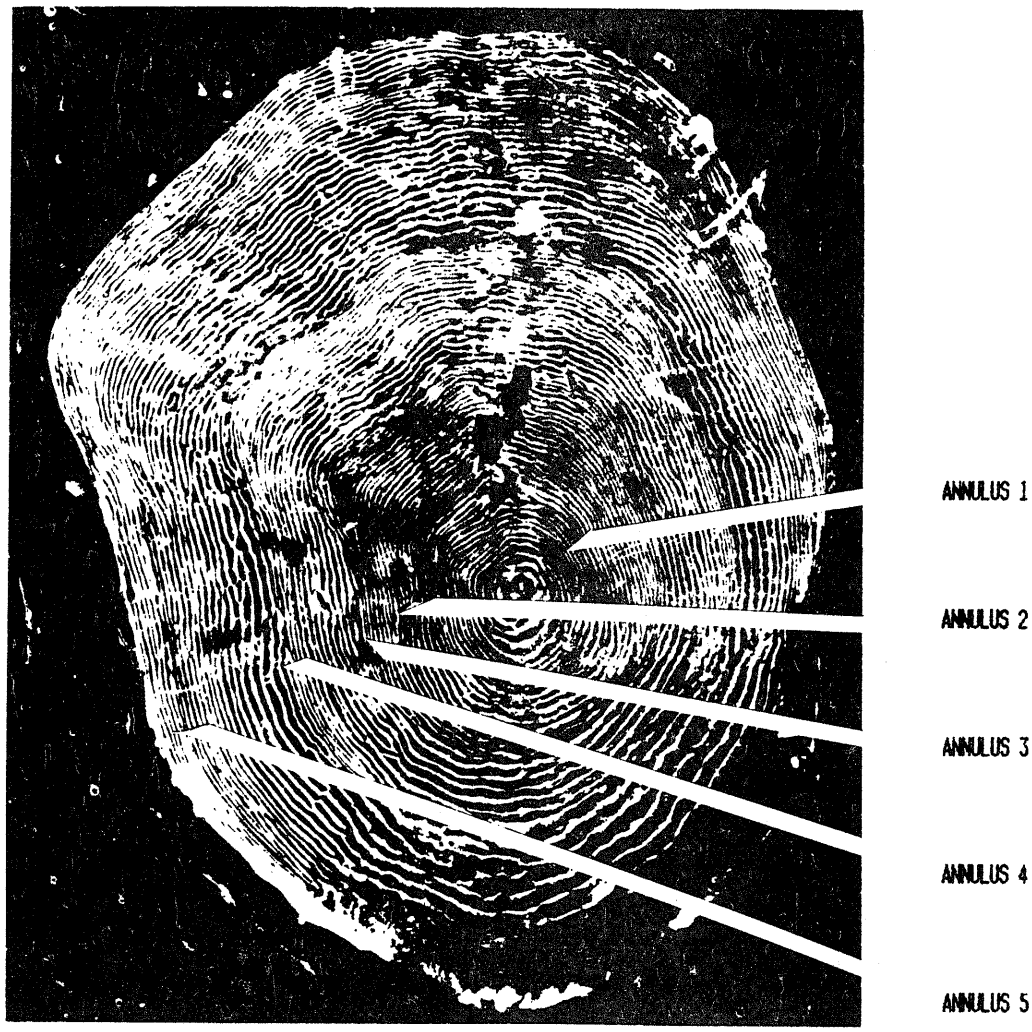

FIGURE 11. Ross Lake rainbow trout scale: age 5, 355mm, immature male.

1986 Length of Catch

A total of 1775 rainbow trout was measured in 1986. The average size of angler caught rainbow trout in 1986 was 294.2 mm (11.6 inches). The length-frequency distribution of rainbow caught on opening day, June 14, is shown in Figure 12; a composite of Ross Lake north and south end catches. At the north end the average size of trout on the opener was 308 mm (565 measured). At the south end average size was 295.3 mm (295 measured).

Growth of trout in Ross Lake throughout the summer, as reflected by the size of fish in the angler catches, is shown in Table 11 and Figure 13.

Age 1 fish increased in size an average of 30 mm between July and October. These new recruits to the fishery did not appear in angler catches until July.

Age 2 fish appeared to increase in size from June to July by 5 mm, then decrease in average size in August by 19 mm, then increase between August and September by 19 mm, the decrease again in October. The actual growth rate of the age 2 fish did not in reality decrease; the declines were caused by smaller near shore and stream resident trout entering the fishery for the first time. The recruitment to the fishery of smaller fish, which early in the summer were near shore and unavailable can be seen (fish < 260 mm) in monthly length-frequency graphs constructed from 1986 data (Figure 14). Table 12 shows this as a declining average size of rainbow as the summer progresses.

The age 3 fish also showed an apparent drop in average size in August, but that was primarily due to larger fish of that age class leaving the lake to enter tributary streams on feeding runs. The age 3 fish showed an overall size increase between June and October of 24 mm.

Age 4 rainbow trout showed little growth over the summer based upon data gathered from angler catches.

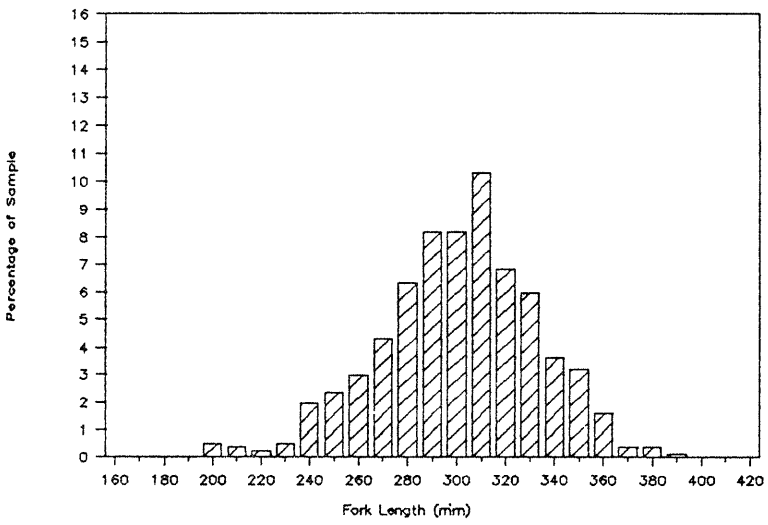

FIGURE 12. Length-frequency distribution of rainbow trout caught on opening day, 1986, from the north and south ends of Ross Lake.

TABLE 11. Ross Lake rainbow trout lengths (mm), by age class, by month, for 1986 Ross Lake angler catches.

	AGE ONE		AGE TWO		AGE THREE		AGE FOUR		AGE FIVE		AGE SIX	
	n	AVG	n	AVG	n	AVG	n	AVG	n	AVG	n	AVG
JUN	0	--	43	262.5	74	302.5	33	338.6	6	361.7	0	---
JUL	2	201.5	28	269.1	50	303.9	18	328.8	4	345.0	0	---
AUG	8	208.4	30	250.3	44	297.6	22	337.8	5	351.0	1	365.0
SEP	22	217.8	37	269.0	29	322.2	21	335.9	6	335.5	2	387.5
OCT	10	231.3	8	258.5	10	326.9	5	335.0	1	395.0	0	
SEASON	42	218.4	146	262.7	207	305.7	99	335.9	22	350.6	3	380.0

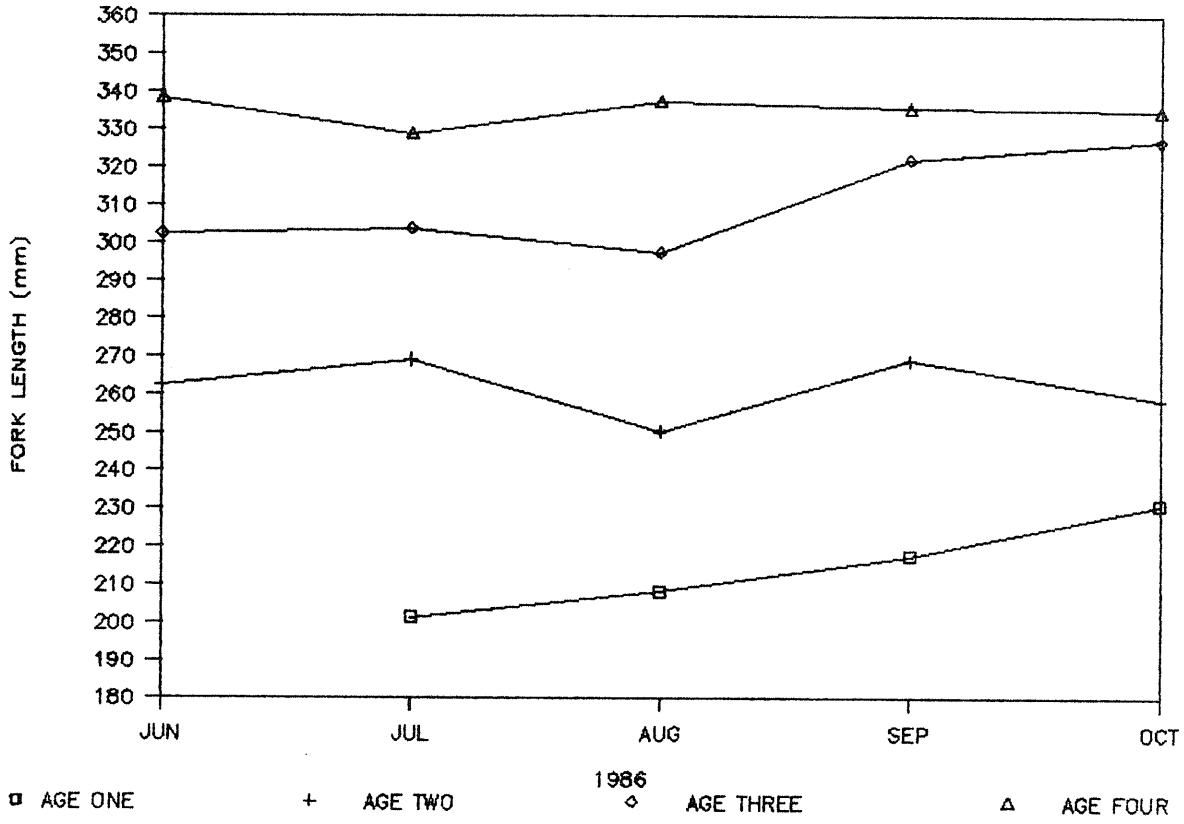

FIGURE 13. Average lengths of angler caught rainbow trout, age 1 - age 4, by month, 1986.

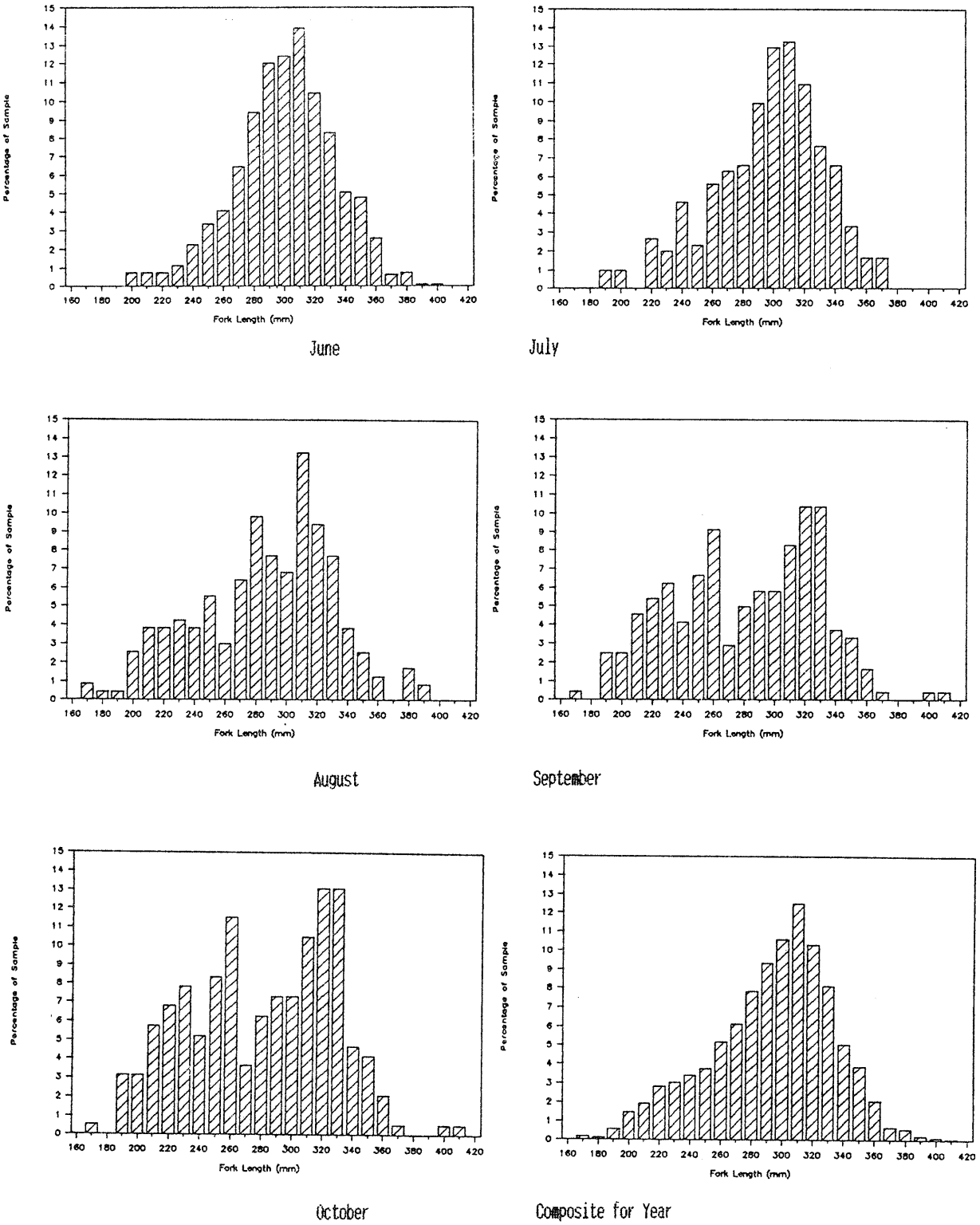

FIGURE 14. Length-frequency distribution histograms, by month, for rainbow trout in angler catches, Ross Lake, 1986.

TABLE 12. Average lengths by month of angler caught trout from Ross Lake, 1986.

Month	Average Length (mm)	No. Measured
June	302	807
July	297	302
August	287	234
September	282	241
October	283	191

The 1986 seasonal average length and size ranges of all angler caught, tagging study, and electro-shocker caught rainbow trout are shown in Table 13.

The zero age rainbow and small age 1 fish in Table 13 were from electro-shocker sampling which captured fish not normally available to the fishery. A total of 30 age 0 fish were captured along the shoreline of the north end of the lake on October 21, 1986. These 30 fish averaged 65.2 mm in fork length. An additional nine age 1 fish were captured by electro-shocking the same areas and averaged 144.7 mm in fork length. The lengths of ages 2 through 6 shown in Table 13 are in close agreement (5 mm) with aged angler caught samples shown in Table 11.

TABLE 13. Ross Lake rainbow trout ages from creel census and electroshocking samples, June 14 to October 31, 1986.

AGE	NUMBER	PERCENT	AVG.LEN(MM)	MIN	MAX
0	30	4.1	65.2	45	100
1	61	8.4	194.6	99	270
2	207	28.4	257.2	157	328
3	251	34.4	301.8	218	380
4	146	20.0	333.4	286	403
5	32	4.4	349.0	295	395
6	3	0.4	380.0	365	409
TOTAL	730	100.0			

1986 Sex of Catch

Based upon a random sample of 34 rainbow trout from the north end catch, 62% of the opening day catch were females and 38% were males.

1986 Sexual Maturity of Catch

North End, 1986

Most of the fish sampled on opening day at the north end of Ross Lake were sexually immature (94%). A randomly gathered sub-sample of 34 fish was checked internally for gonadal development. Twenty-one (21) were females and of these 19 were immature and 2 were mature (kelts). The 13 males were all immature (Table 14). The average size of the opening day caught immature age 3 females (294 mm) and immature age 3 males (301 mm) was very close to the average size of all age 3 fish caught in June (303 mm); making it impossible to separate mature and immature age 3 fish on the basis of size alone.

TABLE 14. Sexual maturity of female and male rainbow trout, by age, Ross Lake opening day, 1986.

SEX	AGE	NUMBER	AVG	RANGE	
Females	2	4	278.0	220	313
Immature	3	14	293.7	235	328
	4	1	320.0	---	
Females					
Mature	4	2	327.5	320	335
Males	2	2	289.0	268	310
Immature	3	10	300.5	285	319
	4	1	314.0	---	

1986 Location of Catch

The locations of catch and effort point out differences between the Canadian and American fisheries. Those anglers interviewed at the Canadian sample site did all their fishing in Zone 7 (the portion of the reservoir in British Columbia), while the anglers

interviewed at the remaining sample sites tended to fish a much larger portion of the reservoir. Table 15 shows the catch and number of anglers for each lake area by sample site and month.

The angler effort distribution in 1986, by lake zone, was: Canadian Zone 7 (19%), Hozomeen Zone 6 (37%), Little Beaver Zone 5 (10%), Lightning Creek Zone 4 (3%), Devils Creek Zone 3 (6%), Roland Point Zone 2 (10%), and Ruby Creek Zone 1 (15%).

TABLE 15. Rainbow trout catches and angler numbers by sampling sites and months, for the different lake zones fished in 1986.

		CANADA					HOZOMEEN					B 2		C	RESORT				
		JUN	JUL	AUG	SEP	OCT	JUN	JUL	AUG	SEP	OCT	JUN	JUL	SEP OCT	JUN	JUL	AUG	SEP	OCT
ZONE																			
7	RB	53	30	57	98		27	3	5	3		1							
	ANG.	47	44	91	136		7	7	15	6		1							
6	RB						540	69	56	220	37	31	65	145					
	ANG.						211	87	109	145	19	20	51	64					
5	RB						91	51	16	41	1	19	20	98		10			
	ANG.						40	32	20	22	2	11	17	31		2			
4	RB						5		10	10	7	27		16	28	2	6	8	
	ANG.						2		5	11	2	7		14	5	4	4	6	
3	RB													15	63	67	42	38	8
	ANG.													8	25	26	24	23	2
2	RB														145	32	63	70	20
	ANG.														49	26	52	52	6
1	RB														126	32	82	101	
	ANG.														53	45	95	81	

1986 Angler Profiles

The vast majority (over 99%) of the anglers at Ross Lake used boats in 1986. The most popular angling methods were trolling with flashers and bait (49.1%), trolling with flashers and lures (25.1%), and still-fishing with bait (21.3%). The types of tackle/methods are determined by access and/or the physical characteristics of the reservoir. The favored Canadian fishing technique was still-fishing with bait, usually over the submerged Skagit River bed. The north end American fishery favored trolling with lures and/or bait, or still-fishing with bait. At the

northern most end of the U.S. portion of the lake much of the effort was concentrated over the submerged river bed or around the creek mouths. South of Hozomeen, the primary fishing method was trolling near the surface, although some still-fishing occurred near the mouths of streams. There was a down-lake camper fishery which was predominantly a boat fishery. Finally there was the Ross Lake Resort fishery. This was mostly south end, mid-lake trolling with bait and/or lures. The number of anglers using each gear type and the number of fish captured by each gear type is summarized by sampling location in Table 16. There was a close correlation between percent gear type chosen and percent of harvest by gear type: approximately 21 percent used bait and harvested 20 percent of the fish; 49 percent trolled flashers with bait and harvested 55 percent of the fish; and 25 percent used flashers with lures and harvested 24 percent of the fish.

TABLE 16. Rainbow trout catch and angler gear type used by sampling location, June - October, 1986.

	CANADA	HOZOMEEN	B-2	SITE C	RESORT	TOTALS	PERCENT
GEAR TYPES							
		NUMBER OF ANGLERS USING					
b b	220	164	5	5	6	400	21.3
b f	21	4	0	0	4	29	1.5
b l	5	2	0	0	0	7	0.4
b Tb	32	320	60	51	459	922	49.1
b Tf	12	18	1	0	2	33	1.8
b Tl	17	234	46	61	113	471	25.1
s b	8	1	0	0	0	9	0.5
s f	2	1	0	0	0	3	0.2
s l	0	1	0	0	0	1	0.1
t f	1	0	0	0	0	1	0.1
TOTALS	318	745	112	117	584	1876	100.0
GEAR TYPES							
		NUMBER OF TROUT CAPTURED BY GEAR TYPE					
b b	174	371	5	0	7	557	19.8
b f	11	2	0	0	0	13	0.5
b l	1	0	0	0	0	1	0.0
b Tb	32	511	94	132	770	1539	54.7
b Tf	4	20	0	0	1	25	0.9
b Tl	10	294	63	142	165	674	23.9
s b	2	0	0	0	0	2	0.1
s f	4	0	0	0	0	4	0.1
s l	0	0	0	0	0	0	0.0
t f	0	0	0	0	0	0	0.0
TOTALS	238	1198	162	274	943	2815	100.0

b b Boat, still-fishing with bait
b f Boat, still-fishing with flies
b l Boat, still-fishing with lures
b Tb Boat, trolling with bait
b Tf Boat, trolling with flies
b Tl Boat, trolling with lures
s b Shore, still-fishing with bait
s f Shore, still-fishing with flies
s l Shore, still-fishing with lures
t f Float tube, still-fishing with flies

1986 Additional Data

1986 Tagging Sexually Mature Rainbow Trout: Sexually mature rainbow trout were tagged as they collected near tributary mouths prior to spawning. Pre-season fish tagging occurred on May 22, June 4, 9, 10, and 11 (Table 17). A total of 160 tags were applied to fish at the mouths of Roland, Dry, Pierce, Lightning, Devils, Arctic, and Thursday Creeks. A total of 17 tags (10% of total) were recovered from fishermen, most within 30 days after tagging (ranged from 8 to 120 days). Few of the fish were recaptured more than 5 miles from the release sites and none further north than Arctic Creek. Recaptured fish were; females (8 recaptured out of 49 tagged) 16% recapture, males (6 recaptured out of 58 tagged) 10% recapture, and unknown sex (3 recaptured out of 46 tagged) for a 7% recapture. All but one of the recaptured males were caught in the immediate vicinity of their respective tagging sites.

TABLE 17. Ross Lake tagged rainbow trout, May 22 - June 11, 1986.

SEX	AGE	NUMBER	AVG.LEN.	MIN	MAX
UKNOWN	2	23	239.1	185	274
	3	11	267.0	227	301
	4	8	312.6	288	332
	5	4	318.3	295	339
FEMALE	2	7	259.1	232	280
	3	13	295.1	253	345
	4	27	330.3	291	365
	5	2	347.5	347	348
MALE	2	28	247.3	157	279
	3	17	282.0	252	329
	4	10	330.8	286	357
	5	3	368.3	357	379

1986 Gold Dredging: A major controversy developed in 1986 concerning opening Ruby Creek drainage to gold dredging by non-claim holders. From the 1986 field work and data on fry emergence collected in 1976 it was determined that unrestricted dredging would seriously harm the trout production, primarily through spawner disturbance and removal of eggs from their redds during hydraulic suction dredging operations. Permits issued to non-claim holders in 1986 were rescinded by WDW in early February, 1987. The area

was reopened to only claim holders, to operate gold dredges between August 15 and September 30 each year, using 2 1/2 inch nozzle dredges, with a cautionary note to avoid spawning gravels as described in all permits.

Migration Blockages: On June 9, 1986 it was noted that a large Seattle City Light boom log was lying perpendicular to the mouth of Roland Creek and had been there long enough to become embedded in the bank gravels. Stream gravels had backed up behind it to the top of the boom log. This condition created a waterfall and an upstream migration barrier for spawning trout. Several thousand trout were milling around in the lake in front of the stream mouth. On June 10, 1986 a diversion channel around the barrier was hand constructed and the stream was diverted into the new watercourse. On June 13th, 2500 to 3000 rainbow trout were observed to have used the by-pass and be spawning in the lower 300 meters of the creek.

A survey of the stream mouths of the other Ross Lake tributaries revealed that Dry Creek was the only other stream to have a partial or complete blockage due to driftwood. In the case of Dry Creek it was determined that the interlocking driftwood was only a partial barrier and that its removal would cause a significant loss of upstream spawning gravels as the creek channel tried to reach stability after jam removal. For those reasons it was determined that the driftwood should not be removed.

Big Beaver Creek Survey: This stream survey was conducted on October 9, 1986, and covered the lower 7.2 km (4.5 miles) of that stream. The first waterfall at the confluence with Ross Lake was probably passable on the survey date for rainbow trout immigrants from the lake as well as dolly varden spawners. The greatest vertical drop in October was between 1 and 2 meters. The second fall was a high velocity chute that fish could pass along the left bank. The lake level was down about 1.5 to 2 meters below full pool and at full pool only the upper chute would restrict passage, depending on water velocity. It was suspected that the upper chute was impassable to the majority of fish in all but the late summer-fall low flow period. There was another chute near the right bank of the stream that, while dry on October 9, did carry water in the spring and summer and provided easier passage for fish when the lake was at full pool; probably in late August the lake level and stream flows would allow fish access up this route. Study of the photographs taken in May and June of 1985 and 1986 and October 1986 leads to the conclusion that these series of falls and chutes could be altered by blasting a series of steps that would provide improved passage for spring/early summer migrations of spawning/feeding run rainbow trout and easier migrations for fall runs of spawning dolly varden.

General Stream Description: Big Beaver Creek meanders through a 400 to 800 meter wide valley with a very low gradient in its lower 8 km (5 miles). The stream banks are high and appear quite stable within this reach. The banks support lush growths of vine maple, devil's club, cascara, and conifers. It was surprising that in a stream which fluctuates in flow as much as Big Beaver, overflow channels and collapsed banks were so rare. At the time of the survey the wetted channel width averaged 8 meters over the survey length and ranged from 6 to 15 meters. Due to the steep banks and relatively flat stream bottom the high flow channel width would appear to average about 10 to 11 meters. With the exception of perhaps a dozen pools with depths estimated to be greater than 3 meters, most of the stream averaged about 1-1.5 meters in depth on the survey date. Stream visibility on the survey date was estimated to be 3+ meters. Flow was estimated to be 90 cfs on October 9th. Spring high flows probably exceed 400 cfs. Due in part to the watershed stability, there are few log jams in the surveyed section, in fact only three forced portages. That is not to say however that large organic debris is scarce in this stream reach. On the contrary, large fallen trees or remnants of trees were encountered every few hundred feet along the 7.2 km, in addition to smaller debris.

Stream Substrate: The quantity and quality of trout or dolly varden char spawning gravel decreased from the top end of this survey section to the mouth. The highest quality 12 mm to 40 mm gravels were observed in the stream section between 4 km and 7 km upstream from the mouth. In this upper reach there were many excellent submerged gravel bars and pool tail-outs with near perfect spawning conditions. There was probably more high quality spawning habitat in this 2 mile section of the stream alone than in all of the other accessible tributaries (with the exception of the Skagit River) combined. Due to the migration barrier at the mouth of the creek, rainbow trout are blocked from reaching these sites during their spring/early summer spawning migrations. Although some pockets of potential spawning gravel exist downstream from river km 4, the lower gradient of that area and reduced input of gravels from side tributaries resulted in a large bed load of sand and silt. The substrate of this lower area was generally not suitable for spawning fish and in only one site, starting approximately 400 meters above the foot bridge near the mouth, does rock dominate the substrate. Some aquatic vegetation was observed in the stream attached to the river bottom but the species was unknown. There were very few sections of the stream with steep enough gradient to erode the channel down to bedrock and expose larger boulders. Only four such sites of less than 100 meters were noted.

Tributaries: On the left bank (facing downstream) only the last tributary before reaching the lake had water running on the surface. This tributary passes through two beaver ponds just before reaching Big Beaver Cr. The flow was approximately 0.1 cfs. The

remaining left bank tributaries were dry on the surface but since they were the lower end of rock chutes and the old creek channels were filled with gravel and boulders, it was impossible to say water wasn't running beneath the gravel. It should be noted that these talus rock filled channels are contributing significant amounts of spawning gravel to the lower portion of Big Beaver Creek. In this section of the stream no similar suppliers of rock are found on the right bank. The three or four potential tributaries on the right bank, with one exception, originated from a series of beaver ponds. No water was observed flowing from these channels.

Fish Observations: During the survey, other than one fish approximately 100 mm long, no fish less than approximately 280 mm (11 inches) long were seen or caught. Fish were first encountered approximately 6.5 km above the lake where a fish believed to be a small dolly varden was seen. Five redds were counted on the tailout gravels of one pool. The redds were approximately 0.3 to 0.6 meters in width and 0.6 to 1.0 meters in length. This was the largest concentration of redds seen during the survey. Other redds were observed singly or in pairs downstream to river kilometer 4.0. Eleven total redds were observed. Rainbow trout ranging in size from 280 to 400 mm were caught or observed feeding upon hatches of mayflies and stoneflies. It was estimated that approximately 200 of these rainbow trout were in the lower 4.8 km of the stream. There was little question that these were Ross Lake fish, not stream resident fish. Had they been stream resident fish we would have seen smaller, younger fish as well. It was believed these fish moved up into Big Beaver Creek between late July and early September when low stream flow and maximum-lake level combined to allow passage at the stream mouth. These rainbow probably returned to Ross Lake to over-winter. No cutthroat were observed or caught.

1987-1988 WDW Studies

1987-88 Catch Per Unit Of Effort (CPUE)

South End, 1987

A total of 27 anglers were checked at the Ross Lake Resort on opening day, June 20, 1987. The anglers had fished a total of 127 hours and had caught 98 rainbow, 1 dolly varden and 1 eastern brook for a catch per unit of effort (CPUE) of 0.79 fish per hour. The fish per angler average was 3.7 for the mix of completed and incompleted trips. Completed trip anglers averaged 5 fish per person on opening day.

North End, 1987

A total of 155 angler trips was recorded for the Hozomeen (B1) sampling site on opening day 1987. A total of 654 hours was expended to harvest 638 rainbow and 6 dolly varden, giving a CPUE of 0.98 fish per hour. The average fish per angler trip was 4.2. Angler trips are referenced rather than individual anglers, as recorded at the south end, because the majority of anglers were checked more than once during the sampling day as they took breaks from fishing but left their catch in camp before returning to fishing. Greater CPUE accuracy was achieved by gathering data as they returned from each fishing excursion rather than waiting to record data from their last trip and relying upon their memory of duration and catch from earlier outings in the day. The average catch per day for completed trip anglers was 6 fish.

South End, 1988

A total of 66 angler trips was recorded at the South end of Ross Lake on the opener, June 18, 1988. These trips were for a duration of 350 hours, during which time the anglers harvested 370 fish for a CPUE of 1.06 (1.05 for rainbow only). The average number of fish caught per angler trip was 5.61. The average catch of completed trip anglers was 6.5 fish.

North End, 1988

A total of 98 angler trips was recorded at the north end of Ross Lake on June 18, 1988. Total duration for these trips was 359 hours and a total of 304 fish were harvested. The CPUE for all fish was 0.85 fish per hour and was 0.83 for just rainbow trout. The average number of fish caught per angler trip was 3.1 and the average catch of completed trip anglers was 4.3 fish.

1987-88 Harvest Species Composition

South End, 1987

On the opening day, 98 percent of the catch was rainbow trout, 1% dolly varden, and 1% eastern brook.

North End, 1987

On opening day, 99% of the harvest was rainbow trout and 1% dolly varden.

South End, 1988

On opening day, 99 percent of the harvest was rainbow trout and 1% was dolly varden and cutthroat.

North End, 1988

On opening day, 98 percent of the harvest was rainbow trout and 1% was dolly varden and cutthroat.

1987-88 Age of Catch

South End, 1987

Out of 56 rainbow trout randomly sampled from opening day catch at the south end of Ross Lake in 1987, the majority were age 3 (43%0) followed by age 2 (30%). There were no age 1 fish in the sample. Twenty-three percent were age 4 and four percent were age 5.

North End, 1987

Out of 57 rainbow trout randomly sampled from the opening day catch at the north end of Ross Lake, the majority were age 3 (40%) and age 4 (39%). There were no age 1 or 2 fish in the sample. Nineteen percent of the fish were age 5 and only 1 fish (2%) was age 6.

South End, 1988

Out of the 53 rainbow trout randomly sampled from the opening day catch at the south end Ross Lake Resort, the majority were age 3 (40%) and age 2 (33%). There were no age 1 or age 6 fish sampled. Age 4 fish comprised 19 percent of the catch and age 5 fish, eight percent.

North End, 1988

Out of the 34 rainbow trout sampled for age composition of the catch on opening day at the north end Hozomeen campground site, the majority were age 3 fish (67%). No age 1 or age 6 fish were sampled. Age 2 fish comprised eighteen percent of the catch, followed in abundance by age 4 (12%) and age 5 (3%) fish.

1987-88 Length of Catch

1987 Opening Day, Total Lake Sample

The average fork length of rainbow trout caught in Ross Lake on opening day, 1987, was 304.4 mm (12 inches). As in other years, it was noted that the fish at the north and south ends of the lake differed in average length. The difference in 1987 was 31.1 mm (1.2 inches).

South End, 1987

The average size of the rainbow trout kept by anglers on opening day, 1987, at the south end of the lake was 283.5 mm (11 inches) and ranged from 212 to 355 mm (8 to 14 inches). The one dolly varden caught was 426 mm and the one eastern brook was 275 mm.

Figure 15 is a histogram displaying the length-frequency distribution of opening day, 1987, angler caught rainbow from the south end of Ross Lake. Note the largest number of fish in any one size group were clustered between 280 and 300 mm. This closely corresponded to the size of the largest age 2 fish and the average size of the age 3 rainbow.

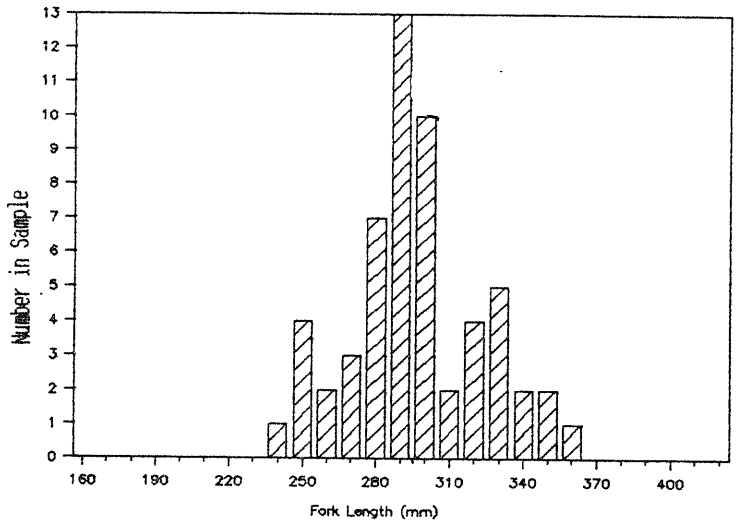

FIGURE 15. Length-frequency distribution of rainbow trout caught at south end Ross Lake, opening day, 1987.

North End, 1987

The average size of the rainbow trout harvested on opening day, 1987 at the north end of Ross Lake was 314.6 mm (12.4 inches) and ranged in size from 225 to 390 mm (9 to 15 inches).

Figure 16 is the length-frequency distribution of rainbow trout caught on opening day, 1987, at the north end or Ross Lake. The large fish grouped between 310 and 340 mm were the largest age 3 rainbow plus the age 4 and 5 trout. Most age 3 fish were between

250 and 300 mm and constituted a much larger percentage of the north end catch than at the south end, in part because there were no age 2 fish in the opening day harvest at the north end.

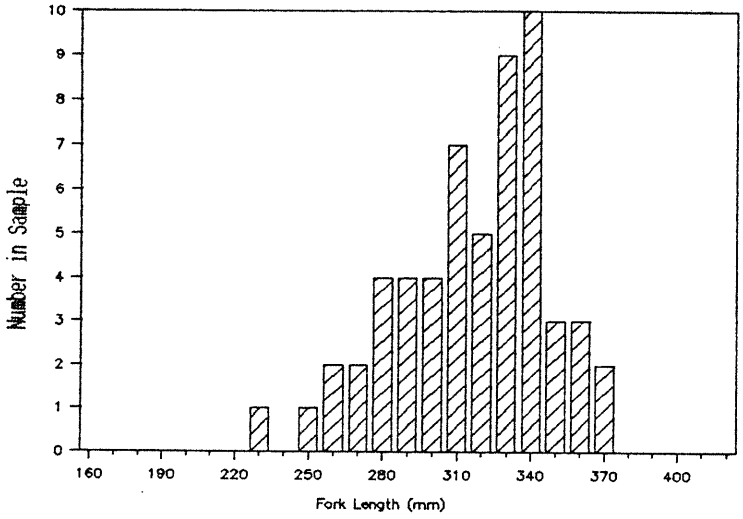

FIGURE 16. Length-frequency distribution of rainbow trout caught at north end Ross Lake, opening day, 1987.

Figure 17 is the length-frequency histogram of the composite of north and south end opening day catches of rainbow trout from Ross Lake. Note that when the two separate histograms are combined, the age 2 and smaller age 3 fish form the spike centered at 290 mm, while the largest age 3 combined with age 4 and 5 fish form the spike centered a 330 mm.

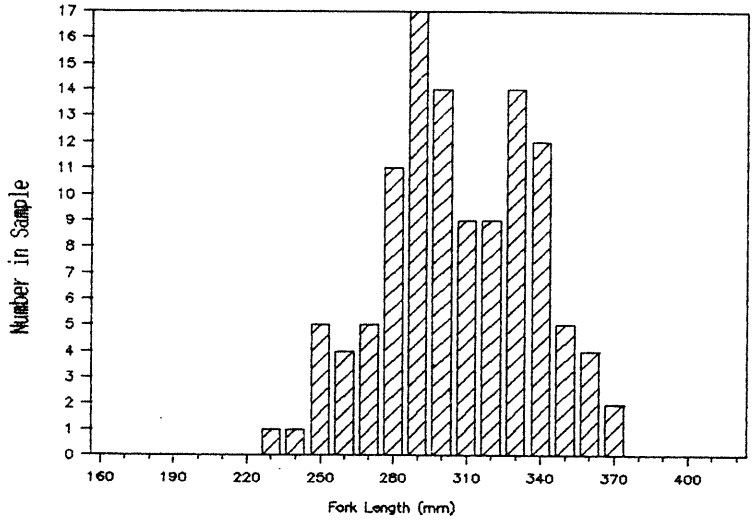

FIGURE 17. Length-frequency distribution of all Ross Lake rainbow caught on opening day, 1987.

1988 Opening Day, Total Lake Sample

On opening day, 1988, the average fork length of all rainbow trout harvested from Ross Lake was 283.4 mm (11.2 inches). The difference in average length between the north end and the south end was 11.7 mm (0.5 inches).

South End, 1988

The average size of the rainbow trout harvested on opening day at the south end of Ross Lake was 278.6 mm (11 inches) and ranged from 210 to 365 mm (8 to 14 inches) in fork length.

Figure 18 displays the length-frequency distribution of rainbow trout caught at the south end of Ross Lake on opening day, 1988. Note that the most numerous fish in any one size group were between 270 and 290 mm. The majority of these fish were age 2 and age 3 rainbow trout.

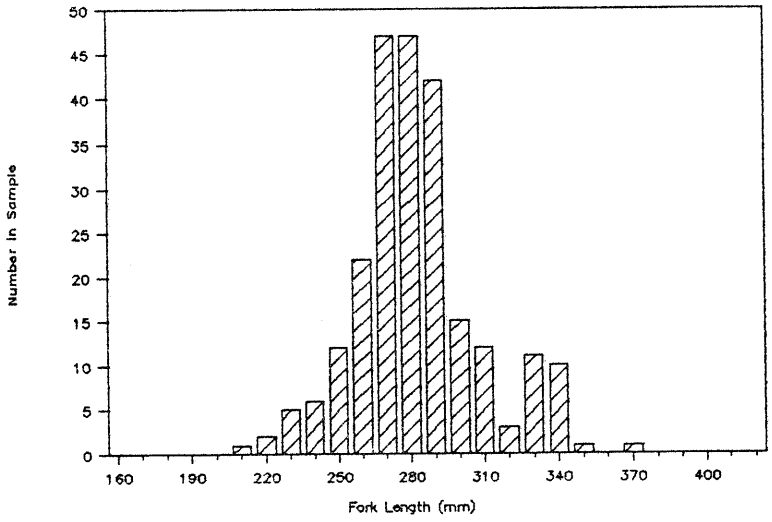

FIGURE 18. Length-frequency distribution of rainbow trout from south end Ross Lake, opening day, 1988.

North End, 1988

The average size of the rainbow trout harvested on opening day at the north end of Ross Lake was 290.3 mm (11 inches) and ranged from 245 to 370 mm (9.5 to 14.5 inches).

Figure 19 shows the length-frequency distribution of angler caught rainbow trout on opening day, 1988, from the north end of Ross Lake. Note the almost classic normal distribution with a peak at 290 mm, which were mostly age 3 fish.

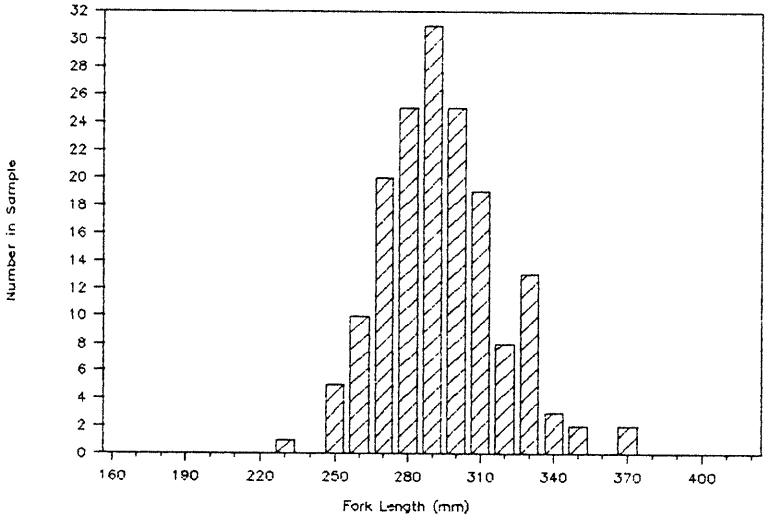

FIGURE 19. Length-frequency distribution of rainbow trout caught at north end of Ross Lake, opening day, 1988.

The composite length-frequency histogram of the north and south end catches of rainbow trout from opening day, 1988, are shown in Figure 20. Note that the largest number of fish in any one size range occurs between 270 and 290 mm.

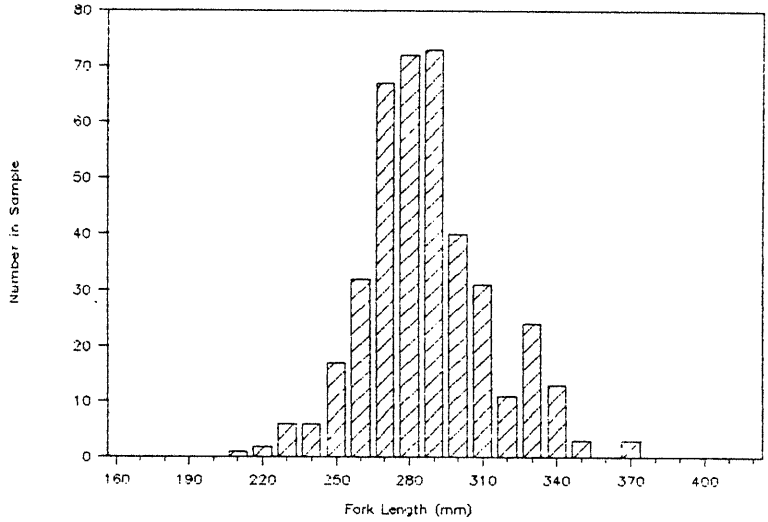

FIGURE 20. Length-frequency distribution all of rainbow trout caught in Ross Lake, opening day, 1988.

1987-88 Sex of Catch

South End, 1987

On June 20, 1987, at the south end of Ross Lake a sub-sample of the harvested rainbow trout was examined internally for sex determination. Out of 57 fish, 27 percent were males and 73 percent were females.

North End, 1987

On the opening day, June 20, 1987, at the north end of Ross Lake a randomly collected sample of the harvested rainbow trout were examined to determine sex composition. Out of 56 fish, 42 percent were males and 58 percent were females.

South End, 1988

On June 18, 1988, at the south end of Ross Lake a sub-sample of the harvested rainbow trout was examined internally for sex of the fish. Out of 53 fish, 21 (38%) were males and 32 (62%) were females.

North End, 1988

At the north end of Ross Lake a sub-sample of the harvested rainbow trout was examined internally for detemination of sex. Out of 34 fish, 11 (32%) were males and 23 (68%) were females.

1987-88 Sexual Maturity of Catch

South End, 1987

Out of 57 rainbow trout examined for sexual maturity at the south end of Ross Lake on opening day 1987, only 5 percent were mature or spawned out, the remaining 95 percent were immature and would not spawn that year. Seven percent (7%) of the males were mature and 93 percent were immature, while 5 percent of the females were mature and 95 percent were immature.

The single mature male was 232 mm in fork length while the immature males averaged 273 mm (range 251-290). The mature females averaged 297 mm (range 295-298) and the immature females averaged 301 mm (range 242-344) as shown in Table 18.

North End, 1987

Out of 56 rainbow trout examined at the north end of Ross Lake on opening day 1987, 21 percent were mature or spawned out and 79 percent were immature. Twenty-one percent of the males and females were sexually mature and 79 percent of the males and females were immature.

The mature males averaged 341 mm (range 280-370) in fork length. The immature males averaged 315 mm (range 250-353). The mature females averaged 324 mm (range 260-365) and the immature females averaged 306 mm (range 230-350) as shown in Table 18.

TABLE 18. Sexual maturity, age and lengths of rainbow trout from Ross Lake, north and south ends, opening day, 1987.

Location	Sex	Age	No.	Length (mm) Avg	Range
North End					
	Females				
	Mature	4	4	311	260 - 340
		5	3	342	321 - 365
	Immature	3	16	296	230 - 340
		4	9	320	280 - 350
		5	1	340	---
	Males				
	Mature	3	1	280	---
		4	2	350	340 - 360
		5	1	355	---
		6	1	370	---
	Immature	3	5	290	250 - 330
		4	7	330	300 - 350
		5	6	321	288 - 353
South End					
	Females				
	Mature	3	2	297	295 - 298
	Immature	3	24	287	242 - 335
		4	13	319	268 - 355
		5	2	337	329 - 344
	Males				
	Mature	2	1	232	---
	Immature	2	14	273	246 - 290

South End, 1988

Out of 53 rainbow trout examined for sexual maturity on the opening day at the south end of Ross Lake, only 7 (13%) were mature or spawned out fish (4 females and 3 males) while the remaining males and females (87%) were immature and had not, nor would not, spawn in 1988 (Tables 19 and 21). The immature females were mostly age 2 and age 3 rainbow, averaging 268 and 279 mm, respectively.

TABLE 19. Rainbow trout, grouped by sex and maturity, average lengths and size ranges, caught on opening day, 1988, at the south end of Ross Lake.

Sex/Sexual Maturity	Average Size (mm)	Range
Males		
Mature	322	275 - 360
Immature	284	245 - 340
Females		
Mature	316	272 - 340
Immature	280	249 - 336

North End, 1988

Out of 34 rainbow trout randomly sampled from the harvest on opening day at the north end of Ross Lake, only one female and 2 males were mature or kelts (9%). The remaining 31 males and females were immature and had not, nor would not, spawn in 1988 Tables 20 and 21). The majority of the immature females were age 3 and averaged 296 mm. Most age classes were longer in fork length at the north end than at the south end in 1988. The age 3 immature females were significantly larger; an average of 17 mm.

TABLE 20. Rainbow trout, grouped by sex and maturity, average lengths and size ranges, opening day, 1988, at the north end of Ross Lake.

Sex/Sexual Maturity	Average Length(mm)	Range(mm)
Males		
Mature	284	278 - 290
Immature	275	245 - 313
Females		
Mature	370	- - -
Immature	292	255 - 330

TABLE 21. Opening day, June 18,1988, north and south ends Ross Lake, rainbow trout sexual maturity, age, and size.

Sampling Site	Sex	Maturity	Age	No.	Length(mm) Avg	Range	
North End							
	Females	Mature	5	1	370	---	---
		Immature	2	4	273	260	290
			3	15	296	283	330
			4	2	324	322	325
	Males	Mature	3	1	290	---	---
			4	1	278	---	---
		Immature	2	2	254	245	262
			3	6	276	245	300
			4	1	313	---	---
South End	Females	Mature	4	2	293	272	315
			5	2	340	---	---
		Immature	2	10	268	249	285
			3	15	279	249	336
			4	3	328	322	333
	Males	Mature	3	1	275	---	---
			5	2	346	332	360
		Immature	2	7	264	245	280
			3	5	283	252	304
			4	5	314	300	340

1987-88 Angler Profiles

South End, 1987

The anglers fishing the south end of the lake on the opener in 1987 primarily fished by trolling with flashers and bait (81%), followed by lure (15%) and bait (4%).

North End, 1987

The north end anglers on opening day 1987 primarily fished by trolling flashers with a lure attached (44%) or with worms attached (36%). The remaining anglers still-fished with bait (30%).

South End, 1988

The anglers fishing the south end of Ross Lake on the opening day in 1988 mainly (86%) used flashers with worms to catch their fish. The remaining anglers used flashers with lures or lures alone (11%) and 3 percent used flies. No one was checked who used bait only (still-fishing).

North End, 1988

The most popular form of fishing at the north end of Ross Lake on the 1988 opening day was still-fishing with bait (51%). Next most popular was trolling with flashers having worms attached (34%). Trolling with flashers having a lure attached was chosen by 15% of the anglers.

DISCUSSION

References will be made in the discussion section to a series of reports published by Seattle City Light and authored as "Anonymous" between 1971 and 1974. These publications contain the results of 4 years of intensive field studies at Ross Lake designed to evaluate the 1971 through 1974 conditions of the fish populations and predict the impacts on those fish if Ross Lake were to be raised to an elevation of 1725 feet by heightening Ross Dam. That alteration of the dam height was averted by environmental conerns, expressed by Canadian and U.S. agencies and concerned citizens. The reports produced during that study contain a wealth of biological and environmental information that are used in this 1989 report for comparison to 1985 - 1988 conditions. The early 1970's studies were designed, coordinated, conducted, reviewed, and results written by a group of British Columbia and Washington scientists known collectively as the International Skagit - Ross Fisheries Committee.

Environmental Description of Ross Lake and Tributaries

Ross Lake Environment

The surface area of the full reservoir is 11,680 acres (18.25 sq. mi.). The area of the reservoir at maximum drawdown (1475') is 4400 acres (6.88 sq.mi.). Figure 21 shows the configuration of the lake at full pool and the dotted line represents its size at maximum draw-down. Mean depth of the full reservoir is 122.5 ft. and mean depth of minimum reservoir is 93.6 feet (Anonymous, 1972b).

Ross Dam Description

Ross Dam was built in three stages. Construction began in 1937 and the dam was completed to an elevation of 1365 feet in 1940. Between 1943 and 1947 Ross Dam was raised to an elevation of 1550 feet. Completion of the dam to its present elevation of 1615 was accomplished in 1949 (Anonymous, 1972b).

Ross Dam is an arch type dam, constructed of concrete, and is 540' high from bedrock to the surface of the roadway atop the dam. The maximum surface elevation of the lake is 1602.5 feet above mean sea level and the minimum is 1475 feet above msl due to the design of the power intake tunnels. Usable water storage for power generation, with 127.5 feet draw down, is 1,053,000 acre feet. In order to provide water storage for flood control, provisions of the federal license limit the maximum allowable

reservoir elevation to 1590 feet during the period from October 1 through March 15. Total present capacity of reservoir with maximum water elevation is 1,435,000 acre feet (Anonymous, 1971).

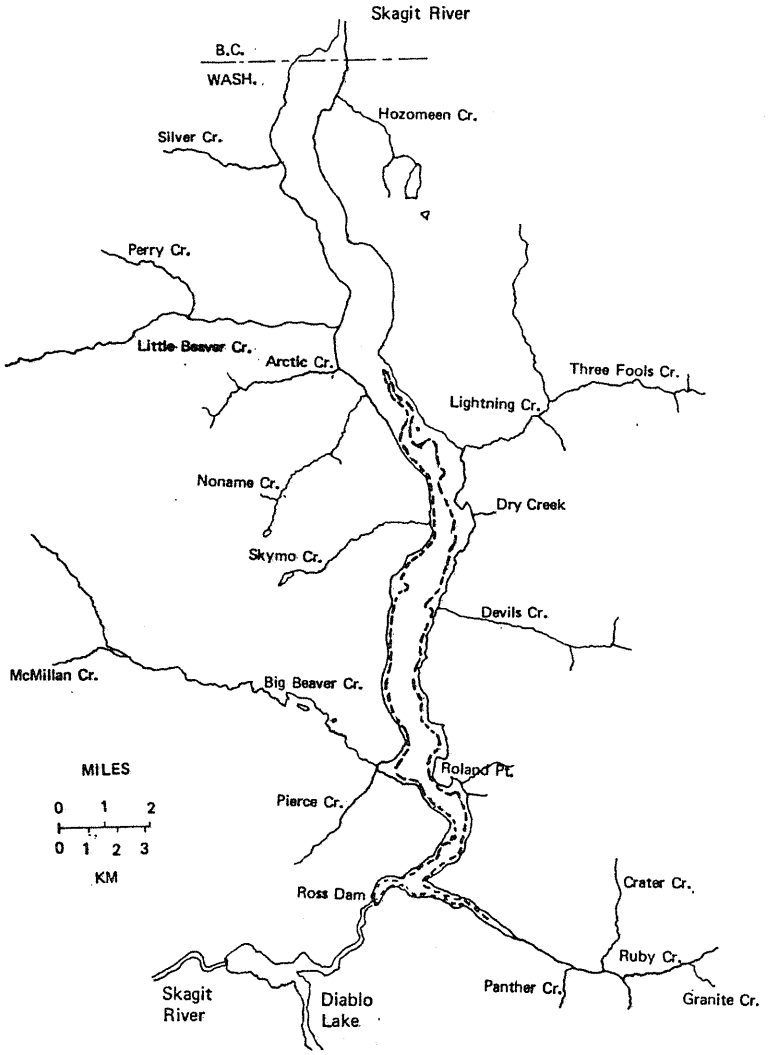

FIGURE 21. Ross lake and tributaries. The perimeter of the lake at full pool is shown and the 1475 foot maximum drawdown contour is depicted as a dotted line.

Ross Lake Drawdown and Variable Surface Area

Lake level fluctuations vary from year to year depending on weather, snow pack, and discharge at the dam. The greatest draw-down normally occurs in March and April. Generally, spring run-off begins in mid-April and continues through July. The rates of filling and draw-down of the reservoir depend on the relative amounts of runoff and water used to generate power. The draw-down schedules for years 1974 to 1986 are shown in Figure 22. In past years the water levels in Ross Lake have fluctuated 30 to 110 feet during a year's cycle. The fluctuations during the critical water recreation period, mid-June to September 30, have ranged from 2 to 15 feet (Anonymous, 1973c).

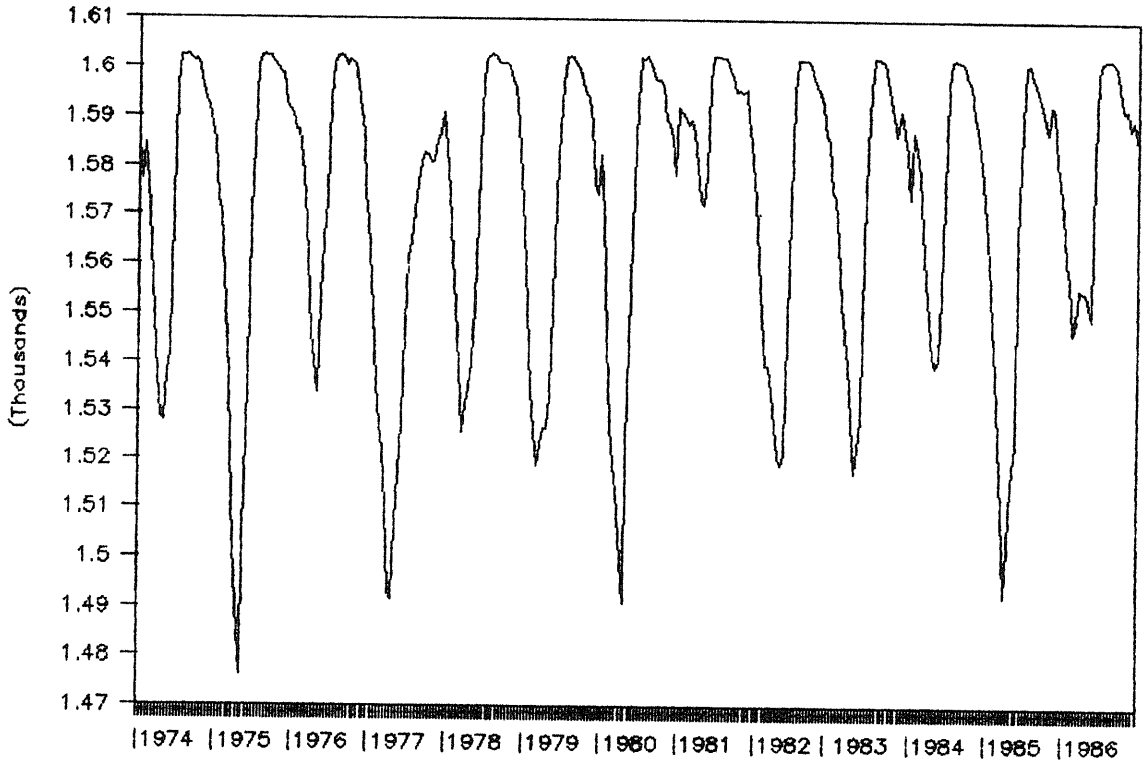

FIGURE 22. Ross Lake annual draw-down elevations from 1974 to 1986.

Table 22 displays lake draw-down elevation versus surface acres of water remaining in the reservoir (Anonymous, 1973a). Ross Lake at minimum water level recedes approximately 13 km (8 miles) south of the international boundary and extensive flats are exposed from December through April each year. Since 1953 the exposed areas have averaged 38 percent and have ranged from 15 to 54 percent of the normal surface area of the lake (Griffith and Greiner, 1983). The minimum level has not been reached since 1952 when the spillway gates were installed (Anonymous, 1972b).

TABLE 22. Ross Lake surface elevations and corresponding surface areas.

Lake elevation (feet)	Shoreline length (miles)	Area (acres)	Lake volume (acre feet)
1602.5	64.5	11,680	1,435,000
1600	64.3	11,600	1,390,000
1575	58.8	10,280	1,125,000
1550	53.3	9,040	890,000
1525	50.3	7,600	680,000
1500	43.7	5,840	520,000
1475	37.4	4,400	412,000
1450	29.1	3,400	285,000
1425	26.9	2,820	210,000
1400	24.3	2,300	140,000
1375	21.2	1,850	90,000
1350	19.4	1,400	60,000
1325	16.7	900	25,000
1300	13.4	420	10,000

During the 1985 and 1986 studies the reservoir dropped to a minimum level of 1491.45 feet above mean sea level (msl) on April 6, 1985 and a maximum of 1602.16 feet above msl on July 5, 1985. The minimum level in 1986 of 1539.40 feet above msl occurred on February 23 and the maximum of 1602.46 feet above msl on July 21 (Figure 23). On opening day of fishing, June 15, 1985, the reservoir level of 1589.43 feet above msl was almost ten feet lower than the 1986 opening day level of 1599.02 feet above msl on June 14. The 1985 level had a significant impact on the opening day fishery in that there was very little water in the Canadian portion of the lake and it was difficult for most anglers to launch and retrieve their boats. The reservoir levels in 1986 remained above the 1600 foot level from June 19 through September 10, while in 1985 these levels were maintained from June 29 through July 26; a much shorter period of time. The lower levels make fishing more difficult at the north end of the

reservoir because of the reduced area to fish in (particularly in Canada), the greater number of stumps exposed, and the increased difficulty in boat launching.

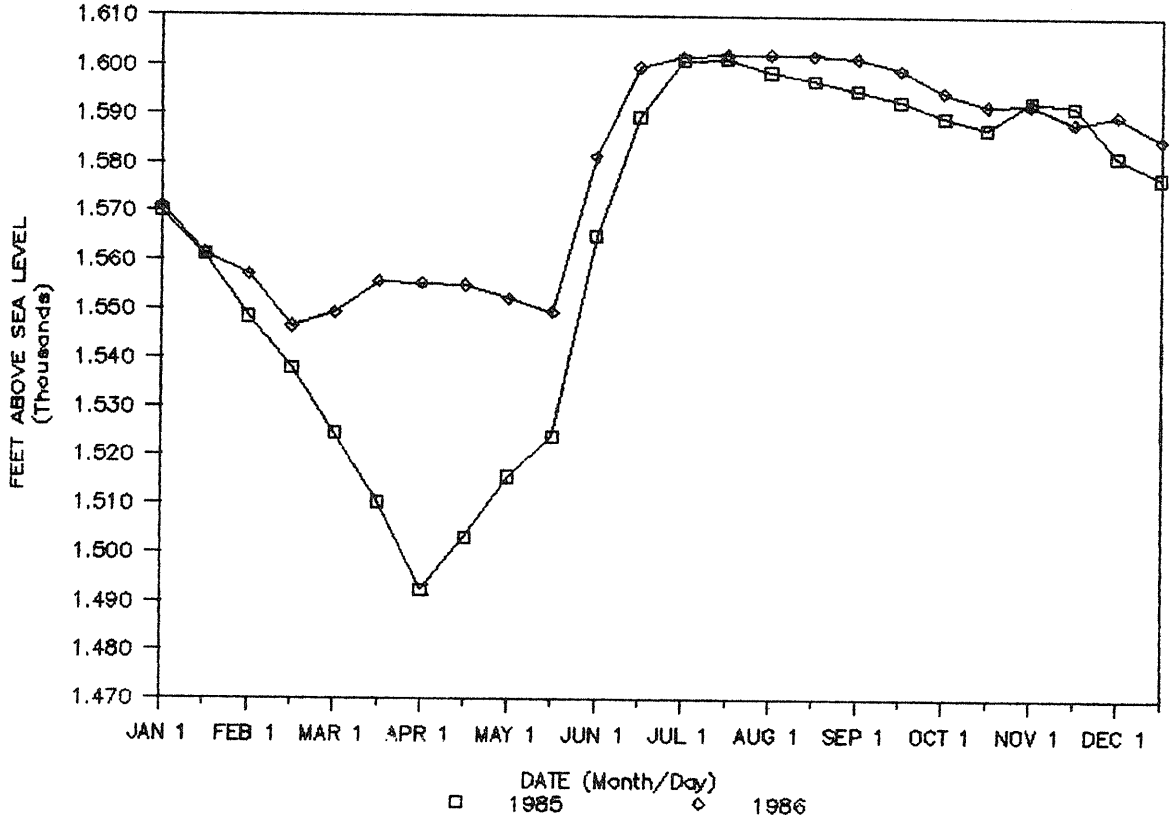

FIGURE 23. Ross lake surface level fluctuations (draw-down), from 1985 - 1986.

Ross Lake Turbidity

Turbidity in Ross Lake is primarily caused by seasonal runoff of silt and glacial flour and has a direct influence on depth of light penetration and therefore water clarity. Depth of visibility (measured with an 8-inch Secchi disk) in June 1972 was as low as 1.5 feet and 3-4 ft was not uncommon near Ruby and Big Beaver Creeks that month. Visibility was generally lowest in late May and late June in 1972. The lake waters gradually cleared in July and August, and at the south end light penetration reached to a depth of over 45 feet by September. Clarity of water at the north end of the lake was slightly less than the south end on the same sampling dates (Anonymous, 1972b). These 1972 findings were similar to observations made in 1985-1988.

Turbidity can have a direct influence on angling success. When waters are very turbid, fish seeking food and anglers seeking fish tend to concentrate their efforts near the surface; large numbers of fish concentrated at a shallow depth frequently result in high angler catch rates. By mid-summer, when the lake is much clearer and the fish spread out in depth following their zooplankton food source, angling methods must involve deeper trolling to be successful. The spreading out of the fish at various depths reduces their concentration and/or availability, which can result in lower catch rates.

Ross Lake Water Chemistry

The water chemistry data for Ross Lake is shown in Tables 23 and 24 (Anonymous 1972b). The chemical values indicate the lake is certainly not nutrient "rich" relative to some other lakes in the state, particularly those in eastern Washington, but much the same in alkalinity, hardness, nitrate and phosphate as some of the more productive alpine lakes in Washington state and many western Washington lowland lakes.

TABLE 23. Ross Lake water chemistry from north and south end sampling sites, at two depths, on May 27, 1971.

Results in milligrams per liter (PPM) except * and BDL - below detectable level

	Sta. # 1	Sta. # 2	Sta. # 3	Sta. # 4
Alkalinity	24.5	25.5	28.4	25.5
Calcium (Ca)	10.4	11.4	11.6	10.4
Free Carbon Dioxide (CO_2)	5.0	2.8	3.7	3.9
Chloride	0.5	BDL	0.5	BDL
Chromium (Cr^{+6})	BDL	BDL	BDL	BDL
Copper	.025	.015	.025	.02
Fluoride	<0.1	<0.1	<0.1	<0.1
Hardness ($CaCO_3$)	32.4	37.0	36.0	32.0
Iron (Fe)	0.05	0.03	0.05	0.03
Lead (Pb)	<0.005	<0.005	<0.005	<0.005
Magnesium (Mg)	1.56	2.07	1.7	1.46
Manganese (Mn)	<0.025	<0.025	<0.025	<0.025
Nitrogen (Ammonia)	--	.03	.015	.015
Nitrogen (Nitrate)	0.25	0.1	<0.05	< .05
Dissolved Oxygen	11.5	11.6	10.9	11.5
Phosphate (PO_4)	.04	.035	.03	.03
Potassium (K)	0.4	0.4	0.45	0.45
Residue (Total)	39	47	24	21
Residue - Filterable	7	8	9	10
Residue - Non-Filterable	32	39	15	11
Silica (SiO_2)	7.0	7.2	7.8	7.0
Sodium (Na)	1.4	1.0	1.5	1.6
Sulfate (SO_4)	4.7	4.3	4.7	3.4

TABLE 24. Ross Lake water chemistry at mid-lake, south end, at two depths on three dates, 1974 (from FRI Unpublished Report, 1975).

Station: Midlake 1 mile north of dam	Depth	3 m			40 m		
	Date:	6/3	7/9	9/20	6/3	7/9	9/20
Alkalinity		40.0	20.0	32.0	40.0	30.0	25.0
CO_2 (dissolved)		2.0	2.0	--	2.0	2.0	--
Hardness (Ca)		30.0	25.0	20.0	30.0	21.0	20.0
Hardness (Mg)		10.0	BDL	12.0	3.0	1.0	9.0
Hardness (Total)		40.0	25.0	32.0	33.0	22.0	29.0
Fe		BDL	0.05	BDL	BDL	0.09	0.02
Mn		0.20	0.49	0.10	0.25	0.25	1.30
$N(NH_3)$		0.30	0.40	0.30	0.30	0.50	0.40
Silica (SiO_2)		2.25	1.62	9.0	2.15	1.20	8.9
Sulfate		--	--	2.0	--	--	3.0
Chloride		2.5			2.5		
Temp. °C (°F)				(61.0)			(50.5)
pH		8.10	7.80		7.70	8.01	
Color (Alpha Pt-Cobalt Std)		20.0	10.0	5.0	20.0	10.0	20.0
Turbidity (JTU)		8.0	10.0	2.0	3.0	13.0	BDL
Secchi disc, m (ft)			(6.0)	(21.0)			
Conductance (μ mhos/cm)							

*BDL = below detectable level.

Ross Lake Primary and Secondary Production

Ross Lake is classified as oligotrophic, or low in productivity (FPC Project 553, 1974). This classification is based upon relatively low mineral nutrients for aquatic plant and animal growth. Other measurements reflecting low nutrient status are low electrical conductivity of the water, oxygen levels at or near saturation in deep water, high incident light penetration because of low organic growth in the water, and low chlorophyll "a" content (a measure of the abundance of phytoplankton) in the euphotic zone. However, The 1973 Seattle City Light report

(Anonymous, 1973a) shows mid-September measurements of chlorophyll "a" nearly double those recorded in 1972; certainly implying variablility in annual productivity. The near doubling of the chlorophyll "a" in 1973 compared to 1972 partially explains why zooplankton abundance was slightly higher in 1973 than 1972 (Anonymous, 1974a).

In 1974, the Washington State Department of Ecology reviewed Seattle City Light's Ross Lake data and offered the following remarks (Anonymous, 1974c) concerning implications that the lake was nutrient deficient: "The assumption is made (References 68 and 78) that the lake's primary production is nutrient limited. This contention is not supported by adequate data. Nutrient data is presented only for one date (May 27, 1971), two locations, and at 25 and 100 feet only (Reference 78). The phosphate levels do not appear to be limiting, but nitrate values are boarderline. Data obtained from FRI give nutrient values for three additional dates in 1973 (Appendix D). Again, phosphate and nitrate levels do not appear to be limiting and are higher than the 1971 values. Burgner (FRI, personal communications) feels that some other unknown nutrient is the limiting factor."

That the reservoir has probably declined in productivity in the years since it was first filled is not in dispute; that is the norm for virtually all reservoirs. Initial increases in nutrient supplies as a reservoir is first filled, and corresponding increases in fish populations are well documented. This situation normally only lasts a few years, followed by a sharp decrease then a leveling off of the productivity at a value considerably lower than originally existed. Anglers would notice this productivity change through a decline in the average size of fish in the first years after the reservoir filled compared to the average size 10 to 20 years later.

Ross Lake Public Access

Ross Lake is approximately 132 miles from Vancouver and accessed over a 40 mile dirt road, built in 1946, from Silver Hope, B.C., to the north end of Ross Lake. U.S. access is via a short trail down to the lake from the North Cascade Highway, or by Seattle City Light boat from Diablo Lake.

Lodging and rental boats for visitors are available at Ross Lake Resort on the south end of the lake. A U.S. National Park campground at the north end provides boat launch access. Hiking trails also follow the lake shoreline on the east side of the lake and portions of the west side, between the dam and Big Beaver Creek.

Until the 1960's Ross lake was clogged with floatage, and boating access to some parts of the lake was limited and hazardous. Today the lake is relatively free of navigation obstacles except when lake level falls below the 1555 foot elevation. At that time areas in the vicinity of the inlets of Big Beaver Creek, Devils Creek and entire north end above Lightning Creek become hazardous for boating due to the presence of large stands of submerged trees left unfallen in the rush to fill the reservoir.

Ross Lake Tributary Descriptions

Ross Lake tributaries are very important to the fishery resource of the reservoir. Additional physical and biological data are available in Eggers and Gores (1971) and other reports (Anonymous, 1971,1972b,1973a,1974a).

The American tributaries have a combined drainage area of approximately 620 square miles; an area almost twice as large as the Canadian Skagit River drainage basin of 389 square miles. Table 25 displays some of the other physical data on the more important (from a fishery management viewpoint) U.S. tributaries and the Canadian Skagit River (from Eggers and Gores, 1971, and Anonymous, 1974a).

TABLE 25. Ross Lake tributaries and their physical properties that influence fish production.

	TRIBUTARY					
	Ruby Creek	Big Beaver Creek	Devils Creek	Lightning Creek	Little Beaver Creek	Canadian Skagit River
Drainage Area (square miles)	186.32	62.86	29.80	142.00	53.40	389.16
Length (miles)	3.36	18.45	9.85	11.01 (to U.S./ Canada Border)	14.35	20.2
Gradient (percent)	1.56	0.61 (lower 8.95 miles to MacMillan Creek)	4.71 (lower 8.52 miles)	2.89 (to U.S./ Canada Border)	2.21 (lower 13.70 miles)	0.38
Discharge (cfs)						
Average	714 (1948-56, 62-69	414 (1940-48, 63-69	No information	237 (1943-48)	No information	See Section 2.3.3.4
Maximum	8640 (27 Nov./49)	4420 (22 Oct./63		2500 (30 May/45)		
Minimum	46 (10 Feb./49)	64(each day 7-12 March/69)		49 (both days 7-8 March/44)		
Substrate	BO, R CGR	SD, ST, FGR-lower 7 mi BO, R, CGR-next 6 mi	Variable-BR, BO, CGR - lower 1 mi	BO, R, CGR, FGR	BR, BO - lower 2 mi, BO, R, GR-upper 12 mi	See Section 2.3.3.3
Character	Rapids, deep riffles, a few pools	Meanders - lower 7 mi, rapids and riffles - next 6 mi turbid in summer months	Variable - falls, rapids, pools - lower 1 mile	Rapids, deep and shallow riffles, pools	Falls, rapids - lower 2 mi, rapids, riffles meanders - upper 12 mi	Many log jams, no water falls or other fish migration blocks
Accessibility of stream areas above stream mouth to fish from Ross Lake	Accessible	Accessible after mid-May for about 7 miles	Not accessible	Accessible after early May for about 1/4 mile	Not accessible	Accessible

TABLE 25 (Continued).

	TRIBUTARY						
	Granite Creek	Canyon Creek	Crater Creek	Panther Creek	McMillan Creek	Three Fools Creek	Freezeout Creek
Tributary to:	Ruby Creek	Ruby Creek	Ruby Creek	Ruby Creek	Big Beaver Creek	Lightning Creek	Lightning Creek
Length (mi.)	17.05	16.10	4.92	13.07	5.70	10.30	6.16
Gradient (percent)	3.29	3.84 (lower 13.26 mi.)	24.04	4.59 (lower 12.34 mi.)	3.48 (lower 4.51 mi.)	4.05 (lower 3.17 mi.)	10.90 (lower 5.66 mi.)
Character	rapids, swift flow over bouldery bottom	rapids, riffles, pools, BO,R,GR	steep falls and rapids	steep rapids and falls, pools, BR,BO,R	variable-rapids, riffles, pools, BO,R,CGR	riffles, rapids, falls swift flow through gorge	---
Accessibility of stream areas above stream mouth for fish from Ross Lake	Accessible for 6.06 miles	Accessible for 9.18 miles	Very limited accessibility	Accessible for .41 miles	Not accessible	Not accessible	Not accessible

	Perry Creek	North Fork Canyon Creek	Slate Creek	Mill Creek	Roland Creek	May Creek	Skymo Creek
Tributary to:	Little Beaver Creek	Canyon Creek	Canyon Creek	Canyon Creek	Ross Lake	Ross Lake	Ross Lake
Drainage area (sq.mi.)					4.76	3.84	5.16
Length (mi.)	5.45	5.59	8.95	6.91	2.65	3.84	3.17
Gradient (percent)	8.90	11.40	8.02	8.99	39.13	25.08	17.59
Character	---	rapids, falls and pools, R,BO,BR substrate, limited GR areas	rapids, falls and pools, BO,BR substrate limited GR areas	rapids and falls, few pools, R,BO, BR substrate, little GR	steep falls and rapids	steep falls and rapids	steep falls and rapids
Accessibility of stream areas above stream mouth for fish from Ross Lake	Not accessible	Accessible for 0.62 miles	Accessible for 0.47 miles	Accessible for 1.23 miles	Accessible for .31 mi.	Not accessible	Not accessible

	Noname Creek	Arctic Creek	Dry Creek	Silver Creek	Hozomeen Creek	Pierce Creek
Tributary to:	Ross Lake	Ross Lake	Ross Lake	Ross Lake	Ross Lake	Ross Lake
Drainage area (sq.mi.)	6.75	13.68	6.35	17.00	6.75	3.64
Length (mi.)	4.00	5.50	3.79	6.20	4.35	3.26
Gradient (percent)	10.62	8.26	20.56	7.62(lower 5.07 mi.)	6.70	17.51
Character	steep falls and rapids	steep falls and rapids	steep falls and rapids, pools	rapids and falls	---	steep falls and rapids
Accessibility of stream areas above stream mouth for fish from Ross Lake	Not accessible	Not accessible	Accessible for .20 mi. in S.fork, .28 mi. in N. fork	Accessible for .49 mi.	Accessible for .05 mi.	Very limited accessibility

Fish Origins

Fish species found in the Skagit River-Ross Lake system include rainbow trout, dolly varden/bull trout, eastern brook, and cutthroat trout.

While it is claimed by Seattle City Light in SLC (1974) that anadromous forms of rainbow trout (steelhead, summer-run or winter-run) and dolly varden did not frequent the Skagit River upstream from Ross Dam prior to construction of Gorge Dam in the 1920's, that conclusion is predicated on only one quick survey of the river, a great deal of supposition, and an obviously biased viewpoint on the part of the City.

The referenced survey by Smith and Anderson (1921), was not an in-depth look at the upper Skagit River but rather a cursory inventory of fish stocks that might be present. They described the Skagit River as follows: "Through this region, the Skagit boils and foams for the greater part of the distance. While no single fall or rapid observed would form an insurmountable barrier to the upward migration of salmon, the continuous series of low falls and rapids seem to have proved effective in stopping the run of salmon through this part of the river." It would have been very easy, in all that boiling, frothing water to have missed summer-run steelhead migrating through the area on their way to the relatively calm river and spawning gravels lying upstream from Ruby Creek. The habits of summer-run steelhead are such that they seek out mainstem areas above waterfalls and other obstructions to find isolation away from winter-run steelhead and salmon. They fill an ecological nich not used by the other fish. Dolly varden display much the same behavior over their natural range. It is interesting that in Smith and Anderson's 1921 report they noted the Skagit River, between Ruby Creek and the Canadian Boarder, to be "well stocked" with rainbow trout and dolly varden. No reference was made to the size of these fish and indeed it would have been impossible to determine whether they were, or were not, anadromous based only on size since summer-run steelhead often weigh less than 5 pounds. They did note however, referencing Ruby Creek, "At the mouth of the creek, where it empties into the Skagit River, much larger fish (rainbow) were found." It has been documented that summer-run steelhead progeny are more likely to residualize (not go to the sea) than winter-run progeny, and, while the percentage that do so is small, over many generations these residualized fish can establish or become part of a resident rainbow stock that co-habits the river with the adults and progeny of the anadromous segment of the population. It therefore should be assumed, until proven otherwise, that adult summer-run steelhead did inhabit the Skagit River upstream from Newhalem prior to construction of the three Seattle City Light Dams (Gorge, Diablo, and Ross). Follow-

ing dam construction the anadromous fish would have been trapped upstream from the dams; destined to become the Ross Lake rainbows and dolly varden we know today.

Researchers in the 1970's believed the resident rainbow trout of Ross Lake had evolved into two separate sub-populations within the watershed: the stream resident rainbow thought to be segregated into genetically distinct breeding groups that remain resident in the streams year around; and the lake resident population believed to be composed of distinct breeding groups which home to specific tributary streams or stream mouth areas for spawning (Woodin, 1974). There is some evidence to support the contention that the rainbow trout populations of the U.S. tributaries contain a resident component that do not migrate to the lake during their life cycle. In 1973, FRI conducted a survey of the genetics of the trout populations in the tributary stream areas isolated by upstream migration barriers. Samples of muscle and liver tissue were taken from a number of fish in each area, and the presence or absence of polymorphism in certain enzyme systems was determined through a standard starch gel electrophoresis technique. Analysis of the frequency of occurrence of polymorphism in the populations sampled showed distinct genetic characteristics among them. This indicated there are resident and migratory components in the Ross Lake rainbow trout stocks.

Not all fish in the Ross Lake drainage are native to that system. There have been a number of fish plants in the Ross Lake drainage in the past (Table 26), but they appeared to have had little impact on the fishery or the wild stocks of Ross Lake. Some of these plants did "take" and are undoubtedly the parent stock of the cutthroat in the Big Beaver Creek beaver ponds, the rainbow trout in the Slate Creek drainage, the twin lakes cutthroat of the Jerry Lakes group and Skymo Lake, and the eastern brook of the Hozomeen and Pierce Creek systems. The cutthroat and eastern brook now caught in Ross Lake and the Canadian Skagit River can be assumed to originate from these early planting efforts.

The present fishery in Ross Lake is totally dependent on natural reproduction. There are no plans to supplementally plant rainbow or any other species directly into the lake. To do so would, in all probability, destroy the current stocks in quality or quantity through competition for the limited food resources or limited spawning habitat, or, through hybridization, alter the life history of the stock or physiology to make it less fit to adapt and survive in the system.

Table 26. Historical fish plants in the Ross Lake drainage.

YEAR	WATER		SPECIES	NUMBER
1916	Big Beaver Creek		Cutthroat	47,000
1919	Big Beaver Creek		Rainbow	1,000
1920	Hozomeen Lake		Steelhead	40,000
1933	Sourdough Lake		Easter Brook	Unknown
1935	Slate Creek **		Rainbow	10,000
1936	Ruby Creek		Rainbow	2,000
	Slate Creek		Rainbow	2,000
	Slate Creek, S. Fork		Rainbow	2,000
1938	Slate Creek, S. Fork		Rainbow	5,000
	Slate Creek, N. Fork		Rainbow	5,000
1947	No Name Lake		Rainbow	Unknown
1952	Ross Lake	Twin Lks	Cutthroat	25,104
1953	Ross Lake	Twin Lks	Cutthroat	25,761
1954	Ross Lake	Twin Lks	Cutthroat	50,861
1960	Willow Lake ***	Tokul Cr	Cutthroat	7,200
1961	Willow Lake		Cutthroat	5,000
	Silver Lake (Glacier Lk.)****		Golden Trout	5,000
1967	Willow Lake		Cutthroat	2,250
	Jerry Lakes (upper)*****		Cutthroat	3,450
	Jerry Lakes (lower)		Cutthroat	3,450
	Skymo Lake	Twin Lks	Cutthroat	Unknown
	Firn Lake		Rainbow	Unknown
	Middle Lakes		Rainbow	Unknown
	East Lakes		Rainbow	Unknown
1975	Ridley Lake	Mt. Whitney	Rainbow	1,200
1978	No Name Lake	Cape Cod	Rainbow	515
	Willow Lake	Mt. Whitney	Rainbow	1,519
1982	Ridley Lake	Mt. Whitney	Rainbow	999
1985	Willow Lake	Twin Lks	Cutthroat	2,800
1988	Willow Lake	Twin Lks	Cutthroat	1,300
	Ridley Lake	Mt. Whitney	Rainbow	1,200

* Hozomeen Creek Drainage
** Ruby Creek Drainage
*** Lightning Creek Drainage
**** Silver Creek Drainage
***** Devils Creek Drainage

The Fishery -- Current and Historic

The fish and fishery of Ross Lake and the Canadian Skagit River are unique for many reasons; not the least of which is that the fishery is totally dependent upon wild, naturally produced trout and char. No hatchery fish are planted directly into the lake or river. The anglers' catch must be constrained to and be dependent upon fish that are surplus to the number needed to maintain the population. The structure and size of the current population is not necessarily best for the future of the fish or the fishery. However, before some optimum population and angler harvest level can be determined, it is essential to understand the life history and population dynamics of the fish residing in the Ross Lake drainage today. Then it will be necessary to determine what environmental limits are restraining the population and what angler harvest impacts are occurring. Many of the answers are to be found from examination of the current fishery and data gathered from its catch, but caution must be taken when drawing conclusions from such data that we do not forget that the fishery itself can be selective in the fish it harvests. For example, often the harvest contains mainly larger, older fish, not because that's all that is in the lake, but rather because fishing regulations set some minimum size or season when larger fish are more available to the angler. In addition to the bias that regulations can create, the anglers themselves can inject bias by "sorting", or keeping only the larger fish. But even with these constraints that the biologist must "sort" out, the anglers' harvest (current and historic) is still the best source of biological data that we have available to determine fluctuations in the Lake fish population and its potential.

Seasons and Limits

Fishing seasons, daily catch limits, possession limits, minimun and/or maximum size limits are all just tools that can be used in a variety of combinations to achieve certain fishery management goals. The highest priority goal must always be to protect the fish stocks from over-exploitation by anglers that could alter a fish population's natural structure or even threaten its survival. Natural structure -- features that could be altered by angling pressure, include: existance of many age classes of fish (e.g. age 1 through age 6) and the relative proportions of the age classes to one another (e.g. number of age 1 fish versus age 2 fish, etc.), the male to female sex ratio, the number of spawners, the natural spawning time, the existance of discrete sub-populations within a large population, the average size of the fish in each age class, and so on. Fishery management harvest strategies and regulations must work on the principle that the first priority is to protect the basic biological structure of a population that is needed for its stability. Harvest must

only come from the excess fish that each population annually produces. Excess should only be defined as those fish that have spawned one time and have high natural mortality rates.

Seasons and limits are tools of fishery management that change as we acquire more knowledge about a particular fish population's needs. Table 27 is a long listing of the management regulations that have been applied to Ross Lake and its American tributaries between 1933 and 1988. The trend and emphasis has been to restrict harvest of spawners.

Ross Lake/U.S. Streams Fishing Regulations

TABLE 27. Regulations pertaining to Ross Lake and its U.S. tributaries, 1933 to 1988.

	FISHING REGULATIONS		
Year	Closed Waters	Open Season	Limits
1933	None	Apr. 15 to Oct.31	Not to exceed 10 pounds and 1 Fish; provided the numbers so taken do not exceed 20 in number
1934	None	Apr. 10 to Nov. 30	Same as 1933
1935	None	Apr. 10 to Oct.31	Same as 1933
1936	None	Apr. 5 to Oct.31	Same as 1933
1937	Skagit River and all tributaries, including Ruby Creek, from mouth of Ruby Creek to the Canadian Border.	Apr. 25 to Oct. 31	Same as 1933
1938	Skagit River and all tributaries, including Ruby Creek, from mouth of Ruby Creek to Canadian Border: Beaver Lake, at head of Beaver Creek; Devils Lake, Hozomeen Lake: No Name Lake at head of No Name Creek.	Apr. 24 to Oct. 31	Same as 1933

1939	Skagit River and all tributaries, from the mouth of Beaver Creek to Canadian border, including Beaver Creek; Beaver Lake, at head of Beaver Creek; Ruby Creek and all its tributaries, from the mouth of Panther Creek to its source; Devils Lake; Hozomeen Lake; No Name Lake at head of No Name Creek.	Apr. 23 to Oct 31	Same as 1933
1940	Same as 1939	Apr. 21 to Oct. 31	Same as 1933
1941	Devils Lake; Hozomeen Lake; No Name Lake at head of No Name Creek	Apr. 6 to Oct 31	Same as 1933
1942	Same as 1941	May 24 to Nov.1	Same as 1933
1943	Same as 1941	May 23 to Oct. 31	Same as 1933
1944	Same as 1941	May 28 to Oct. 31	Same as 1933
1945	Same as 1941	May 27 to Oct. 31	Same as 1933
1946	None	May 26 to Oct. 31	Same as 1933
1947	Skagit River and all tributaries, including Ross Lake, from Ross Dam to Canadian Border.	May 25 to Oct. 31	Same as 1933
1948	Skagit River and all tributaries, including Ross Lake, from Ross Dam to the Canadian Border except Ruby Creek and its tributaries from mouth of Crater Creek to its source.	May 23 to Oct. 31	Same as 1933
1949	Same as 1948	May 22 to Oct. 31	Same as 1933
1950	Big Beaver Creek and its tributaries; Ruby Creek and its tributaries from its mouth to Crater Creek.	May 21 to Oct.31	Same as 1933
1951	Big Beaver Creek and its tributaries above posted marker on Ross Lake; Ruby Creek and its tributaries from posted marker on Ross Lake; Ruby Creek and its tributaries from posted marker on Ross Lake to Crater Creek; Skagit River from a line 300 yards out in Ross Lake to the Canadian Border.	July 1 to Oct. 31	Same as 1933

1952	Big Beaver Creek and its tributaries above posted marker on Ross Lake; Devils Creek from posted marker on Ross Lake for one mile upstream; Lightning Creek from posted marker on Ross Lake for one mile upstream; Ruby Creek and its tributaries from posted marker on Ross Lake to Crater Creek; Skagit River from a line 300 yards out in Ross Lake to the Canadian Border.	June 29 to Oct. 31	15 fish, the weight of which shall not exceed 7 1/2 pounds and 1 fish
1953	Big Beaver Creek and its tributaries above posted marker on Ross Lake; Devils Creek from posted marker on Ross Lake for one mile upstream; Lightning Creek from posted marker on Ross Lake for one mile upstream; Ross Lake, that portion lying between the Canadian Border and the following established line: from a point on the north side of the mouth of Little Beaver Creek directly east to a marker on the east shore of Ross Lake: Ruby Creek and its tributaries from posted marker on Ross Lake to Crater Creek; Skagit River from Ross Lake to the Canadian Border.	June 28 to Oct. 31	Same as 1952
1954	Same as 1953	June 27 to Oct. 31	Same as 1952
1955	Big Beaver Creek and its tributaries above posted closed water markers on Ross Lake; Devils Creek from posted closed water marker in Ross Lake for one mile upstream; Lightning Creek from posted closed water marker in Ross Lake for one mile upstream; Ruby Creek and its tributaries from posted closed water marker on Ross Lake to Crater Creek.	July 1 to Oct. 31	Same as 1952
1956	Same as 1955	July 1 to Oct. 31	Same as 1952
1957	Same as 1955	July 1 to Oct. 31	Same as 1952
1958	Same as 1955	July 1 to Oct. 31	Same as 1952
1959	Same as 1955	July 1 to Oct. 31	Same as 1952

1960	Same as 1955	July 3 to Oct. 31	Same as 1952
1961	Same as 1955	July 1 to Oct. 31	Not to exceed 6 pounds and 1 fish; provided the numbers taken do not exceed 12 fish, 6-inch minimum size
1962	Same as 1955	July 1 to Oct. 31	Same as 1961
1963	Same as 1955	July 3 to Oct. 31	Same as 1961
1964	Big Beaver and its entire drainage above closed water markers on Ross Lake; Devils Creek from closed water markers in Ross Lake for one mile upstream; Lightning Creek from closed water markers in Ross Lake for one mile upstream; Ruby Creek and its tributaries from closed water markers in Ross Lake to Crater Creek.	July 1 to Oct. 31	Same as 1961
1965	Same as 1964	June 27 to Oct. 31	Same as 1961
1966	Same as 1964	June 26 to Oct. 31	Same as 1961
1967	Same as 1964	June 25 to Oct. 31	Same as 1961
1968	Same as 1964	June 23 to Oct. 31	Same as 1961
1969	Same as 1964	June 22 to Oct. 31	Same as 1961
1970	Same as 1964	June 21 to Oct. 31	Same as 1961
1971	Same as 1970	June 19 to Oct. 31	Same as 1961
1972	Same as 1970	June 17 to Oct. 31	Same as 1961
1973	Big Beaver and its entire drainage above closed water markers on Ross Lake; Devils Creek from closed water markers in Ross Lake for one mile upstream; Lightning Creek from closed water markers in Ross Lake for one mile upstream; Ruby Creek upstream from closed water markers in Ross Lake. Pierce Creek closed. Granite Creek fly fishing only.	June 16 to Oct. 31	Same as 1961
1974	Same as 1973	June 15 to Oct. 31	Same as 1961

1975 Same as 1973	June 21 to Oct. 31	Same as 1961
1976 Same as 1973	June 19 to Oct. 31	Same as 1961
1977 Same as 1973	June 18 to Oct. 31	Same as 1961
1978 Same as 1973	June 17 to Oct. 31	Same as 1961
1979 Same as 1973	June 16 to Oct. 31	Same as 1961
1980 Same as 1973	June 21 to Oct. 31	6 pounds and 1 fish not to exceed 8 trout, 6-inch minimum size
1981 Same as 1973	June 20 to Oct. 31	Same as 1980
1982 Same as 1973	June 19 to Oct. 31	Same as 1980
1983 Same as 1973	June 19 to Oct. 31	8--not more than 3 over 14"
1984 Closed waters: Big Beaver Creek and Ruby Creeks: entire streams. Devils and Lightning Creeks: one mile upstream of closed water markers. Granite Creek fly fishing only.	June 16 to Oct. 31	Same as 1983
1985 Same as 1984	June 15 to Oct. 31	Same as 1983
1986 Closed waters. Big Beaver Creek: entire stream. Ruby Creek: entire except Granite Creek. Devils and Lightning Creeks: one mile upstream of closed water markers. Pierce Creek: entire stream. Granite Creek no longer fly fishing only.	June 14 to Oct. 31	No minimum size 8 fish daily and possession limit, no more than 3 over 14 inches.
1987 Same as 1986	June 20 to Oct. 31	Same as 1986
1988 Closed waters: The following tributaries to Ross Lake are Closed from the closed water markers near their mouths upstream the distance indicated. Big Beaver Creek, entire stream; Ruby Creek, entire stream; Pierce Creek, entire stream. All other tributaries--one mile.	June 18 to Oct. 31	Same as 1986

Canadian Skagit River Fishing Regulations

The largest tributary to Ross Lake, the Canadian Skagit River, is under the fishery management control of British Columbia Ministry of Environment's, Fisheries Branch. Even though the fish of Ross Lake and the Canadian Skagit River are for all intents and purposes the same fish, the regulations for the U.S. and Canadian waters have often been quite different. The differences do not reflect more or less concern for the welfare of the fish, but rather management goals. The goal of British Columbia's management for the river has been to increase the numbers and size of fish in the river to improve the quality of the angling experience. To accomplish this goal the Canadian Skagit River 1986 regulation were:

Minimum size limit	300 mm (12 inches) fork length
Daily catch quota.....	2 fish
Possession limit	2 days daily catch quota
Gear restriction.....	use only single barbless hooks no bait permitted

Canada's regulations that apply to their portion of Ross Lake were different than either their stream regulations or the Washington Department of Wildlife's regulations on the U.S.portion of Ross Lake. The British Columbia regulations for the lake have, like Washington's, been designed more to maximize harvest of all age classes of rainbow. In addition, these regulations were written more to conform to general region-wide regulations rather than be tailored specifically for the biological needs (other than spawning) of Ross Lakes fish populations. In some years the opening day on the Canadian portion of Ross Lake has been later than the opening day on the U.S. portion. This deviation from Washington's opening day has reflected a desire to protect more of the spawning population and to delay opening fishing until the lake level was high enough to permit boat launching from from Canadian access points.

Canada's 1988 lake regulations were:

Minimum size limit.....	200 mm (8 inches) fork length. B.C. regulations are in fork length, not total length as in Washington.
Maximum size limit.....	no more than 2 over 500 mm (20 inches) fork length
Daily catch quota.....	4 fish
Possession limit.....	8 fish

Catch Per Unit of Effort (CPUE)

Catch per unit of effort (CPUE) is frequently used as an indicator of the abundance of fish. If the total effort remains relatively constant then change in the catch per effort will reflect the abundance (or availability) of the fish being sought. In this report CPUE is defined as the catch per angler hour.

Two studies were conducted in 1985 -- one by the British Columbia Ministry of Environment and the other by the Washington State Department of Wildlife -- and one study in 1986 by the WDW. The 1985 and 1986 CPUE statistics are given in Table 28. The 1985 and 1986 studies show similar patterns with the June opening day CPUE's at 0.83 and 0.80 fish per hour, respectively. Both years show a similar pattern with the highest CPUE on the opening day followed by a rapid decline in success which then begins to rise in September and October. The overall CPUE for 1985 and 1986 were 0.33 and 0.41 fish per angler hour, respectively. The 1985 value is lower, due in part to the much smaller sample size on opening day. There were no angler checks made at the south end of the lake from June 15 to July 21.

For comparison with the 1980's CPUE, the overall CPUE values from the 1971, 1972 and 1973 seasons were 0.48, 0.52 and 0.49 fish per hour, respectively. These figures were for the whole season. No breakdown was given on a monthly basis for 1973, but monthly CPUE data was available for the 1971 and 1972 seasons, which allows comparative alignment with the 1985 and 1986 data. Table 29 and Figure 24 display the CPUE by month for the four years. Note that the overall CPUE by month for the 1971 - 1972 period was significantly higher than the catch per hour values for the same months in 1985 and 1986. There can be little question that angling success has dropped sharply; from an average of 0.50 to 0.37; a 26 percent decline in CPUE. While data indicating a declining CPUE does imply a decline in total population of fish, it could also simply be a reflection of the fact that more fishermen are catching the same total numbers of fish from a population which has not changed in size over the years.

Looking at numbers of visitors using Ross Lake (Table 30), especially vehicle counts, which best reflect fishing pressure at the north end of the lake, little change can be noted between the early 1970's and the mid-1980's. Most observers and anglers with a 15-year history of visiting the lake, who were interviewed in 1985 and 1986 agreed that little change in numbers of anglers had occurred.

Comparison of 1980's angler distribution on the lake with data gathered in the 1970's indicated that anglers also had not significantly changed their preference for fishing location on the lake. In the 1970's, 60 percent of the angling effort occurred north of Lightning Creek, while in the 1980's, 63 percent of the

angling effort occurred in that same area. The average of 1985 and 1986 total angling effort was distributed between the zones of the lake as follows: Canadian Zone (15.5%), Hozomeen Area (31%), Little Beaver Creek Area (11.5%), Lightning Creek Area (5%), Devils Creek Area (8%), Roland Point Area (15.5%) and Ruby Creek Area (13.5%). The 1971 to 1973 average distribution of anglers on Ross Lake was: Canadian Area (8.1%), Hozomeen Area (34.2%), Little Beaver Creek Area (12.2%), Lightning Creek Area (5.5%), Devils Creek Area (4.8%), Roland Point Area (16.7%), and Ruby Creek Area (18.5%). There had been very little change in angling effort location in the intervening 12 to 15 years between the two studies.

Focusing only on opening day CPUE would lead one to conclude angling success was even better in the 1980's, but the rapid drop in CPUE in July and August in those years suggests the fish population could not sustain the fishing pressure, unlike the 1970's.

The decline in CPUE then most likely reflects a reduction in the number of fish in the lake.

TABLE 28. 1985 and 1986 data summaries by month for number of anglers, number of rainbow trout kept, catch per unit of effort, average length and size range (mm).

YEAR	MONTH	NUMBER OF ANGLERS	NUMBER OF RB KEPT	CPUE	AVG.LEN	RANGE
1985	JUN	305	168	0.39	285	224-383
	JUL	427	143	0.18	282	190-451
	AUG	538	392	0.25	273	158-384
	SEP	416	653	0.37	269	162-410
	OCT	156	403	0.45	284	188-424
1986	JUN	477	1155	0.45	302	199-400
	JUL	339	381	0.29	297	186-373
	AUG	430	344	0.23	287	169-390
	SEP	482	588	0.37	282	168-409
	OCT	148	347	0.49	283	180-395

TABLE 29. Overall CPUE for each month and opening day, 1971, 1972, 1985, and 1986 fishing seasons.

Year	Opener	June	July	August	Sept	Oct
1971	0.56	0.53	0.49	0.43	0.49	0.62
1972	0.52	0.49	0.76	0.63	0.66	0.68
1985	0.83	0.39	0.17	0.27	0.38	0.47
1986	0.81	0.45	0.29	0.23	0.37	0.49

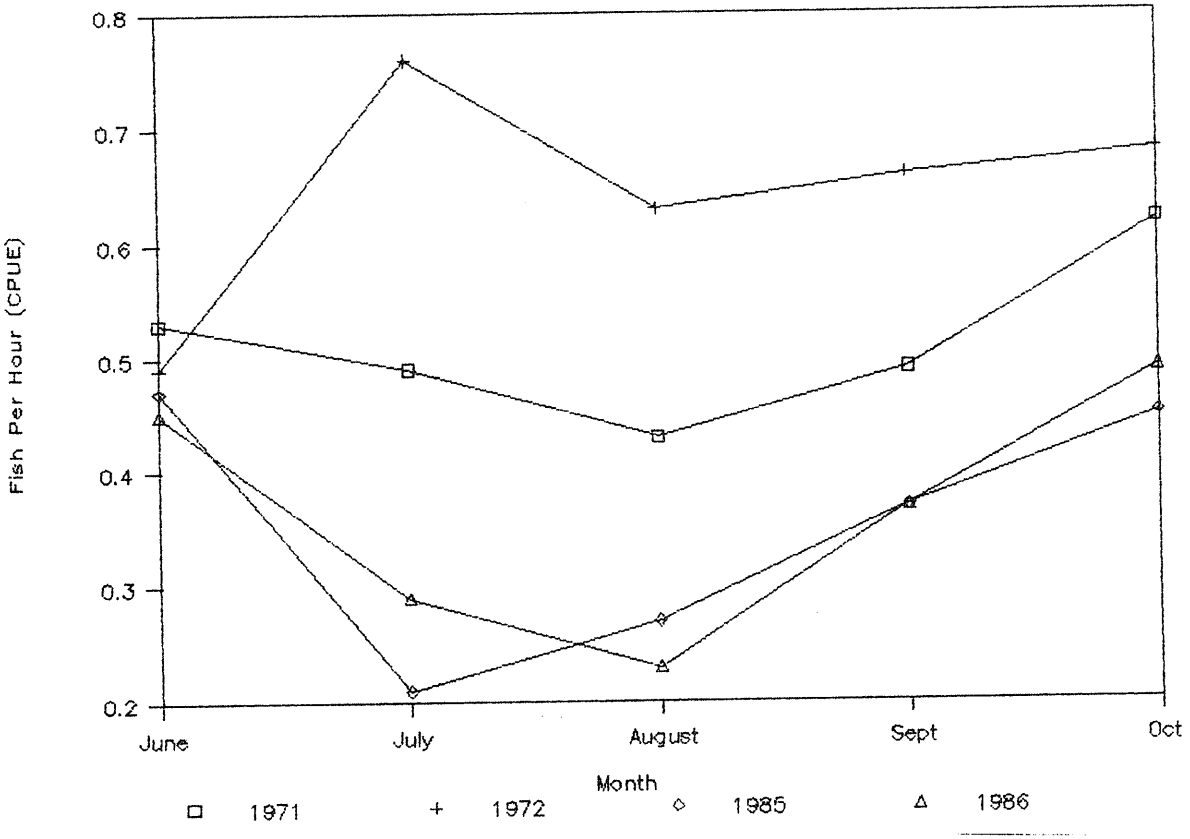

FIGURE 24. Overall CPUE for rainbow trout, by month, for 1971, 1972, 1985 and 1986 fishing seasons at Ross Lake.

TABLE 30. National Park Service historical use data for the Hozomeen and boat-in campgrounds at Ross Lake.

	HOZOMEEN				BOAT-IN CAMPGROUNDS
YEAR	VEHICLES	RV'S	TENTS	VISITORS	VISITOR NIGHTS
1970					
1971 ^1	6,886			25,377	
1972	6,662			18,498	
1973		2,814	911		
1974 ^2		*	*		
1975		6,154	1,419	23,882	7,902
1976		5,296	1,374	22,055	6,152
1977 ^3		*	*	11,232	1,517
1978		*	*	22,907	4,904
1979		6,075	1,212	23,332	8,307
1980		5,765	1,175	20,008	7,116
1981		5,142	1,445	24,363	11,711
1982		5,250	1,481	23,171	8,733
1983		6,215	1,553	31,586	9,283
1984 ^4					
1985	5,033	5,641	1,531		
1986	6,254	3,285	1,507		

^1 1971 and 1972 data were obtained from Interim Report #2, Vol. 1, 1973 All other data from the National Park Service
^2 * Data missing
^3 Ross Lake remained significantly below full pool in 1977
^4 Blank areas due to data not obtained

Catch per angler hour values in the 1970's were also uniformly high in most areas in the lake (Table 31). That was not the case in 1986. The CPUE values in Table 31 for the different sample sites reflect that in 1986, angler success was somewhat close to the 1970's CPUE values for the mid-lake zones (5-3), but much lower at the north (7-6) and south end zones (2-1). In 1986 CPUE values for the north and south ends were high in the first 2 weeks of the season and then again in September, but the extreme drop in CPUE in mid-summer at both ends of the lake indicated excessive fishing mortality.

TABLE 31. Season catch per hour (CPUE) for fishing zones 1 through 7 on Ross Lake, 1971, 1972, 1973, 1974, and 1986.

Lake Zone	1971	1972	1973	1974	1986
1 (Ruby Cr)	0.50	0.57	0.54	0.53	0.29
2 (Roland Pt)	0.47	0.70	0.45	0.50	0.42
3 (Devils Cr)	0.49	0.72	0.45	0.49	0.48
4 (Lightning Cr)	0.44	0.43	0.36	0.48	0.45
5 (L. Beaver Cr)	0.43	0.52	0.43	0.39	0.46
6 (Hozomeen)	0.53	0.46	0.36	0.39	0.35
7 (Canada)	0.46	0.53	0.35	0.44	0.28

In 1984, on June 22-23, one week after opening day, 71 anglers were checked in all zones of Ross Lake. They had harvested 97 rainbow trout and had fished a total of 284 hours; for a CPUE of 0.34 fish per hour. This is further indication that monthly CPUE in the mid-1980's did not remain as high after opening day as it did in the early 1970's.

One of the first questions that must be answered before we can point to the cause of the decline of the fishing success is when did the CPUE decline occur. Was it between the 1970's and mid-1980's or was that decline just a step in a much more protracted decline.

Creel checks for the years 1941 through 1982 are shown in Table 32. The checks show a decline in catches from an average of 13.7 fish per angler day in the 1940's to 5.7 fish in the 1950's, 3.6 fish in the 1960's, 2.1 fish in the 1970's and to 1.8 fish per angler day in the early 1980.'s.

The catch per angler day for only rainbow trout in 1986 showed differences in catch/angler by location in the lake and by month (Table 15 in 1986 Results Section). The rainbow catch per angler by month for all zones of the lake combined were: June (3.0 fish/angler day), July (1.1), August (0.8), September (1.2) and October (2.4 fish/angler day). The 1986 season average catch/angler day for rainbow trout only was 1.7, which only slightly lower than the early 1980's value, which was lower than the 1970's catch per day. The 1970's and early 1980's values were primarily based upon rainbow trout; after the mid-1960's, dolly varden showed a significant decline in contribution to catch.

In 1986 the catch per angler day for rainbow trout also showed differences between zones of the lake for the season. The catch per day was greatest in the mid-lake zones and least at the north and south ends: Canadian Zone 7 (0.8 fish/day), Hozomee Zone 6 (1.7), Little Beaver Zone 5 (2.0), Lightning Creek Zone 4 (2.0), Devils Creek Zone 3 (2.2), Roland Point Zone 2 (1.8), and Ruby Creek Zone 1 (1.2 fish/angler day).

TABLE 32. Ross Lake angler creel checks, seasonal (includes opening day) and opening day-only if indicated, 1941 through 1982, from WDW files.

Year	Opener or Season	Anglers	Rainbow	Cutthroat	Eastern Brook	Dolly Varden	Total	Catch/ Day	Catch/ Hour
1941		14	212				212	15.1	
1946		12	144			3	147	12.2	
1950		364	2213	769	6	159	3147	&.6	
1951		160	1371		2	36	1409	8.8	
1952		243	1146	46		68	1260	5.2	
1953		165	735	58	2	12	807	4.9	
1954		277	1413	55	6	27	1501	5.4	
1955		261	964	60	26	49	1099	4.2	
1956		218	642	88	42	65	837	3.8	
1957		64	222	8	39	24	293	4.6	
1958		70	323	4	19		346	4.9	
1959		290	1933			26	1959	6.8	
1960		585	2452	4	40	84	2580	4.4	
1961		675	2248	2	17	212	2479	3.7	
1962		907	4334	4	81	107	4526	5.0	
1963		484	2498		1		2499	5.2	
1964		42	87	3		3	93	2.2	
1965		162	515				515	3.2	
1966		458	1928		63	6	1997	4.4	
1967		336	940	1	7	4	952	2.8	
1968	Opener	163	865			3	868	5.33	
1968		520	1392			4	1396	2.7	
1969		366	751	6		8	765	2.1	
1970		717	2593	5		17	2615	3.6	
1971		646	1304			11	1315	2.0	
1972		756	1345				1345	1.8	
1973		494	1441		5	48	1494	3.0	
1974	Opener	171	601				601	3.4	0.67
1974		729	1209	3		34	1246	1.7	
1975	Opener	106	456				456	4.2	0.93
1975		219	418				418	1.9	
1976	Opener	195	805				805	4.1	0.87
1976		198	284			1	285	1.4	
1977	Opener	94	333				333	3.5	0.78
1977		190	270	2			272	1.4	
1978	Opener	20	55				55	2.8	0.67
1978		-							
1979		-							
1980	Opener	56	231				231	4.1	0.9
1980		476	746			1	747	1.6	
1981	Opener	79	511				511	6.5	0.98
1981		380	954				954	2.5	
1982		120	173			3	176	1.5	

While the above Ross Lake angler checks, conducted by WDW from 1941 to 1982, indicated a general decline in catch per day, these data may be influenced by reductions in catch limit. The daily catch limit has changed from 20 fish to 15 fish in 1952, 15 to 12 in 1961, 12 to 8 in 1980, and to the present regulation in 1983 of 8 fish with no more than 3 over 14 inches long. These regulation changes were mostly state-wide regulation changes and were not tailored for the needs of Ross Lake's fish or fishery.

Another influence on the recorded fish in possession was the change in the possession limit from two daily catch limits to a possession limit of one daily catch limit in 1961.

Day and time these data were collected also influences the reliability of the records. Many checks were made during high effort time periods (weekends and holidays) and often after the anglers had been fishing for two days; reflecting possession limits as much as daily bag limits.

Another problem with these data was the way they were collected. If the opening day creel sample made up the majority of a year's sample, then the results were probably higher than the actual fishery due to the better fishing normally experienced at the opening. Note in the table the high catch per angler and CPUE values for the opening days compared to the season checks.

It is also unknown what percentage of the anglers interviewed were completed fishing for the day and what percentage were going to attempt to catch more trout. Any change in these percentages could have an influence on the catch per angler day recorded.

In general it does appear that there has been a decline in the catch per angler day at Ross Lake, but the changes in limits and the non-standardized data collection methods used to gather the data, preclude us from determining from this data whether the cause has been a declining fish population or regulatory influence. This leaves the comparison between the 1971-1974 fishery and the 1985-1986 fishery as the best determinant of whether a decline in angling success has taken place and whether there is a biological and/or harvest related basis for the decline.

Ross Lake Annual Harvest

The estimate of the 1986 rainbow trout harvest from Ross Lake was 22,524 fish. The 1986 harvest estimate was larger than the 1985 estimate of 18,504 (Scott and Peterson, 1986).

The 1986 survey design was based on an "access point" survey while previous studies (1985 B.C. and WDW; and 1971 - 1974 IS-RFC studies) estimated harvest by estimating the total effort on the reservoir at selected times and dates and extrapolating these data to estimate the season effort. Catch data in all the studies were obtained from angler interviews and used with the estimate of total effort to obtain an estimate of total (season) harvest. While each survey design had its own strengths and weaknesses, in actual application, given limited survey personnel, the 1985 design was much better suited for Ross Lake.

Seasonal weather conditions differed in the two years of the survey. In 1985, conditions became so hot and dry that the British Columbia Ministry of Forests closed the B.C. Forests to recreational use from June 23 to August 7. This closure did not keep people from traveling to Hozomeen but did prevent anglers from camping at the Canadian campgrounds. That could have reduced some lake angling effort, particularly on the Canadian side of the lake, and reduced the 1985 season harvest. No such closures took place in 1986.

In 1985, access by Canadian and Hozomeen anglers was restricted at the north end of Ross Lake due to low water levels in September and October, which partially explains why north end catches in 1986 were higher than in 1985.

In 1985, 65% of an estimated 3579 catch in the Canadian Skagit River was harvested compared to only 12% out of 5722 fish caught in 1986 (Scott and Lewysnsky, 1987). The declining harvest of rainbow from the Skagit River influenced CPUE for Ross Lake. The unharvested fish returned to the lake starting in September and may have kept the Ross Lake fall fishery, at the north end, from total collapse. Older, surviving Skagit River rainbow that returned to the mouth of the river the following spring also appeared to have provided a large portion of the opening day catch. That was certainly the case with the absence of age 2 fish on opening day, 1987, and when only 18 percent of the catch on opening day 1988 was comprised of age 2 rainbow.

Comparing annual harvest in 1985 and 1986 with annual harvest estimates from 1971, 1972 (Anonymous, 1973a), 1973, and 1974 (FRI Unpublished Report, 1975) does indicate the annual harvest has declined. The catch estimates published for the 1970's did not separate a rainbow trout estimate from all other fish but the reports did give the species composition of the season's harvest. The adjusted estimates of rainbow harvested in the 1970's and 1980's are shown in Table 33.

TABLE 33. Estimates of season rainbow trout harvest from Ross Lake, 1971, 1972, 1973, 1974, 1985, and 1986.

Year	All Species	Rainbow Contribution	Rainbow Estimate
1971	36,552	97.9%	35,784
1972	37,380	94.0%	35,137
1973	38,937	91.8%	35,744
1974	41,700	91.0%	37,947
1985	21,007	89.0%	18,503
1986	23,054	97.7%	22,524

The four 1970's rainbow trout harvest estimates for Ross Lake only (does not include the average annual harvest of 4000 from the Canadian Skagit River) averaged 36,156 fish per season. The two 1980's estimates averaged 20,514 rainbow trout per season. The estimates indicate a drop in average annual harvest of Ross Lake rainbow of 15,642 fish per year between 1974 and 1985. The drop in daily catch limit from 12 to 8 undoubtedly accounted for some of this reduction in annual harvest, but since few anglers ever caught their limit in the 1970's, the influence of the limit change can be considered minor. A 43 percent reduction in annual harvest, given near equal angling effort, is certainly indication that the Ross Lake rainbow population has declined. In fact, if the Canadian Skagit River rainbow trout had been harvested while in the river in Canada, at the same rate they were in the early 1970's (4000+ per year), instead of 2307 in 1985 and 684 in 1986, that many fewer fish would have re-entered the reservoir to enhance the lake fishery and the reduction in Ross Lake harvest would have probably approached 50 percent.

Age of Catch

Rainbow trout begin to grow scales when their fork lenght is approximately 35 mm, or 1.4 inches (Smith, 1955). Many of the downstream-migrating fry reach the lake before attaining that size.

Age of individual fish can be determined from the spacing of the growth rings on the fish scale. The rings, or circuli, are spaced further apart during the best growing season (spring, summer, and early fall) and closer together during the winter when food is scarce. When the rings are very close together, as during the

part of winter when low food supply and cold water virtually stop the growth, the scales not only show tightly spaced circuli but often "checks", or rings cutting off other rings. These tightly spaced rings and/or checks are called annuli and normally are followed by wide spaced rings denoting the resumption of growth in the spring. The number of winter annular marks determines the age of the fish.

It appeared that fish residing longer in stream habitats, to age 2 and 3, had slower growth rates than those which start growth in the lake or moved into the lake at an early stage. Rainbow trout of Ross Lake do not form as distinct annular marks on their scales as do most trout populations (Woodin, 1974).

The time of formation of the annulus for immature fish was found to be between the last week in April and the second week in May. Rainbow trout spawning occurred between early May and the end of July; thus the spawning check was at the same location on the scale as the annulus for mature fish. This means that new growth on the scales does not occur for spawners until July or August.

The rainbow fry emerge from the stream gravels from late July through September and the majority migrate to Ross Lake soon after emergence (SCL, 1973a). Because of the timing of spawning and fry emergence, there are only about eight months of fish growth represented from emergence to the time of formation of the first annulus.

Table 34 contains the age composition of the rainbow trout caught in Ross Lake in 1985 and 1986.

The age 1 rainbow were seen first entering the fishery in July and generally increased in abundance and contribution as the season progressed. These fish were recruited into the mid-lake fishery from streams and near shore areas. In all probability the streams were contributing the majority of these fish or they would have shown up in the June fishery, especially in the creels of still-fishing anglers that used single egg bait at the mouths of the creeks that enter Ross Lake and were still open to angling in 1985 and 1986 (Arctic, No Name, Silver, Roland, Little Beaver, May, Dry, and Skymo Creeks).

It should be noted that in both years the June catch was dominated by age 3 rainbow, which, either in July (1985) or August (1986) were replaced by age 2 fish as the most abundant age class in the catch. In 1985, age 3 numbers stayed nearly the same from June to July, but the abundance of age 2 fish increased; again probably due to recruitment into the mid-lake fishery from stream or shoreline rearing areas. However, in 1986, the relative numbers of age 3 fish declined as the summer progressed and the age 2 fish did not increase in numbers as much as they had the previous summer.

Recruitment of age 2 fish is to be expected each year and the numbers will in many cases be determined by the number of fish spawning two years prior and the environmental conditions in the spawning streams and draw-down of the lake during that intervening two years before the age 2 fish enter the fishery. It would also have been expected to have seen some additional recruitment to the fishery of age 3 fish which would have been spawning in closed-to-angling tributaries when the fishery opened in June. Only in July 1986 did that appear to have happened. Judging from the lack of increasing numbers of age 3 fish during any part of the summer season, and in the case of 1986 the declining contribution by that age group to the fishery after July, it appeared; 1) recruitment of age 3 spawners was significantly less than age 2 recuitment, 2) natural mortality of age 3 spawners was high, and/or 3) the anglers caught such a large portion of the age 3 fish in June that they could not contribute significantly to the catch after July.

As pointed out above, the age 3 fish dominated the June catch in both 1985 and 1986 but for the total year's contribution by age class, the age 2 fish were the most abundant of all age classes in 1985 while the age 3 rainbow were the most abundant age class in 1986. This shift in dominance of one age class to another from year to year has a significant bearing upon the variablility in the average size of fish when all age groups are combined to get an average length, as for a sample on opening day. This will be discussed more in the next section on rainbow lengths.

Age 4 rainbow contributed large numbers of fish to the fishery in 1985 and 1986 (12 and 19 percent of the harvest, respectively).

Age 5 and 6 fish contributed about the same to the fishery in 1985 and 1986, averaging 4.1 and 0.7 percent of the catch, respectively.

TABLE 34. Percent age composition of Ross Lake sport catch, by month, for 1985 and 1986.

		MONTH											
		JUN		JUL		AUG		SEP		OCT		TOTALS	
YEAR	AGE	n	%	n	%	n	%	n	%	n	%	n	%
1985	ONE	0	0	3	4.1	22	17.2	44	23.7	35	22.9	104	17.5
	TWO	15	27.8	42	57.5	53	41.4	56	30.1	50	32.7	216	36.4
	THREE	26	48.1	21	28.8	30	23.4	51	27.4	41	26.8	169	28.5
	FOUR	9	16.7	6	8.2	17	13.3	26	14.0	18	11.8	76	12.8
	FIVE	4	7.4	1	1.4	6	4.7	6	3.2	7	4.6	24	4.0
	SIX	0	0	0	0	0	0	3	1.6	2	1.3	5	0.8
TOTALS		54		73		128		186		153		594	
1986	ONE	0	0	2	2.0	8	20.0	22	18.8	11	31.4	43	8.3
	TWO	43	27.6	28	27.5	30	48.2	37	31.6	8	22.9	146	28.1
	THREE	74	47.4	50	49.0	44	27.3	29	24.8	10	28.6	207	39.8
	FOUR	33	21.2	18	17.6	22	15.5	21	17.9	5	14.3	99	19.0
	FIVE	6	3.8	4	3.9	5	5.5	6	5.1	1	2.9	22	4.2
	SIX	0	0	0	0	1	0	2	1.7	0	0	3	0.6
TOTALS		156		102		110		117		35		520	

In Table 35 note the shift in age 2 contribution to age 3 and 4 when comparing 1971-73 to 85-86. In the 1970's samples the age 2 rainbow were the dominant age group in the anglers' harvest. In the 1980's the older age 3 and age 4 fish became the dominant age groups in the angler catches. The majority of these older fish came from the north end of the lake and appeared to be primarily Canadian Skagit River fish that enter the lake fishery in June and then again in September and October. The 1985 age 3 rainbow contribution may have been lower than 1986 just because the opener was not sampled for an estimate of catch in 1985, nor was the south end catch sampled until July 21. A significant portion of the age 3 fish available to anglers was probably harvested at the south end before mid-July.

TABLE 35. Percent age class contribution to total season sport catch, Ross Lake, 1971, 1972, 1973, 1985, and 1986.

Age	Percent of Season Harvest 1971	1972	1973	1985	1986
1	11	2	2	17	8
2	55	49	62	36	28
3	26	39	29	29	40
4	7	8	6	13	19
5	1	2	1	4	4
6	0	0	0	1	1

The opening day catch age compositions from 1973, 1974, 1985, and 1986 are shown in Table 36. The predominant age class in the 1973 and 1974 opening day samples was age two, while in the 1985 and 1986 opening day samples it was age three. There are three reasons which could account for this difference: 1) the dominant age class of the recent catches is one year older, 2) there was a significant difference in the way the fish were aged, or 3) the samples are not really comparable. The third explanation was carefully examined and it appeared as if a significant portion of the samples from the 1970's came from the resort at the south end of the reservoir, while the samples from the 1980's, with the exception of 1985 which was a north end only sample for opening day, were a combination of both the north and south end samples.

The samples from 1986, 1987 and 1988 were separated into the two sample sites and are also shown in Table 36. The samples from the south end more closely resembled the samples from the 1970's, but still consisted of more age three fish.

If the sampling site was not causing a bias when comparing the 1970's to the 1980's age class contribution, then the other possible bias was that the fish were aged differently by the scale readers. In the next section in this report, dealing with length of each age class of fish it will be shown that there was no significant difference between the lengths of age 2 or 3 fish in the 1970's compared to age 2 or 3 fish in the mid-1980's. That tends to confirm that error in reading ages, if any existed, was at least the same for both sets of data, and not the basis for data showing a greater contribution of age 3 fish in the 1980's than in the 1970's.

It does appear then that the contribution of younger age 2 fish was higher on opening day and for the season in the 1970's than the 1980's. A possible reason for this was much lower recruitment of younger fish to the fishery in the 1980's due to environmental factors or less spawners. The environmental factors that could have been resonsible for lower survival of the younger fish included lake draw-down and delayed refilling. These factors would prevent spawners from reaching spawning areas above the 1602 foot elevation, or cause them to spawn in areas of the lake that later were inundated by rising reservoir levels.

Other damaging environmental conditions would have been reduced stream flows, either at spawning time or after spawning, but prior to fry emergence from the gravel, or summer-fall low flows that could have caused reduced carrying capacity in the streams for age 0 through age 3 residents prior to their normal lake emmigration. To be environmentally caused, one or more of these conditions would have had to be present in the 1983 - 1984 time period to have seen the resultant reduction in age 2 fish in 1985 and 1986. While no extreme environmental conditions were noted in the 1983-1984 period, no discreet measurements were being taken then either. See the Mitigation Section for more discussion on the environmental issue.

The possibility reduced numbers of spawners caused inadequate recruitment deserves the most consideration. Given the apparent reduced population of rainbow trout in the lake, as reflected by the low CPUE and annual harvest for the 1980's compared to the 1970's, low spawner numbers was very likely a primary factor causing reduced recruitment (contribution to catch) of age 2 fish in 1985 and 1986. Previous years' over-harvesting of prespawners, either during their spawning time in late June, or as immature fish the previous year, particularly the age 3 immature females, could lead to such a population collapse. This issue will be discussed in more detail in the section on Age at Sexual Maturity.

TABLE 36. The age class composition of rainbow trout of the 1973, 1974, 1985, 1986, 1987, and 1988 opening day sport catch at Ross Lake with separation into north and south end contributions.

	1973		1974		NORTH 1985		N & S 1986		SOUTH 1986		NORTH 1986	
AGE	n	%	n	%	n	%	n	%	n	%	n	%
ONE	0	0.0	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0
TWO	150	65.2	131	57.2	15	27.8	43	27.6	20	33.9	23	23.7
THREE	61	26.5	74	32.3	26	48.1	74	47.4	24	40.7	50	51.5
FOUR	16	7.0	17	7.4	9	16.7	33	21.2	12	20.3	21	21.6
FIVE	3	1.3	5	2.2	4	7.4	6	3.8	3	5.1	3	3.1
SIX	0	0.0	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0

	N & S 1987		SOUTH 1987		NORTH 1987		N & S 1988		SOUTH 1988		NORTH 1988	
AGE	n	%	n	%	n	%	n	%	n	%	n	%
ONE	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
TWO	17	15.0	17	30.0	0	0.0	23	27.0	17	33.0	6	18.0
THREE	47	42.0	24	43.0	23	40.0	43	51.0	21	40.0	22	67.0
FOUR	35	31.0	13	23.0	22	39.0	14	16.0	10	19.0	4	12.0
FIVE	13	12.0	2	4.0	11	19.0	5	6.0	4	8.0	1	3.0
SIX	1	(1.0	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0

Length of Rainbow Trout

Ross Lake

The average length of rainbow trout sampled from the sport catch in 1985 was 275.4 mm (10.8 inches) (1469 fish measured) and the average length of the 1986 sport sample was 294.2 mm (11.6 inches)(1775 fish measured). The primary reason that the 1986 harvest averaged 19 mm larger than the 1985 sample was the presence of greater numbers of larger age 3 and 4 fish in the 1986 harvest (Table 37). Young fish dominated the harvest in 1985 and older fish in 1986. The average size of fish in each age group, when 1985 is compared to 1986, was virtually the same. That indicates growing condition differences (water temperature,

food supply, etc.) between the years would not explain differences in 1985 and 1986 seasonal average size of rainbow trout; year-class abundance exerted the primary influence.

In Table 37 it can be seen that the age 2 fish dominated the catch in 1985 and this strong age class survived the ensuing fishing season and winter to become the strongest year-class in the 1986 harvest. Large variation in opening day or seasonal average size of fish, from one year to the next, can be influenced by the relative numbers of either age 2 or age 3 fish in the creel.

The range in sizes in this table, for any age class, was due in part to sampling over the whole summer. The same age fish at the beginning of summer was going to be larger if sampled at the end of summer.

TABLE 37. 1985 and 1986 Ross Lake rainbow trout ages and lengths.

Year	Age	No.	Length (mm) Avg	Range	
1985	0	0	--	--	--
	1	104	220.7	158	272
	2	216	259.6	183	337
	3	169	302.0	207	369
	4	76	334.3	275	378
	5	23	346.9	307	384
	6	5	393.6	374	424
1986	0	30	65.2	45	100
	1	61	194.6	99	270
	2	207	257.2	157	328
	3	251	301.8	218	380
	4	146	333.4	286	403
	5	32	349.0	295	395
	6	3	380.0	365	409

The zero age fish in the 1986 sample and the smaller minimum lengths were from electro-shocking samples, and were not used. to calculate average size of fish in the sport fishery.

The average length of rainbow trout for 1986 season (294 mm) was within the range of average seasonal lengths noted in the 1970's. The average lengths of rainbow trout from the 1971, 1972, 1973, and 1974 season sport fish samples were 282 mm (814 fish), 303 mm (572 fish), 294 mm (436 fish), and 299 mm (672 fish), respectively. The 1985 seasonal average length of 275 mm was, however,

the smallest on record for the Ross Lake rainbow. This was primarily due to fewer, older fish in the catch compared to the relative abundance of smaller, younger fish in 1985. It was not due to fish being significantly larger at a given age in the 1970's compared to the 1980's sample. For example, in 1971 (Table 38) age 2 fish averaged 263 mm at capture compared to 260 mm in 1985; age 3 fish averaged 301 mm at capture in 1971 compared to 302 mm in 1985; age 4 fish averaged 339 mm at capture in 1971 compared to 334 mm in 1985; and age 5 rainbow averaged 362 mm at capture in 1971 to 347 mm in 1985 (Anonymous, 1973a). As in 1985, the 1972 sample was dominated by age 2 and age 3 fish, which had the greatest influence on determining the seasonal average size. Note also that there was no significant difference in average size at a particular age when comparing 1971 to 1986, or 1985 to 1986, yet the seasonal average was 19 mm larger in 1986 than either of those other two years.

TABLE 38. Average length at capture and to annulus for Ross Lake rainbow trout, 1971.

	TOTAL			MALES			FEMALES		
AGE	No.	Aver. Length at Capture (cm)	Aver. * Length to Annulus (cm)	No.	Aver. Length at Capture (cm)	Aver. * Length to Annulus (cm)	No.	Aver. Length at Capture (cm)	Aver. * Length to Annulus (cm)
1	41	19.5	15.1	16	20.8	15.0	2	18.4	15.0
2	714	26.3	22.8	248	25.5	22.4	200	26.3	22.5
3	831	30.1	28.0	214	29.2	27.0	346	29.8	27.8
4	328	33.9	32.3	65	32.4	30.8	139	34.0	32.5
5	67	36.2	35.0	14	35.8	34.7	36	36.2	35.1

One of the best ways to compare sizes of fish between years is to look at the opening day samples. Some of the variables caused by recruitment into the fishery of younger age classes in mid-summer, the recruitment of larger Canadian Skagit River fish in the fall, and the variabiability of growth caused by an extended sampling season are avoided for the most part. In addition, since opening day normally occurs in mid-June, close to the time of annulus formation of the scales, it is possible to approximate

annual growth from fish sampled on opening day. Table 39 displays the average sizes of rainbow trout caught on opening day in Ross Lake for the years this data is available.

TABLE 39. Average size of rainbow trout on opening day, Ross Lake, from 1973 - 1988.

Year	Average Fork Length (mm)	Location
1973	294.0	South End
1974	302.7	N & S End
1976	300.8	N & S End
1984	302.1	N & S End
1985	285.1	North End
1986	308.0	N & S End
1987	304.4	N & S End
1987	283.5	South End
1987	314.6	North End
1988	283.4	N & S End
1988	278.6	South End
1988	290.3	North End

It is evident that to be able to compare opening day average lengths, the sampling locations (north vs south ends of Ross Lake), must be considered. The average size of the fish at the south end tended to be smaller than the average size at the north end. That was not because the south end fish grow more slowly than north end fish, but rather because Canadian Skagit River rainbow at the north end of the lake were comprised of older, larger fish. On opening day these river-origin rainbow were available to lake anglers either prior to entry into the river, or as spawning or spawned out fish holding in position over the inundated river channel. Many of these fish were survivors of the previous year's run of Skagit River fish that were protected by restrictive angling regulations (300 mm minimum fork length regulation) while in the Skagit and were vulnerable to less restrictive Ross Lake U.S. regulations (no minimum size). Even considering these variables it does appear that average size of fish on opening day varied significantly from year to year. An Analysis of Variance statistical test comparing mean lengths for 1974, 1975, 1976, 1985, 1986, 1987 and 1988 indicated there was a significant difference between years 1985/1988 and the other

years. The difference appears to have been caused by the relative abundance of age 3 and older age classes compared to the abundance of age 2 fish in the harvest.

Figure 25 graphically displays variability of year class contribution when the 1987 and 1988 length-frequency distribution histograms are lined up beside each other. Note in 1987 the low numbers of larger age 3 and 4 fish at the south end sample conpared to the north end sample. Note in 1988 the reduced contribution of these larger fish at both ends of the lake.

Figure 26 displays the same type of length-frequency distribution histograms for opening days in 1973, 1974, 1976, 1986, 1987, and 1988 for all samples gathered (north and south ends combined). The variability in contribution by different size groups (age groups) is apparent and indicative of unstable recuitment.

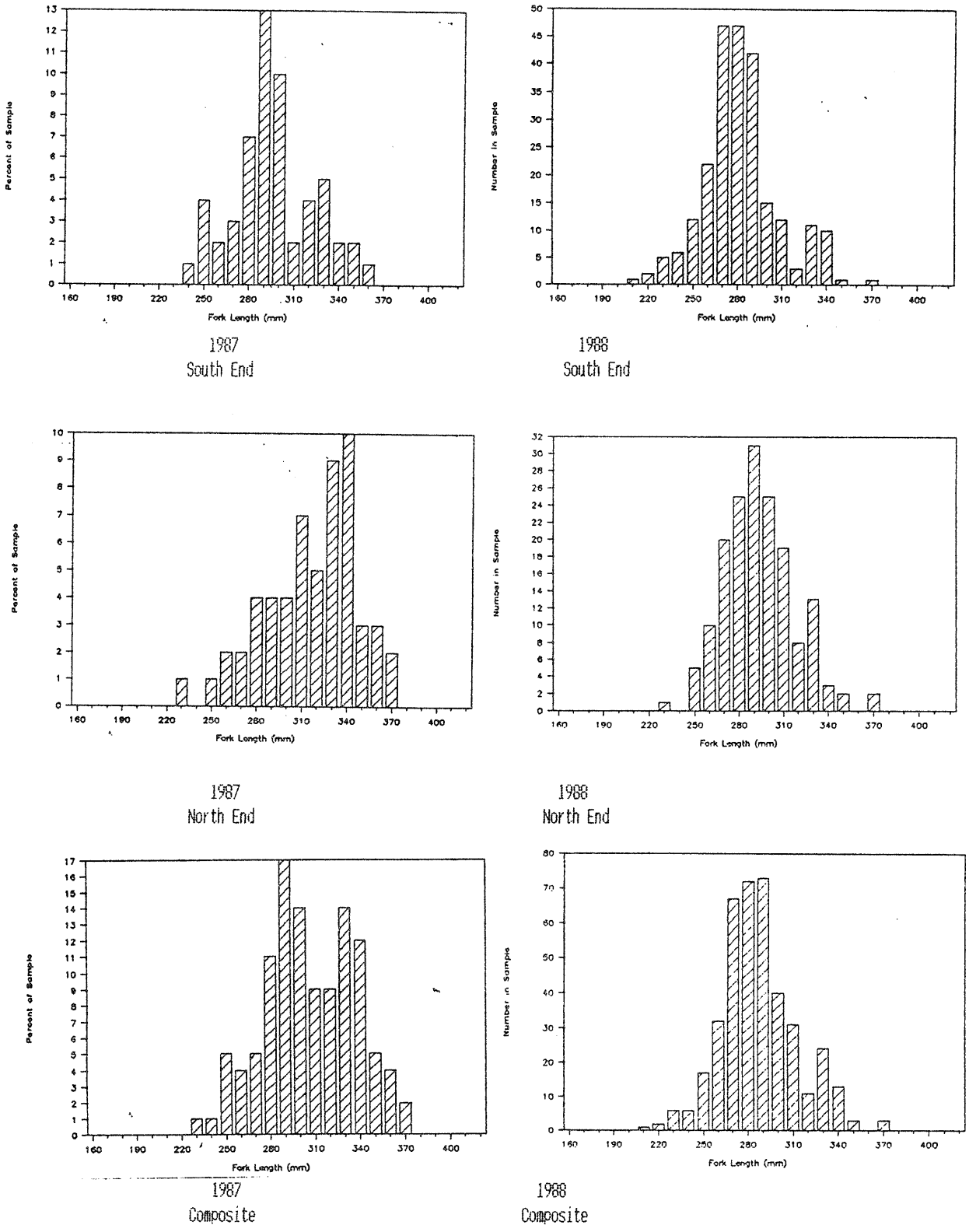

FIGURE 25. Length-frequency distribution of the opening day 1987 and 1988 rainbow trout harvest, separated into south and north end and composite Ross Lake samples.

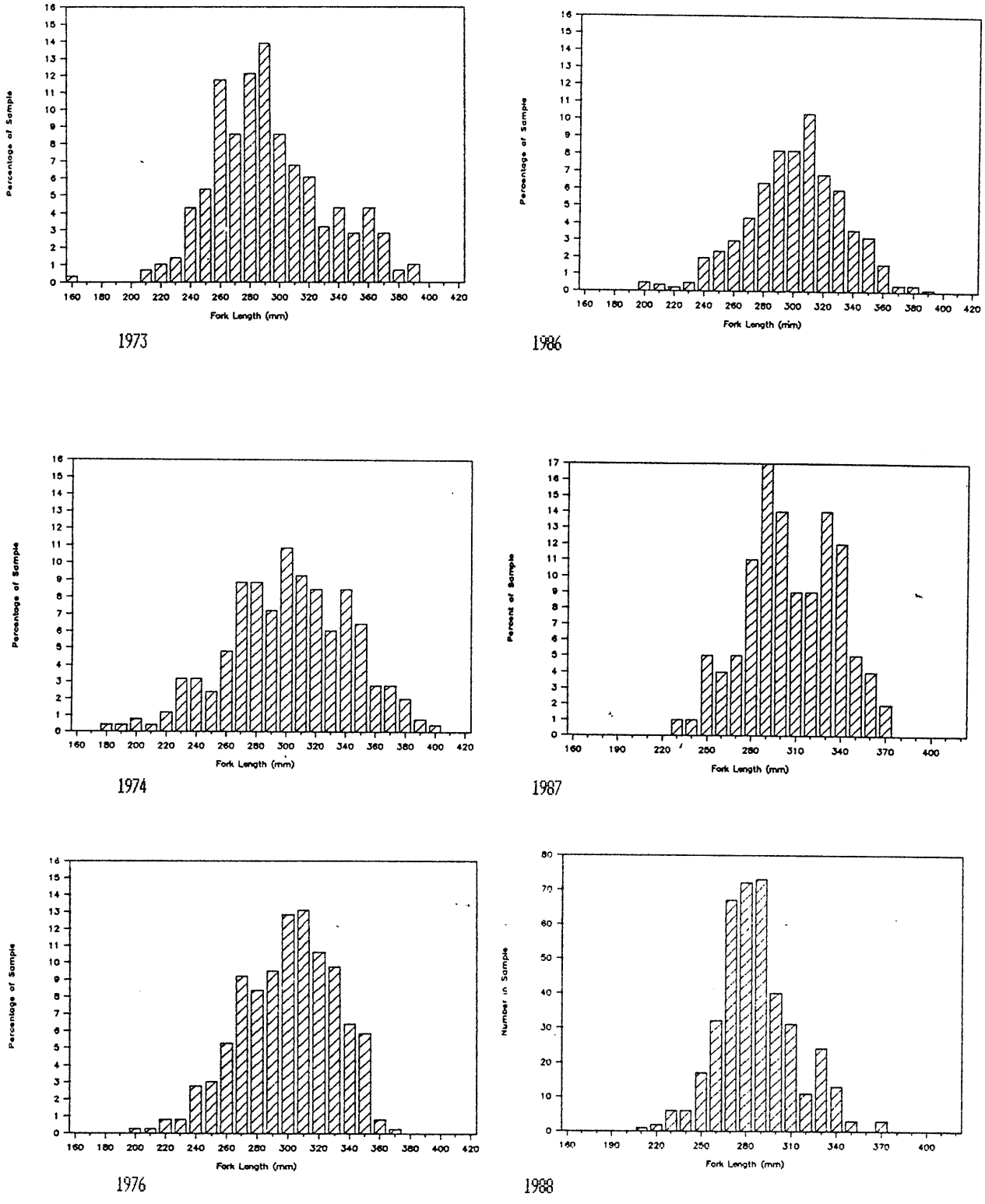

FIGURE 26. Length-frequency distribution of Ross Lake rainbow trout from opening day composite (north and south end) samples, 1973, 1974, 1976, 1986, 1987 and 1988.

Tables 7 and 11, in the Results section show the average lengths by month for 1985 and 1986. The average lengths, by month, in both years were not always similar (Figure 27). In June and July, 1985, the age 2 rainbow's average size showed negative or no growth. Since that period of time was part of the major growing season, the only reasonable explanation is the recruitment to the lake fishery of smaller age 2 fish that had been in the tributary streams or along the lake shoreline. It was noted in the 1970's that age 2 fish were not fully recruited to the lake fishery, and 1985 data indicated that large numbers entered the fishery for the first time time prior to August. In 1986, most age 2 fish in the streams or along the lake shoreline moved into the lake fishery in July. That caused the big decline in average size, shown in Figure 27, between July and August, 1986. The recruitment timing difference between those two years can also be seen in Table 34, which shows the age 2 fish percent contribution to catch peaked in July, 1985, but did not reach a peak until August in 1986. The earlier recruitment in 1985 was probably weather related. Hot dry weather (90 °F)in June reduced stream flows and probably encouraged earlier emmigration of age 2 fish and accelerated mid-lake zooplankton blooms that probably brought the small rainbow trout into the mid-lake fishery. The apparent decline in growth rate in September, 1986, of age 2 fish is believed to have been caused by natural variation and a very small sample size of 8 fish. Had a larger sample size be available the average size would probably have been near 280 mm in October.

In 1985 and 1986, the age 3 fish appeared to have different growth rates in June (Figure 27). In all probability, however, that was not the case and instead the apparent rapid growth shown in 1985 was due to delayed entry into the fishery of larger post-spawning age 3 fish, which had occurred one month earlier in 1986. The 1985 delay could have been caused either by lower lake levels in 1985 than 1986 during the spawning period, which caused mature rainbows to delay spawning but hold in closed-fishing areas until higher lake levels allowed access to spawning grounds, or, by a protracted spawning period compared to 1986. The mid-summer decline in average size of age 3 fish in both years was probably caused by immigration of larger age 3 fish into tributaries on feeding-runs (seeking larger size food items) and by some emmigrations of small age 3 fish from streams or near-shore areas into the mid-lake fishery.

Differences in 1985 and 1986, age 2 and 3 growth rates from August to October, probably reflect better season-long growing conditions in the lake in 1986.

Life history events then masked the true steady growth of the age 2 and age 3 fish during the summer growing season. The actual annual growth of Ross Lake rainbow trout in the 1970's and 1980's averaged:

alevin to age 1 = 138 mm
age 1 to age 2 = 107 mm
age 2 to age 3 = 63 mm
age 3 to age 4 = 37 mm
age 4 to age 5 = 21 mm

Generally, length and weight data indicated the following; 1) that the growth in length was greatest in the first year from length at emergence to length at 1st annulus and that growth rate in length decreased in each succeeding year, 2) After their first year, growth rate of stream resident rainbow was considerably less than trout residing in the reservoir, 3) the greatest growth in weight occurred in the third year and growth rate in weight decreased with each succeeding year, and 4) there was little difference in annual increments of growth between males and females.

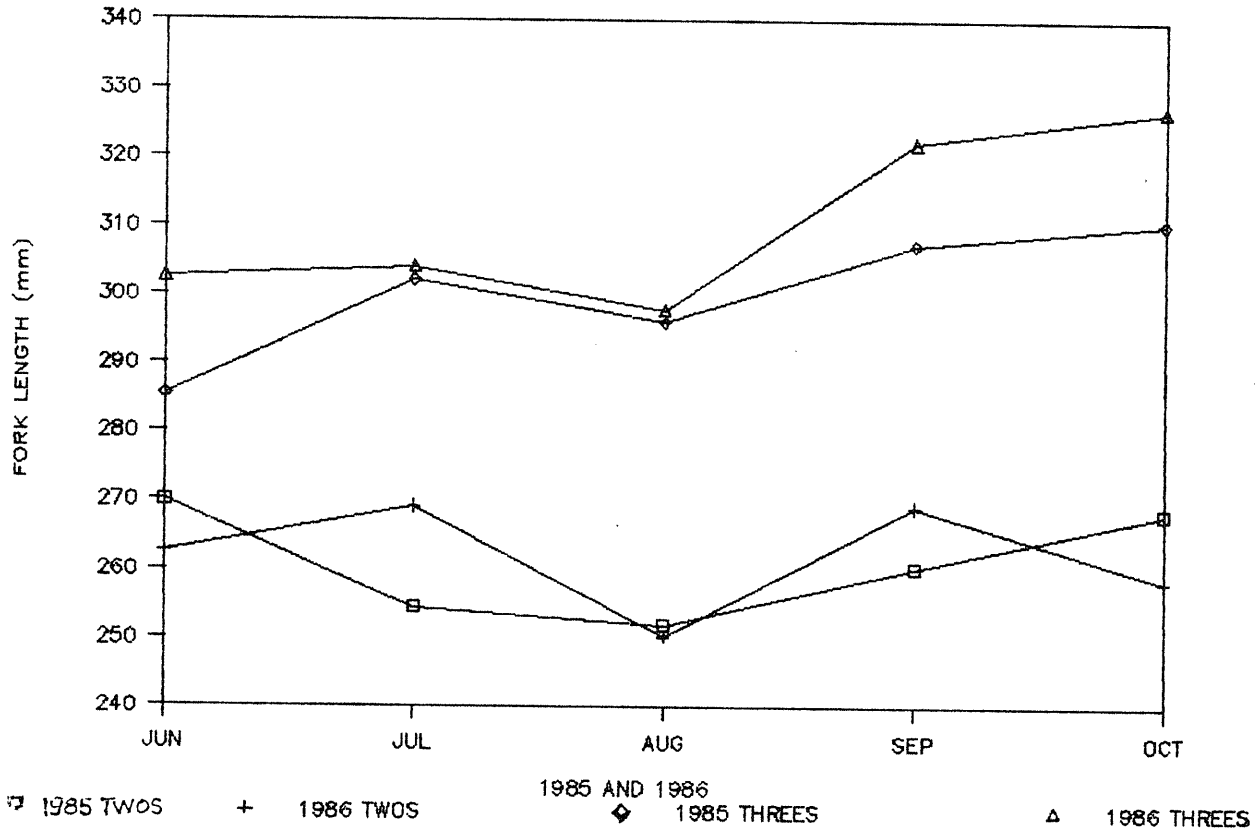

FIGURE 27. Average fork length by month of age 2 and age 3 Ross Lake rainbow trout in the sport catch, 1985 and 1986.

Canadian Skagit River

The average length of rainbow trout caught from the Canadian Skagit River in recent years can not be compared to historical data due to restrictive regulations imposed in 1985 that required anglers to release all fish less than 300 mm fork length. Perhaps some of the most important historical data on fish length was collected in 1962 and 1963 that showed over 30% of the summer harvest of rainbow were greater than 355 mm (14 inches). Table 40 contains the data from those two years of angler surveys.

TABLE 40. Skagit River rainbow trout catch data, 1962 and 1963 (Whately, 1970).

Month	#Anglers	#hours	#Rb	CPUE	Length (mm) <250	250-355	>355
1962							
May	105	355.5	141	0.40	7	102	32
June	76	256.5	92	0.36	2	76	14
July	212	1128.0	417	0.37	24	252	141
August	60	440.0	174	0.40	11	102	61
1963							
April	77	262.0	139	0.53	6	81	52
May	69	231.0	123	0.53	6	79	38
June	240	837.0	366	0.44	11	236	119
July	167	573.5	164	0.29	29	94	41
August	120	406.5	123	0.30	15	78	30

The 1960's data showed that rainbow trout in the Canadian Skagit River were larger than river samples collected in mid-1980 surveys. While the 1980's river fish were smaller than the 1960's rainbow, they were still larger on average than Ross Lake's fish. Rainbow trout captured and tagged at the mouth of the Skagit River in late spring and early summer in 1983 averaged 317 mm (range 210-430 mm); in 1984 averaged 327 mm (range 250-400 mm); in 1986 averaged 329 mm (range 175-395 mm); and in 1987 the fish averaged 324 mm (range 213-413 mm). By comparison, in 1985, the Ross Lake rainbow trout averaged 275 mm, and in 1986, 294 mm. In all likelyhood the abundance of large fish in the 1960's reflected lower angling mortality giving the fish the opportunity to live longer and grow larger. Based on length at specific ages available from current studies, the majority of these fish over 355 mm were age 5 and older.

Rainbow Trout Sexual Development

Fecundity

Fecundity (number of eggs per female) counts made in 1971 indicated no significant linear relationship between fish length and number of eggs/female (Figure 28). The average number of eggs per female was approximately 1900, and ranged from 600 to 3000 eggs per female. The fish sampled ranged in size from 270 to 390 mm (Anonymous, 1972a).

In some trout populations, older, larger females carry more eggs than younger, first-time spawners. In such cases, even though angling and/or natural mortality allows only a few fish to survive to reach older age, they often contribute a very large share of each year's production. In the case of steelhead and sea-run cutthroat, population stability is dependent upon older, repeat spawners that carry more eggs. In cases such as Ross Lake's rainbow, with no significant difference in egg count vs age of fish, first-time spawning age 3 or age 4 females are just as important to stock stability and future recruitment as the older females. If maximum production is to be attained, fishing regulations need to ensure that the majority of females will spawn one time before they can be legally harvested.

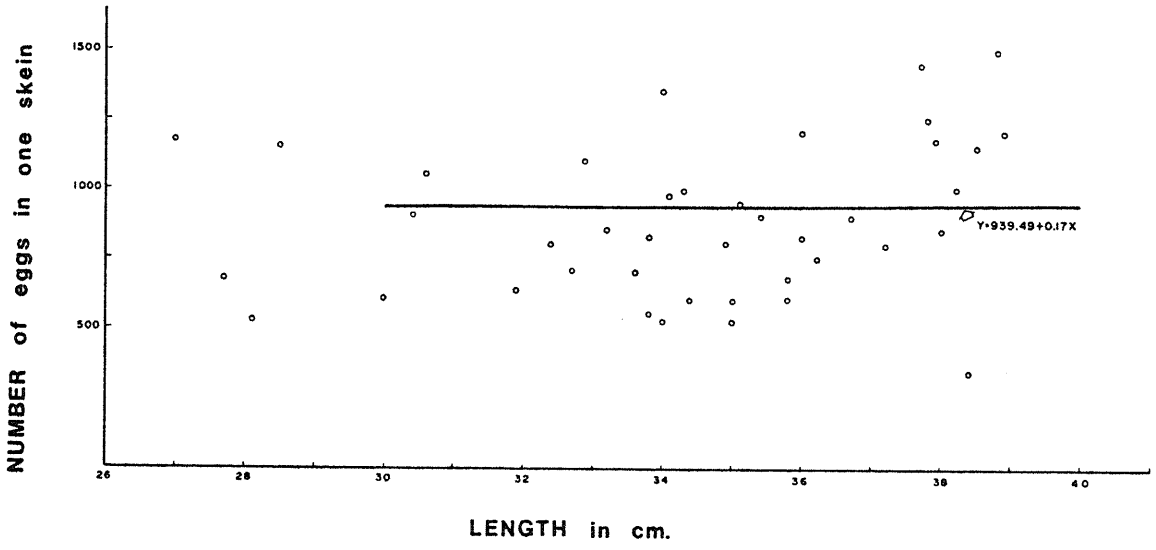

FIGURE 28. Fecundity (number of eggs per female) of rainbow trout (270-390 mm), from Ross Lake, 1971.

Spawning Time

Researchers at Ross Lake in the early 1970's found trout with running milt or loose eggs in early May and spawned-out fish by late May. They also found ripe unspawned fish as late as the end of July. The best observations of spawning activity were in Dry and Roland Creeks. Spawning activity was under way in early June and continued until late June in those two lake tributaries. The rainbow trout spawning period in the majority of American tributaries began at the end of May or early June and extended over about a 2 month period (Anonymous, 1974a).

In the Skagit River, maximum numbers of spawning fish were observed in May and early June, 1971 (Anonymous, 1972a). The first rainbow spawning in 1973 occurred about May 2, peak spawning June 4, and last spawning July 29th (Anonymous, 1974a).

Appendix 4 contains field notes on observations of spawning rainbow trout in several U.S. tributaries in 1974 (FRI Unpublished Report, 1974).

In 1985 and 1986, peak spawning in U.S. tributaries occurred in mid-June and spawners were still observed on redds in late July.

Sexual Maturity of Catch

The sexual condition of the 1974 and 1976 opening day samples are compiled from Fisheries Research Institute data. The sexual condition of the 1986, 1987, and 1988 samples were taken during opening day creel surveys at the Hozomeen Campground and Ross Lake Resort. In both the 1970's and 1980's, an egg size of 2 mm and larger was considered to be from a fish that would have spawned in the year sampled

Very little difference in percent of females vs males existed in the opening day catch between years (Table 41). The percentage of females ranged from 53 to 66 percent, between 1973 and 1988. The average was 62 percent females and 38 percent males for the 1055 fish sampled between 1973 and 1988. The cause of the unbalanced sex ratio is unknown, but it may have been due to age at maturity for males as compared to females.

TABLE 41. Sexual condition of opening day caught rainbow trout, Ross Lake, 1973, 1974, 1976, 1986, 1987 and 1988.

YEAR	SEX	IMMATURE	MATURE	SPAWNOUT	TOTAL	PERCENT BY SEX
1973	FEMALES	113	5	14	132	53.2
	MALES	104	11	1	116	46.8
1974	FEMALES	146	5	2	153	65.1
	MALES	69	13	0	82	34.9
1976	FEMALES	203	9	12	224	66.3
	MALES	89	24	1	114	33.7
1986	FEMALES	19	0	2	21	61.8
	MALES	13	0	0	13	38.2
1987	FEMALES	65	0	9	74	65.0
	MALES	33	1	6	39	35.0
1988	FEMALES	50	1	4	55	63.0
	MALES	27	1	4	32	37.0

In 1974 fish scales were examined for previous spawning checks. The spawning checks indicated that males first spawned at age 2 and females first spawned at age 3. That is not to say that all fish in the lake first spawned at those ages; the samples indicated 10 percent of the female spawners were first time spawners at age 4, and one waited till age 5 to spawn for the first time. Among the males, some were found to spawn for the first time at age 4. The males were noted to have a higher frequency of repeat spawning than the females. This could have been due to the earlier age at which males mature, or males were more likely to lay down a spawning check than females. Another interesting factor was the sex ratio in the spawners sampled; 1.22 females per male. If there was more repeat spawning in males, there must have been less mortality on females, or else there was an unbalanced sex ratio throughout their life cycle. The angler catch for the 1973 season was 1.34 females per male, and in 1974 the ratio was 1.93 females per male; which did indicate an unbalanced sex ratio (FRI Unpublished Report, 1974) as previously discussed.

In 1974 the incidence of rainbow trout that were spawning in 1974 and had spawned in previous years was noted from spawning checks on their scales. Out of a sample of 55 males it was noted that 52.7 percent were spawning for the first time, 41.8% were spawn-

ing for the second time and 5.4% were spawning for the third time. Among a sample of 67 females, 61.2% were spawning for the first time, 38.8 percent were spawning for the 2nd time and 2.9 percent were third time spawners. It was noted that 3 females and 3 males sampled were not spawners in 1974 but had spawned in 1973; indicating skip-spawning occurred or the fish were not always laying down a spawning check.

On opening day, between 1973 and 1976, mature, yet to spawn fish were more prevalent in the Ross Lake catch (8% mature and 4% spawnouts) than in the 1986 to 1988 catches (1% mature and 11% spawnout). Since the opening day of fishing occurred at approximately the same time in mid-June in these years, it was possible there had been a shift in time of spawning. Such a change could occur if fish spawning during or after the opening day of fishing were subjected to high angling mortality and the genetically controlled late spawning segment of the population was disappearing. That explanation is more likely than environmental change. In fact, reservoir operations that affect lake level and cause destruction of early spawning nests should have quite the opposite affect, i.e., inundation of early spawners' nests and subsequent poor survival would select for later spawning fish.

Table 41 also shows that betweem 1973 and 1976, 91 percent of all females caught on opening day were immature, and between 1986 and 1988, 89 percent of all females were immature. Females comprised 62 percent of the catch on opening day. Table 42 contains data on sexual maturity of male and female rainbow for the full fishing season harvest in 1971, 1972 and 1973 (Anonymous, 1974b). It also shows that throughout the fishing season females constituted a higher proportion of the catch than male rainbows and that a little less than half of all females caught from June to October were immature and did not spawn in the year sampled. Since contribution by females changed little over the season, it is important to look at the ages of the immature females to determine whether a significant portion of the harvest was comprised of females destined to spawn the following year.

TABLE 42. Sexual maturity of Ross Lake rainbow during the 1971, 1972, and 1973 fishing seasons.

Year	Age	No. fish sexed	No. females	% females mature	No. males	% males mature	Total mature	% Total mature females	% Total mature males
1971	1	50	23	0.0	27	0.0	0		
	2	170	79	0.0	91	35.16	32	0.0	100.0
	3	116	75	41.33	41	56.10	54	57.40	42.59
	4	35	20	55.00	15	26.66	15	73.33	26.67
	5	12	11	54.54	1	100.0	7	85.71	14.28
	6	1	1	100.0	0		1	100.0	0.0
1972									
	1	71	34	0.0	37	0.0	0		
	2	161	66	0.0	95	54.73	52	0.0	100.0
	3	102	62	43.55	40	62.50	52	51.92	48.08
	4	54	35	62.86	19	73.68	36	61.11	38.89
	5	10	8	87.50	2	50.00	8	87.50	12.50
	6	1	1	100.0	0		1	100.0	0.0
1973									
	1	38	20	0.00	18	0.00	0		
	2	434	195	0.00	239	44.77	107	0.00	100.0
	3	442	288	58.33	154	66.23	270	62.22	37.77
	4	212	143	86.01	69	78.26	177	69.49	30.50
	5	21	12	91.66	9	77.77	18	61.11	38.89
	6	0	0		0		0		

In 1988 and 1987, age 3, immature, females comprised 61 and 62 percent of all immature females caught on opening day, with the remainder being predominantly age 2 fish. Out of every 100 fish caught on opening day, 35 were age 3 immature females.

In 1988, the average fork length of age 3, immature, female rainbow trout was 287 mm. That is very close to the average size of these same fish in 1987; 291 mm. Figure 29 is a picture of two anglers', opening day catch in 1987 from the north end of Ross Lake. All of the fish in the photograph were immature age 3 females, less than 300 mm (12 inches) fork length.

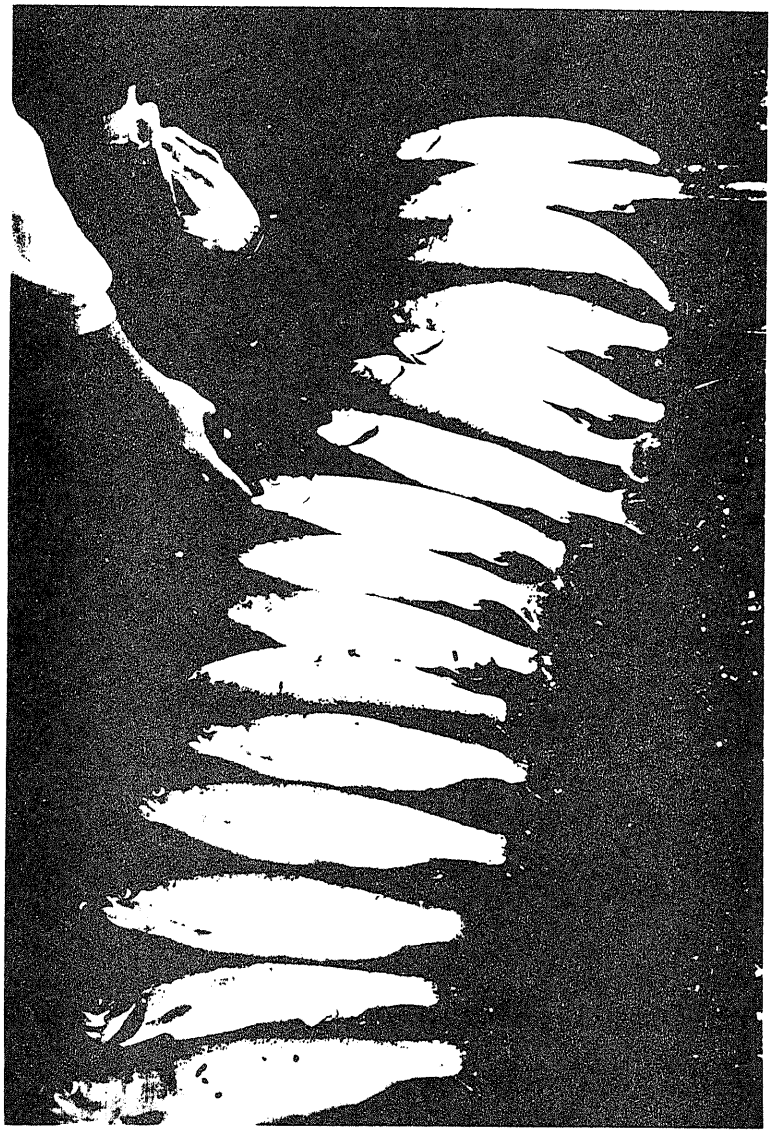

FIGURE 29. Photograph of two anglers' opening day catch at the north end of Ross Lake, 1987. All fish were immature age 3 female rainbow trout.

There are strong indications that not all rainbow trout migrating into the Ross Lake tributaries are spawning fish. For example, Skagit River samples in 1971 showed a greater proportion of ripe fish were males than females, both early and late in the spawning season and, between May 11 and June 24, gill net samples showed 38 out of 356 females and males were immature fish (11%). In a 1985 study of the Canadian Skagit River some of the fish were sacrificed to determine sexual maturity (Table 43). Most were caught on the U.S. side of the border in the draw-down area. Many of the relatively large rainbow in the sample (up to 369 mm) were immature and would not spawn in 1985. These findings give further indication that not all fish which are part of the spawning run are going to spawn and that often what could be termed "feeding run" fish are large, older fish that may be skip-spawning, or age 3 fish (predominantly immature females).

TABLE 43. Canadian Skagit River rainbow, non-randomly selected for sexual maturity confirmation, 1985.

Date	Length (mm)	Sex	Maturity
4/19	325	F	Immature
4/20	336	M	Immature
4/20	340	F	Immature
4/29	321	F	Immature
5/4	295	F	Immature
5/13	297	F	Immature
5/13	340	F	Mature
5/13	332	F	Mature
5/13	309	F	Mature
5/13	330	F	Mature
5/13	340	F	Mature
5/13	315	F	Immature
5/14	349	F	Mature
6/30	365	F	Immature

Inter-relationship Between Fish of Ross Lake and Tributaries

Migrations

Accessible Spawning Locations

While some references cite estimates of lineal stream distances accessible to spawning migrations of Ross Lake fish, most have not accurately totaled the distances involved. The best estimate

available is 48.7 miles of U.S. tributaries and, according to Whately (1970), 20.2 miles of Canadian streams; for a total of 68.9 miles (Table 44).

Even though the lineal distance of the U.S. tributaries is twice the distance of the Canadian streams, in total flow and surface area, the two are about equal. In terms of abundance of suitable spawning gravel and gradient, the Canadian Skagit River is a more optimum fish spawning environment.

TABLE 44. Lineal stream miles of accessible spawning areas for Ross Lake fish.

Stream	Spawning Sites
International Creek	mouth
Hozomeen Creek	mouth and lower 0.50 miles
Silver	mouth and lower 0.49 miles
Arctic Creek	mouth
No Name Creek	mouth
Little Beaver Creek	mouth and lower 0.09 miles
Skymo Creek	mouth
Lightning Cr.	mouth and lower 0.23 miles
Dry Cr.	mouth and lower 0.48 miles
Pierce Cr.	mouth and lower 0.08 miles
Roland Cr.	mouth and lower 0.31
Ruby Cr.	mouth and 3.60 miles
Canyon Cr.	16.10 miles
N.F. Canyon Creek	0.62 miles
Slate Creek	0.47 miles
Mill Creek	1.23 miles
Panther Creek	0.41 miles
Granite Cr.	16.45 miles
Roland Creek	mouth and lower 0.31 miles
May Creek	Mouth
Devils Creek	Mouth and lower 0.08 miles
Big Beaver	Mouth and lower 6.94 miles
Total miles of accessible U.S. tributaries	48.69 miles
Total miles of accessible Canadian Skagit River	20.20 miles

In addition to stream spawning, the shoreline of Ross Lake in the immediate vicinity of the mouths of Ruby, Lightning, Big Beaver, and Roland Creeks appear to support spawning by rainbow trout. The survival of any eggs deposited in these areas is questionable due to inundation by lake waters as the reservoir is filled.

Migration Barriers

In several of the U.S. tributaries there are partial or complete barriers to migrations of Ross Lake trout and char. Some of these barriers are seasonal and caused either by low lake water levels and/or accumulation of driftwood debris along the beach line (Dry Creek and Roland Creek). Other obstacles are steep gradient and/or waterfalls at the mouths of some of the tributaries (Big Beaver Creek, Little Beaver Creek, Devils Creek, May Creek, Skymo Creek, Arctic Creek, and No Name Creek). Other instream migration barriers are caused by temporary or semi-permanent log jams and gravel accumulations (Lightning Creek). In some instances, removal of the barriers, or provision for access routes around the barriers, would add several miles of spawning and rearing habitat for the Ross Lake fish; a necessity if we want the depressed fish populations to recover as rapidly as possible and maintain themselves. The following are descriptions of three of the more serious barriers and suggested remedial actions.

Lightning Creek Migration Barrier

In Lightning Creek there are four known barriers to fish migration. If the 1648' level fish migration block in Lightning Creek were removed the fish could migrate an additional 1.75 miles upstream to approximately the 2000' elevation level near the confluence of Three Fools Creek. In addition, three migration blocks are located a short distance upstream from the confluence of Three Fools Creek (Eggers and Gores, 1971). Each block could easily be made passable to fish by removing the logjams which form them, thus making another 3.9 miles of stream accessible to fish. This additional stream section has excellent potential for trout and char spawning because of its clean gravel substrate and long riffles.

The removal of the Lightning Creek log jams could carry an unknown degree of genetic/biological liability. The opening of the upper 3.9 miles of tributaries would probably allow the migratory Ross lake rainbows to hybridize with the stream resident rainbow. The resident rainbow must be genetically programmed not to migrate to the lake in any significant numbers. If that were not the case there would be no resident fish left today. The impact of hybridization on both resident and migratory populations would likely be a loss over time of the resident fish and an overall increase in rainbow trout production of Ross Lake origin fish. It would also result in the necessity to close to fishing that portion of Lightning Creek and its tributaries used by the spawners. However, this loss of stream-fishing, recreational opportunity should be more than off-set by increased harvest of Lightning Creek origin fish in the lake fishery.

Big Beaver Creek Migration Barrier

The falls at the mouth of Big Beaver Creek are at times a migration barrier to fish, depending upon reservoir draw-down levels and refilling schedules. It was reported in 1971 (Anonymous, 1972b) that a 9-foot falls formed a fish migration block at the 1578'elevation with the top of the falls at the 1587'elevation. According to that report, fish are prevented from entering Big Beaver Creek until the lake rises sufficiently to eliminate the barrier. However, additional falls and a high velocity chute located above the 1587' elevation further restrict fish access under high stream flow condition.

Ripe cutthroat trout were captured off the mouth of Big Beaver Creek on June 1, 1972 at a time when a falls at approx 1596' elevation probably blocked trout migration into Big Beaver Creek.

On the June 16-17, 1971, Big Beaver Creek float trip, covering the lower 4 miles up to 1625' elevation, three rainbow and one cutthroat greater than 250 mm and 6 fish of undetermined species were observed. In the upper 3 miles above 1625' elevation, three rainbow, 2 cutthroat and 1 dolly varden, all greater than 250 mm, plus 1 dolly varden 250 mm and 25 undetermined species, were counted. This data would indicate that some rainbow are able to ascend the falls at the mouth of Big Beaver Creek during the peak spawning period for that species. The counts should be considered as an indicator of access only, since stream visibility precluded any true assessment of abundance.

Biologists floated Big Beaver Creek June 20-22, 1972, covering the upper 4 1/2 miles of the lower 7 miles of stream. The lower 2 1/2 miles were floated on April 26, 1972. No rainbow trout spawners were observed, but considering the timing of the April float (the lake was down and the falls at the mouth would limit trout entry) and the avoidance of the lower 2 1/2 miles on the June float (the area where all of the rainbow were seen in the October, 1986 float), the 1972 surveys of this stream must be considered incomplete and not definitive regarding rainbow spawner utilization.

A one time survey of Big Beaver Creek was made on October 9, 1986 to determine its productive potential for rainbow trout and dolly varden. Previous surveys done in the 1970's by the Fisheries Research Institute of the University of Washington indicated little or no rainbow trout usage. The 1986 survey does not support those earlier findings in that this latest assessment showed the stream being used by hundreds of 250 - 375 mm rainbow trout. These fish appeared to enter the stream on a spawning and/or feeding run. The timing of their entry into the stream was unknown but it most likely coincided with maximum lake level and falling stream flows, which would place entry sometime after

mid-July. In all probability then, these fish were entering the stream too late to spawn and were feeding-run fish. The trout probably return to the lake by mid-November. It is known that at least one large rainbow took such a journey. A rainbow trout (373 mm), which was tagged at the mouth of Lightning Creek on April 19, 1971, was recaptured and released in the mouth of Lightning Creek on July 6, 1971 and was again recaptured and released in Big Beaver Creek 6 3/4 miles upstream from the lake on October 7, 1971.

It appears that one of the primary limiting factors to rainbow trout production in Big Beaver Creek is the falls at its mouth. Steps could be drilled or blasted into the rock that would provide dependable access during the rainbow trout and dolly varden spawning runs over a wide range of lake levels and stream flows. That would add approximately seven miles of stream for more consistant Ross Lake rainbow trout and dolly varden char production.

Roland Creek Migration Barrier

It was noted on June 9,1986 that a large Seattle City Light boom log was lying perpendicular to the mouth of Roland Creek, creating a water fall and trout spawning migration blockage. Several thousand trout were milling around in the lake in front of the stream. On June 10th, Washington Department of Wildlife diverted the stream channel into a new course to bypass the barrier. On June 13th, 2500 to 3000 trout were observed spawning in the lower 300 yards of the creek. Contact was made with National Park personnel and they arranged removal of the barrier with SCL. These temporary barriers located near the stream mouths should be identified and their removal be part of an annual maintenance program (with the exception of the interlocking debris at the mouth of Dry Creek which is retaining the stream's best spawning gravel but is not a blockage to fish migration).

Migrations of Fish Tagged in Ross Lake

Results from tagging 514 rainbow, 21 cutthroat, 33 dolly varden, and 1 eastern brook in Ross Lake and the Canadian Skagit River in 1971 indicated considerable movement in the lake and some movement into the Skagit River during tagging and recovery (April through October, 1971). Fish tagged in the Lightning Creek area showed the greatest variation in pattern of movement. Fish tagged in this area were recovered in every lake area although more were recovered north of Lightning Creek than south of this area. This undoubtedly reflected, in part, the greater fishing effort toward the north end of the lake. Ten rainbow tagged in the lake were recovered in the Canadian Skagit River, but only one of these came from the three tagging areas to the south of

the Lightning Creek area, although more than half of the tagged fish were released in these areas. Cutthroat tended to stay near the area tagged--Big Beaver Bay (Anonymous, 1972b).

In 1972, researchers tagged 837 rainbow, 36 cutthroat, 77 dolly varden, and 4 eastern brook in the lake and Skagit River. Most tagging was done at the south end of the lake. 1972 recoveries of fish tagged in the Ruby and Roland Point areas were made in all areas of the lake but not in the Skagit River (Anonymous, 1973a).

Distribution and movement were recorded in 1973 for 1353 rainbow, 230 cutthroat, 36 dolly varden, and 8 eastern brook tagged in Ross Lake, Skagit River, and Big Beaver Creek beaver ponds. Fish tagged in the Ruby Creek area of Ross Lake were found in all lake areas and up to 28-Mile Creek on the Skagit River. Recovery locations indicated a uniform distribution of tag recoveries in the lake and river (Anonymous, 1974a).

Migrations of Fish Tagged in the Canadian Skagit River

Movement of fish into and out of the Skagit River, as well as their density over time, were recorded in 1970-71. Snorkle floats were conducted between October 1970 and October 1971. Density of rainbow trout varied from 2.6 to 67.1 fish per mile surveyed. Numbers were low in mid-October of 1970 and 1971; numbers were high throughout August and September. These data indicated rainbow trout leave the Skagit River in the fall. In 1973, divers counted low numbers of rainbow trout (0.3-7.8 fish per mile) from late March to mid-April and increasing numbers (7.3--57.8 fish per mile) from late April to late May (Anonymous, 1972b).

A series of Skagit River floats in 1973 showed a large increase in trout entering the stream between April 17 and April 30: 1 fish in 3 miles versus 217 rainbow in 5.5 miles of stream (Anonymous, 1974a). These appeared to have been the first pulse of the annual spawning run from Ross Lake and gave further indication that few rainbow over-winter in the Canadian Skagit.

Swim Surveys of the Skagit River were again conducted between August 23-31, 1982. Divers observed that 95% of the total fish in Skagit River were rainbow (1110 of 1162 fish observed). Catchable sized fish, fish greater than 200 mm, appeared thinly scattered, but the largest number were concentrated in first 16.5 km above Ross Lake. An estimated 2400 fish (>200 mm) were in the river up to barrier falls and 1000 in mainstem above falls (8m, 25m, and 15m high falls). Based on analysis of scale samples from stream-caught and reservoir-caught fish, it was concluded that 70-80% of the catchable size rainbow observed in the Skagit

drainage below the falls were migrant fish from the lake. The authors felt the results indicated the major function of the Canadian Skagit drainage was to provide rainbow recruits to Ross Lake (Griffith and Greiner, 1983). Scale samples from the river fish supported that contention. Stream caught rainbow trout scale samples from 1952, 1965, and 1978-80, indicated that the majority exhibited the same patterns of growth found on scales from 1982 Ross Lake caught fish.

A Skagit River rainbow trout tagging study was conducted from July 9 to Sept 3, 1983. Researchers tagged 232 fish and recovered 60 tags; 54 from the river and 6 from Ross Lake. The fish recaptured in the river showed little or no movement over extended periods. Fish recaptured in Ross Lake were from both the upper and lower section of the Skagit River. Fish were recaptured as far as 25 km down lake. Fish tagged ranged in fork length from 215 mm to 425 mm, with a mean length of 319 mm. Snorkle floats during August indicated 94 percent of the fish in the river were rainbow trout. A snorkle float on October 24, 1983 indicated few large fish were left in the river. Tagging data provided no evidence of any gradual downstream movement; movement out of the river and into the lake was rapid. (Bech, 1984).

Scale analysis and other data from 1982 and 1983 suggested that the majority of Skagit River rainbow were immigrants from the Lake, holding over the summer in the river following spawning and/or feeding run migrations (Griffith, 1985). With the exception of areas above and immediately below the barrier falls on the Skagit mainstem, there did not appear to be a significant population of resident rainbow trout of catchable (>200 mm) size. The author concluded that the Skagit mainstem appears to be the system's major juvenile trout production area. Highest densities of these fish, on average, were located in the lower most reach, and declined with progression upstream. Swim surveys in 1982 and 1983 supported the conclusion that areas below the falls served primarily for recruitment/rearing of reservoir migrants. It appeared that once sub-catchable rainbow left dense rearing habitat areas below the falls, the large majority did not take up residence in deeper portions of the stream and remain as year around stream residents.

Instream movement of rainbow trout was investigated in the Canadian Skagit River, in 1983 and 1984. In 1984 investigators marked (Floy tagged) 159 rainbow greater than 250 mm fork length between July 11 and Sept 30, 1984. The results were similar to the 1983 study findings. Some fish tagged in 1983 were recaptured in 1984, in close proximity to where they were tagged--suggesting a homing mechanism may be functioning within the system. Summary of movements: 10% showed minor upstream movement, 60% showed little or no movement, and 30% showed downstream move-

ment in late summer-early fall. Nearly 75% of marked fish showing downstream movement were recaptured after Sept 15 (Usher, 1986).

Bech (1984) suggested that when the catchable rainbow leave the system, they probably migrate rapidly. It may be that falling stream temperatures or other environmental stimuli trigger the emigration.

In a 1985 tagging study, with 297 tags applied between May 1-17, 1985, in the drawdown area of the reservoir but in the Skagit River channel, results indicated at least 14% of the tagged fish were captured by the sport fishery between June 15 and October 17, 1985. The majority (76%) were recovered from Ross Lake while 24% came from the Canadian Skagit River. Tag recoveries from Ross Lake were most frequent during late June and early July and declined thereafter. Early tag recoveries were near tagging sites while later recoveries were more evenly distributed throughout the Lake. Tagged fish were reported at the south end of reservoir on June 14th. Results of this study showed that only a portion of the Skagit River rainbow spawning stock remained in the river after spawning (to contribute to the fishery). The earlier tagging studies (pre 1985) could not have detected the portion of the migratory stock that returns to Ross Reservoir shortly after spawning since those fish would have migrated back before initiation of the tagging study (Scott and Peterson, 1986).

Rainbow tagging and test fishing studies were conducted in the Canadian Skagit River between April 15 and October 31, 1986. From April 15 to May 19, 1986, 1276 rainbow were captured and tagged in the lower reaches of the Skagit River. Between June 9 and October 25, 1986, 1034 rainbow were caught in the test fishery in the Skagit River. Seventeen of these fish were from the 1986 study and one from 1985. The author concluded the trout displayed a life history that showed a dependence upon both lake and stream environments (Scott, 1986).

Summary on Migrations: The Ross Lake-Skagit River tagging studies, conducted between 1971 and 1973 showed that fish tagged in all areas of Ross Lake were subsequently caught randomly throughout the lake and in the Skagit River fishery. Conversely, rainbow tagged in Skagit River studies in the 1970's and 1980's were later recovered in all areas of the reservoir fishery-- most of those rainbow had been tagged in the Skagit River or in the draw-down area at the mouth of the Skagit, during the spring and summer months, but this does not mean those fish originated from the Skagit. These rainbow trout could have been feeding-run fish with natal streams other than the Skagit River. The movement observations tended to support the theory that the Ross Lake rainbow trout populations have both spawning and feeding runs; in some cases to a stream(s) other than natal spawning stream fol-

lowing spawning, or non-spawners (immature fish) that moved into natal or non-natal streams just to feed, and then return to Ross Lake in the fall. The inter-mixing of fish populations, from different Ross Lake tributary streams with Skagit River fish and movement of Skagit River fish into Ross Lake, creates mixed stock fishery problems in setting harvest regulations. Minimum size limits designed to promote survival and growth in one area may not be succssful in the long term, as potentially the case of the Skagit River, if the protected fish migrate to Ross Lake during an open lake season with less restrictive regulations. Cooperative fisheries management necessitates regulations for British Columbia's and Washington's portion of the Ross Lake drainage that do not preclude attainment of either country's management goals.

Fry Production From Tributaries

A review and discussion of the inter-relationships between the fish and fishery of Ross Lake must include fry production. Migrations of fish between the lake and stream environments and use by spawning fish are just part of the picture.

Each tributary, based upon habitat, flow, temperature, and spawner access, can contribute highly variable fry numbers to the total lake/tributary system fish production. Seemingly insignificant small tributaries can be major contributors and the cumulative contribution of all small tributaries can potentially exceed the trout production of the largest.

Fry Emergence and Emigration Timing

The timing of fry emergence and emigration from the Ross Lake tributaries varies from year to year. Stream flows and water temperature seem to be the two most important variables that control spawning time, emergence, and emigration of the progeny. Low stream temperatures and low flows at spawning time tend to delay spawning, and therefore subsequent fry emergence. During the period the eggs are in the gravels of the tributaries, low temperatures delay egg development and hatching dates. Low flows following hatching can accelerate the outmigration timing of the newly emerged fry.

Table 45 compares mean stream temperatures during the primary rainbow trout incubation period in several of the U.S. tributaries. The year to year and stream to stream variablility in temperatures is clearly shown and explains to a large degree why, for example, in 1974 spawning was later than in 1973 and why emergence of fry from the gravel and timing of downstream migra-

tion to the lake was about two weeks later in 1974 than 1973. These annual variations in time of arrival of the fry into the lake environment can have an influence on the first year's growth rate of the fry and even their survival. Many of the fry do not enter the lake until late fall when lake levels are dropping and food supplies are beginning to diminish.

TABLE 45. Mean stream temperatures (°F) from June through mid-August in U.S. tributaries, 1971 - 1974.

Year	Ruby	Big Beaver	Roland	Dry	Lightning
1971	46.0	43.9	---	---	45.7
1972	44.0	45.8	45.8	45.6	45.0
1973	48.8	46.8	50.2	50.3	49.1
1974	45.4	---	45.2	47.5	44.6

Between 1971 and 1975 fry emergence/outmigration were studied on several tributaries to Ross Lake. Newly emerged rainbow trout fry, 21 to 24 mm in length, were usually first observed in mid-August. The first stream the fry normally appeared in was the Canadian Skagit River on dates ranging from July 19 to August 14 over four years of observation. Closely following Skagit emergence, fry were first observed in Dry Creek (August 6 to 16). Several streams with similar first emergence timing of August 13 to 30 were observed over the four year period (Ruby, Lightning, Roland, Big Beaver, and Devils Creek).

The duration of emergence and emigration of fry often extended into October on the study streams (Table 46).

Fry Contribution Estimates

The estimates made of fry contribution from tributaries between 1971 and 1973 are suspect due to timing of trap placement (often after downstream migration had begun) , due to location of trap placement and design (failed to capture fish). This is unfortunate for it was during those years that the Canadian Skagit River was trapped, while during the 1974-1975 time period, when trap design, placement and timing were perfected, the Skagit was not trapped. In general terms, however, if we assume equal inefficiency in trapping on all streams in 1971-73, then approximately 45 percent (129,249 fry) of production measured in that time period may have come from the Canadian Skagit River. The 1971-1975 sampling did not include all tributary streams or

any stream mouths, therefore any conclusion that the Skagit produced approximately one-half of all fry emigrating into Ross Lake would be too generous; it would be probably more valid to estimate contribution ranged from 30 to 40 percent of total system production.

Rainbow trout fry were monitored as they emigrated from their natal streams to Ross Lake in 1973, 1974, and 1975. The trout were captured in fyke nets (2X4 foot openings for Lightning and Ruby Creeks and 2X2 foot openings fished in Dry and Roland Creeks. Rigid live boxes were attached to prevent fry mortality. The fyke nets were fished near the lake level, or in the case of Beaver Creek, at the 1645 foot elevation (7 miles upstream from mouth). The nets in Big Beaver Creek were normally set for one twenty-four hour period each week. The nets in the rest of the tributaries were normally set on Monday and checked daily until they were removed on Friday. Table 46 contains the actual fry catches made in 1975 and Table 47 contains the expanded estimates from actual catches after adjusting for stream discharge (Wyman, 1975).

TABLE 46. Actual fry catches from five U.S tributaries sampled om 1975 (from Wyman, 1975).

Date	Roland Cr. (1603')	Dry Cr. (1606')	Lightning Cr. (1603')		Ruby Cr. (1604')		Big Beaver Cr. (1645')	
			North Net	South Net	North Net	South Net	North Net	South Net
8/1	0	0			0	0		
8/5	0	0	0	0	0	0	0	0
8/6	27	0	0	0	0	0		
8/7	24	25	0	0	0	0		
8/8	23	4	0	0	0	0		
8/12	142	29	0	0	0	0	0	0
8/13	91	19	0	1	0	0		
8/14	75	48	0	0	0	0		
8/15	**	54	0	0	1	0		
8/19	**	25	6	5	0	0		
8/20	143	95	3	5	1	0		
8/21	225	69	0	4	0	0	2	0
8/22	277	17	1	2	0	0		
8/26	116	44	3	**	2	1	1	1
8/27	70	65	11	24	2	5		
8/28	1*	10*	6	27	4	5		
8/29	37*	15*	2	19	0	4		
9/3	111	77	8	5	1	2	1	0
9/4	113	35	0	30	3	6		
9/5	84	19	11	49	4	8		
9/9	61	26	7	27	13	10	0	2
9/10	101	48	9	15	4	14		
9/11	87	59	0	18	5	6		
9/12	52	48	3	25	7	13		
9/16	23	6	3	3	8	2	0	0
9/17	8	6	2	5	7	2		
9/18	10	14	1	1				
9/19	11	8	3	2	11T	7T		
9/23	11	8	0	6	2	3	0	0
9/24	8	7	3	6	5	5		
9/25	14	5	1	8	1	3		
9/26	4	5	5	2	3	2		
9/30	4	1	3	8	0	6		
10/1	2	5	1	1	1	3		
10/2	1	1	1	3	1	4		
10/3	2	0	0	4	2	0		
10/7	0	0	1	0	1	4		
10/8	1	1	0	2	0	0		
10/9	1	0	0	0	0	0		
10/10	3	1	0	1	1	3		
10/14	0	2	0	0	0	0		
10/15	1	0	0	0	1	0		
10/16	0	0						

TABLE 47. Estimated catches of rainbow fry from four tributaries to Ross Lake, 1975 (from Wyman, 1975).

Date	Roland Cr. (1603')	Dry Cr. (1606')	Lightning Cr. (1603')	Ruby Cr. (1604')
8/6	456			
7	254	41		
8	200	11		
9	436*	23*		
10	673*	34*		
11	909*	46*		
12	1145	57		
13	561	79*	31	
14	779	101	0	
15	859*	155	0	34
16	939*	132*	10*	26*
17	1019*	110*	21*	17*
18	1099*	87*	31*	9*
19	1179*	64	41	0
20	1259	242	50	33
21	1729	324	60	0
22	2289	61	38	0
23	2109*	68*	113*	24*
24	1930*	74*	188*	47*
25	1750*	81*	264*	71*
26	1570	87	339*	94
27	1190	110	414	176
28	1762	123	435	263
29	1335	136	321	109
30	1407*	149*	287*	102*
8/31	1479*	163*	253*	95*
9/1	1551*	176*	219*	89*
2	1624*	189*	185*	82*
3	1696	202	151	75
4	1727	150	348	224
5	816	90	651	311
6	716*	100*	594*	384*
9/7	616*	110*	536*	457*
8	516*	120*	478*	529*
9	416	130	421	602
10	620	95	350	422
11	594	191	164	272
12	357	139	210	532
13	307*	108*	172*	466*
14	258*	78*	134*	399*
15	208*	47*	96*	333*
16	158	16	58	266
17	33	16	68	261
9/18	24	30	22	248
19	16	20	55	248
20	16*	21*	60*	216*
21	17*	23*	66*	185*
22	17*	24*	71*	153*
23	17	25	76	121
24	18	21	91	236
25	28	13	85	99
26	7	10	62	134
27	8*	8*	76*	136*
28	9*	7*	90*	138*
29	9*	5*	103*	140*
9/30	10	3	117	142
10/1	5	18	22	109
2	3	3	39	137
3	25	0	39	65
4	19*	0*	32*	83*
5	13*	0*	24*	101*
6	6*	0*	17*	119*
7	0	0	9	137
8	4	4	20	0
9	3	0	0	0
10/10	11	2	10	116
11	8*	3*	8*	87*
12	6*	4*	5*	58*
13	3*	5*	3*	29*
14	0	6	0	0
15	2	0	0	28
16	0	0		
TOTAL	47,334	4770	8933	10,069

Table 48 contains values for estimated fry production for 1973, 1974 and 1975 from U.S. tributaries. The 1975 estimate of 71,106 rainbow fry produced in the four tributaries was similar to the 1974 estimate of 57,675 but substantially less than the 1973 estimate of 158,863. If the estimates of fry production were directly related to the actual, total fry production, then 1973 could have been considered a "high" production year. That would have made 1974 and 1975 "average" years (or 1973 an average year with 1974 and 1975 "poor" years). Regardless, the effects of a peak year in 1973 and lower production in 1974 should have been observable in CPUE or size of fish in the 1976 angler catches compared to 1975 catches. The analysis of 363 rainbow trout sampled on the 1976 opening weekend showed no obvious changes from previous samples in length or weight frequency distribution, or in CPUE (Wyman, 1975).

One plausible explanation for no differences in CPUE or average length of fish in 1976 compared to 1975 was that in terms of total fish produced by a tributary over a one or two year period, there was no difference in actual production between 1973 and 1975. Spring run-off may explain the balancing of production. The flows in all three years were similar through May, then in 1973 the in-flow declined, while in 1974 and 1975 it reached a peak in June and remained higher than the 1973 inflow until August. If substantial numbers of fry normally rear in the streams, then the low flow condition 1973 may have resulted in a crowding condition which caused a larger percentage of fry than normal to emigrate.

The decision to sample Big Beaver Creek during these years, primarily at the 1645 foot elevation and not at the mouth, must be questioned. That elevation (approximately 5 miles upstream from the mouth) was upstream from the most suitable spawning gravel. It is not surprising that rainbow fry production was not found to be significant.

TABLE 48. Estimated fry production for 1973, 1974, and 1975 for selected U.S. tributaries to Ross Lake (Wyman, 1975).

	1973		1974		1975	
Stream	#	%	#	%	#	%
Lightning	52,416	33	7,171	12	8,933	13
Ruby	73,321	46	18,978	33	10,069	14
Roland	23,046	15	14,760	26	47,334	67
Dry	10,080	6	16,766	29	4,770	6
Totals	158,863	100	57675	100	71,106	100

Rainbow Trout Population Size in 1970's

In the 1970's a series of tagging and recapture studies were conducted to develop rainbow trout population estimates for the Ross-Skagit system. The standard assumptions that are made in such studies include: 1) that fishing effort is proportional to the density of the fish population throughout the lake, 2) that tagged and untagged fish are equally susceptible to capture, 3) that recruitment to the fish population does not occur during the recovery program, 4) that losses thought to be from natural mortality or emigration are the same for tagged as for untagged fish, and 5) that all tags recovered are reported. These assumptions were probably violated but that was never evaluated, for example:

1) To what extent non-reporting of tagged fish occurred is unknown. If it occurred it would bias the population estimate upward.

2) To what degree natural mortality differed between tagged and untagged fish is not known. If natural mortality was higher for tagged fish the population estimate would be biased upward. It was suspected that this occurred because many tagged fish were sexually mature at the time of tagging, and sexually mature fish normally experience a higher mortality than immature fish.

3) To what extent recruitment occurred to the fishery during the study is unknown. It is known, however, that age 1 and age 2 fish are not fully recruited to the fishery at the start of the fishing season and additional recruitment would tend to inflate the population estimate, and

4) Fishing effort was not proportional to density of fish in that the mid-lake area maintained a CPUE equal to other areas of the lake (indicating similar fish density) yet angling pressure was much lower in the mid-sections than at the north or south ends of the lake.

Regardless of all the assumptions and possible or actual violations of them, the population estimates do give us an approximation of the number of the "catchable" rainbow trout in the lake in the early 1970's (Table 49).

TABLE 49. Population estimates of harvestable Ross-Skagit system rainbow trout, 1971, 1972, and 1973.

Year	Population Estimate	95% Confidence Interval
1971	146,352	120,263 - 186,898
1972	206,185	174,500 - 237,870
1973	191,480	170,751 - 212,209

As previously discussed, CPUE can reflect the abundance of fish in a body of water. The CPUE values for 1971 (0.48), 1972 (0.52), and 1973 (0.49) would then indicate differences in the fish population existed between those years. That indication can be seen in the population estimates that were lowest in 1971 and highest in 1972. If a 0.04 drop in CPUE (1971 vs 1972) was equated with a drop in the total fish population of 60,000 (1971 vs 1972), then a drop of 0.13 (1972 vs 1985/86) would indicate a decline in the population of as much as 195,000 fish. However, it must be remembered that the relationship between CPUE and total fish is not a straight line relationship nor was the drop in CPUE in 1985/86 in all areas of the lake. The decline in CPUE was greatest at the north and south ends of the lake in those years. This information does indicate that there has been a major reduction in fish at the two ends of the lake since the 1970's.

Impacts of Ross Dam Operations on Fishery Resource

Migrations and Losses Through the Dam

The spill over Ross Dam in 1972 may have resulted in a significant loss of fish from the Ross Lake system according to IS-RFC discussions held in April, 1973. From tag recoveries in the two reservoirs, immediately downstream from Ross Reservoir, indications were that large numbers went over Ross Dam's spillway.

In 1972, 14 tagged fish were recovered below Ross Dam; 4 in Gorge Lake and 10 in Diablo Lake. Two of the fish had been tagged in 1971 and 12 tagged in 1972. One of the 1971 fish was recaptured in Gorge Lake and 1 in Diablo Lake. No tagged fish were recovered below Ross Dam in 1971. The passage of fish from Ross Lake past the dam was attributed to the heavy continuous spill over Ross Dam lasting from May 22 to July 20 (60 days) in 1972. Average spill during this time was 8280 cfs, with a one day maximum of 16,800 cfs. In 1971 the longest period of spill over Ross Dam was from June 23 to August 2 (41 days). Average spill was 4463 cfs with a one day maximum of 9400 cfs.

Assuming that tag recovery rate was the same in Gorge and Diablo lakes as in Ross Lake (19%) approximately 58 tagged fish (8% of number at large in Ross Lake) survived the passage. On the basis that a similar percentage of the untagged fish population passed over Ross Dam and survived, it was estimated that approximately 16,000 fish from Ross Lake entered Diablo and Gorge lakes. How many died in the passage is unknown.

To put the magnitude of this loss in perspective, remember that the total angler harvest of rainbow trout in Ross Lake for the 1985 season was only 2500 more fish than were lost over the spillway in 1972.

If Ross Dam operations, for whatever reason, are not able to prevent spilling water at a rate greater than the 1971 rate (which appears not to have caused a significant loss of fish), then a mitigation plan needs to be developed so that Seattle City Light can compensate the citizens of the state for the loss of fish. Obviously not all fish that go over the spillway are lost to anglers. Some survive to be caught in the lower lakes. A needed study would estimate numbers of fish dropping over the spillway at different flows and determine mortality at these different flows. Such a study would not alleviate the need for compensation for determined losses; it would just define the dollar value.

Drawdown Impact on Trout Food Sources

Ross Lake Zooplankton

Zooplankton is the single most important food source of the rainbow trout in Ross Lake. Interestingly enough it is the zooplankton that gives the flesh of the Ross Lake rainbow its characteristic red color. The abundance of zooplankton is directly related to the surface area of the lake. During winter and early spring maximum draw-down this food supply may become limited, resulting in slower fish growth and a slightly smaller rainbow trout on opening day of fishing season.

Although copepod crustaceans and rotifers formed a considerable portion of the zooplankton present in the lake, they were virtually absent from trout stomachs in 1971 diet studies. The most important food item for rainbow trout was planktonic crustacea of the order Cladocera. Monthly averages for Cladocera ranged form 22% to 76% of the food eaten. Of the cladocerans, only the species Daphnia and Leptodora were consumed in great numbers. Leptodora, roughly 3 times the size of Daphnia, was heavily selected even though Daphnia was many times more abundant. Efficiency of feeding on plankton by trout is undoubtedly influenced by visibility and mobility of the zooplankton, their distribution, and their individual size. These crustaceans are extremely small and after the trout reach 300 mm (approximately 12 inches) they have difficulty filtering the small zooplankton out of the water with their gill rakers. Smaller fish have their gill rakers spaced lose enough together to be much more efficient grazers of the tiny animals. Those fish greater than 300 mm feeding in the lake took a smaller proportion of cladocerans and a greater proportion of terrestrial insects, other aquatics (snails and amphipods) or mayfly, stonefly, or caddisfly nymphs, pupae or adults between May and October. Small fish had greater proportions of cladocern in their diets.

In all probability it is the food filtering inefficiency of larger trouts' gill rakers that cause them to migrate into Ross Lake tributaries on feeding-runs. In the streams, during the trout spawning period, they primarily feed on drifting trout eggs. Smaller fish, those less than 300 mm, feed mainly on mayflies and terrestrials. In August all sizes of fish in the streams prefer mayflies (Anonymous, 1972b).

Ross Lake Benthos

Benthos, or bottom dwelling invertebrates, can be an important food source for Ross Lake rainbow trout. Two of the most important benthic invertebrates are snails and amphipods (gammarus). While snails formed up to 90% of the benthos in fish diets in some months, amphipods comprised up to 70% in other months.

As fortunate as it is that the trout, particularly the larger fish, have these important large invertebrates available for good growth and recovery from the nutrient losses associated with spawning, it is unfortunate the benthos of Ross Lake can never develop stable populations due to the draw-down and refilling cycle of the reservoir. That limitation on the development of stable invertebrate populations lessens the chance large rainbow will survive spawning or add significant annual growth after age 5, and at least partially explains the rapidly declining growth rate of age 3 and 4 fish as well.

Lake bottom samples taken in the 1970's indicated that the abundance of benthos on the lake bottom was directly related to whether, and for how long, a given portion of the lake bottom was exposed by drawdown. Below maximum drawdown the greatest abundance of benthic food tended to be found in the shallower areas of the lake bottom, and was lower in very deep water. Above maximum drawdown the least amount of benthic food was found on those portions of the lake exposed for the greatest length of time. At depths above maximum drawdown there was a gradual summer increase in abundance depending upon the length of time of exposure by drawdown and length of time for invertebrate recolonization.

Indications were that abundance of benthos was less in summer 1972 than in 1971. In 1971 the drawdown was to the 1531' elevation; the area exposed exceeded 30% of total lake area. In 1972 draw-down was to the 1523' elevation: exposed area was 36% of total lake area. Draw-down could partially explain the invertebrate abundance difference between 1971 and 1972 (Anonymous, 1973a).

The substrate samples taken off the creek mouths showed that production of benthic food at creek mouth sites was considerably higher in the area continuously inundated by the lake, as compared to areas exposed by lake draw-down. In addition it was found that the abundance of benthic food in the creek mouth samples was considerably greater than in the lake shore transects (Anonymous, 1974a).

Were the reservoir drawdown schedule to require attainment of full pool by June 1 and maintenance at that level until late October, the invertebrate populations would significantly increase and survival of older trout would improve.

Spawner Access and Redd Inundation

Reservoir operations which affect lake level are under the control of Seattle City Light. In addition to the impacts that could affect population size and growth of trout and char already discussed (spill at dam, limiting food production, etc.), are the impacts of limiting spawning fish access to tributary streams and redd inundation.

Spawner access to tributary streams can be blocked not just by boom logs or wood debris at the mouths of the streams. Large organic debris blockages can also occur during the draw-down cycle when this material accumulates in the stream channels that course across the dry lake bed. This material, left behind when the lake level recedes, can block upstream migrating fish that are attempting to reach their spawning grounds in May or June. This can force the fish to spawn in portions of the stream that will later be inundated by rising lake levels. A similar but more permanent access problem can exist when lake levels are not at full pool by June 1st and a spawning stream, such as Big Beaver Creek, has a waterfall at its mouth that is only passible when inundated by the lake at full pool. Under this latter condition the fish are also forced to spawn in areas later inundated by rising lake levels.

In the 1970's one of the studies involved determining if inundation of rainbow trout eggs caused higher mortality than would be expected if the eggs had been deposited in a normal stream environment. In that study 50-100 fertilized eggs from ripe fish caught near each of three respective study areas were placed in small plastic containers with gravel, and buried in the lake bottom at various depths. The containers were freezer containers; 1/2 pint size screw top with 5/64" diameter holes at 2/10" on center.

Study areas were Roland Bay, Pierce Creek, and Lightning Creek. Stations at varying depths were provided with four egg containers each for later recovery by scuba diving. Results were quite variable. At Roland Bay all but two stations at depths ranging from 2 to 45 feet (with respect to full pool) were recovered. Very low egg survival was noted to 31 feet. At Pierce Creek, results were not conclusive. Most containers were washed out or could not be found. In Lightning Creek, 100% mortality was noted in those containers recovered. Heavy siltation of all but the shallowest stations was observed, and thought to be the main cause of mortality. High mortality of all redds should be expected. The spring/early summer period is the time of maximum stream flows carrying maximum quantities of silt and mud. When the streams reach their confluence with the lake, and water velocities slow, the suspended sediments settle out of the water

onto the lake bed, and on top of the fish redds. The layer of silt blocks the movement of fresh water to the eggs and they smother from lack of oxygen.

In conclusion, maximum draw-down occurs in March/April each year, followed by a slow refilling of the lake. Should rainbow trout atttempt to spawn in the exposed channels at the traditional time (May - early June), the likelihood of a successful hatch before inundation is very small. Only eggs deposited in the uppermost limits of the reservoir would stand a chance of hatching successfully before inundation in late June or early July.

To minimize the mortality problem associated with inundation there is one direct solution; Seattle City Light should ensure that the reservoir is at full pool by June 1 each year.

CONCLUSIONS

The following conclusions are derived from data collected at Ross Lake from 1985 to 1988, and from comparison af that data to research results from similar studies conducted between 1971 and 1975:

1. The rainbow trout population in Ross Lake has declined in abundance since the 1970's.

In the early 1970's, the Ross Lake fish population was estimated to range between 146,000 and 206,000; comprised of 95 percent rainbow trout, 4 percent dolly varden, and 1 percent cutthroat and eastern brook. During this period the anglers' catch rate (CPUE) averaged 0.5 fish per hour (2 hours to catch one fish). The annual harvest averaged 38,642 fish, of which approximately 36,000 were rainbow trout.

In 1985 and 1986, the average angler catch rate (CPUE) fell to 0.37 fish per hour (almost 3 hours to catch one fish) and the average annual harvest had fallen to 22,031 fish, of which 20,514 were rainbow trout.

While population estimates were not made in the 1980's, the CPUE normally reflects fish abundance. A 26 percent decline in CPUE, as occurred between the 1970's and mid-1980's, indicated a large drop in total population of fish in Ross Lake. The CPUE values dropped primarily at the north and south ends of the lake in the zones of the lake receiving the greatest fishing pressure. In the 1970's CPUE remained near 0.50 fish per hour from opening day to the end of the fishing season. In 1985 and 1986, two weeks into the season, the catch per hour sharply fell. The catch per hour in July and August in 1985 and 1986 averaged 0.24, while for the same months in 1971 and 1972, CPUE was 0.58. That mid-summer decline of CPUE by 59 percent in the 1980's, compared to the 1970's, indicated that the population could not absorb the fishing pressure, particularly at the north and south ends of the lake. Figure 30 shows the monthly combined CPUE for 1971 and 1972 plotted with the monthly combined CPUE for 1985 and 1986. These values were for the whole lake's fishery and clearly show the near total collapse of the 1985 and 1986 fishery in the summer months.

An oddity in the CPUE data was that in the 1980's, opening day catch per hour was significantly higher than in 1971 or 1972. How can that occur if CPUE is an indicator of fish abundance? The most probable explanation is that by the 1980's, a majority of the anglers fishing Ross Lake had been participating in this "destination" fishery for 10 to 15 years. That's in contrast to the anglers fishing Ross Lake in the late 1960's and early 1970's when it was still a relatively "new water". The present-day anglers have, in the intervening years, learned the habits and

favored habitat of their quarry and are now far more efficient in catching fish than when they first started. Most of these long-term anglers target their holidays on the opening weekend of Ross Lake. They have become so efficient that after the first 2 weeks, catch per hour in the zones most of them fished (Hozomeen and Roland Point Zones) dropped to as low as 0.17; a 79 percent decline from opening day. In the remainder of the lake's zones the CPUE values in 1986 remained closer to 1970's values.

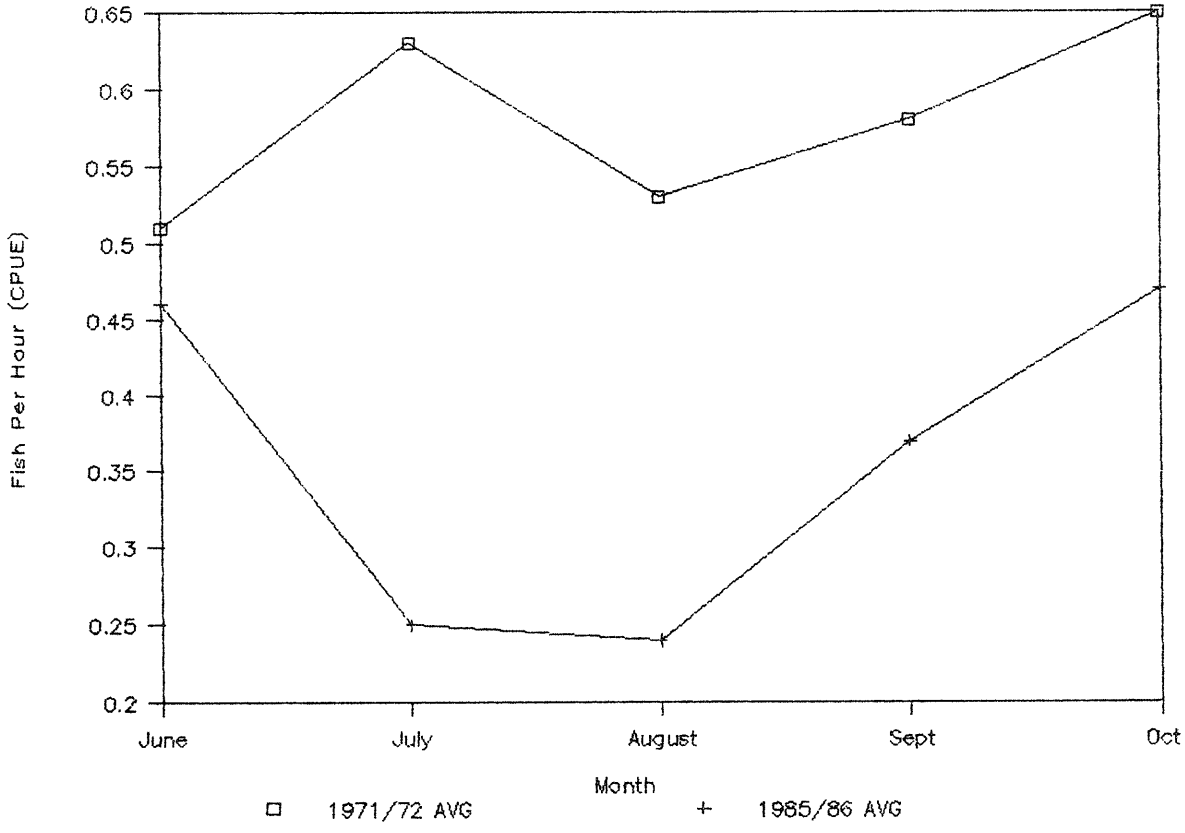

FIGURE 30. Combined 1971 and 1972 CPUE and Combined 1985 and 1986 CPUE.

The migrations of rainbow trout in the Ross Lake system also contribute to the vulnerability of the fish during the early and late portions of the fishing season. The rainbow trout of Ross Lake, the Canadian Skagit River, and the U.S. tributaries are essentially one stock of fish that freely migrates between the streams and the lake each year. Major migrations include;

1) Migration from their home stream to the lake shoreline for the first time, usually at age 0 or age 1. Some delay lake entry until age 2 or 3.

2)Migration off-shore into the mid-lake feeding areas, usually in mid-summer at age 1 or 2.

3) Migration for feeding only to mouths of streams or into the streams. This normally occurs as the fish approach 12 inches (305 mm) and they experience difficulty filter feeding small zooplankton (their main diet in the lake). They seek larger food organisms and/or drifting eggs. This feeding migration usually occurs in late spring or early summer and the fish remain in the feeding areas until mid-fall, when they return to the lake. These feeding-runs are not always to the individual fish's natal, or "home", stream. This acts to mix the lake's discrete tributary stocks.

4) Migration for spawning to the natal stream usually peaks between late April and late June. After spawning the fish either return to the lake, hold near the stream's mouth, or remain in the stream to feed until mid- to late September. In the fall the fish return to the lake to over-winter.

The above migrations tend to mix the lake's tributaries' populations and probably explains consistant opening day availability of fish at the mouth of the Canadian Skagit River (north end) and in the Roland/Ruby Creek areas (south end). However, significant numbers of new fish do not move into these areas until fall, and after depletion of the localized stationary fish at the first of the season, the fishery collapses.

As mentioned at the start of this section on population decline, the annual harvest of rainbow trout, between the early 1970's and the mid-1980's, has also declined by about 43 percent. That drop in annual harvest is most likely attributable to a decline in the total lake's fish population. The harvest reduction can not be attributed to fewer anglers fishing Ross Lake nor can it be accounted for by the reduction in catch limit from 12 to 8, that went into effect in 1980; very few anglers caught 8 fish in either the 1970's or 1980's studies.

A portion of the reduction in annual harvest may be due to lessening of the total hours that anglers fished per day in the 1980's compared to the 1970's. In the 1970's, the average angler trip lasted a little over 4 hours, while in 1986 the average completed trip duration was 3.6 hours. This decline in total angling effort of about 4000 hours in 1986 would have resulted in 1500 fewer fish caught (at 0.37 fish per hour) than would have been harvested if trip duration was the same as in the 1970's. That decrease in harvest still leaves 15,000 less fish caught in the 1980's, that only can be explained by a reduction in the total population.

2. The current population of rainbow trout in Ross Lake is showing signs of instability that will probably soon lead to an increased rate of population collapse.

The anglers have noted it and remarked on it at every opportunity. Ross Lake's rainbow trout are getting smaller. It must be remembered that many anglers' observations were made over a 10 to 15 year time span and are good trend indicators. Few biological surveys on Ross Lake, or the Skagit River, go back far enough in time to track a decline in size of fish. However, one study in the Canadian Skagit River in 1962 and 1963 found that over 30 percent of the rainbow catch was greater than 14 inches (355 mm). It must be remembered that these were Ross Lake fish on a spawning/feeding-run to that river. In the 1970's studies, the fish averaged approximately 12 inches (305 mm) and few fish were found to be over 5 years of age, which encompass the 14-inch and larger fish. By the 1980's, less than 10 percent of the Ross Lake fish were greater than 14 inches. One must wonder if the fish in the early 1960's just grew larger by a given age because the lake was more nutrient rich. On the other hand, only a certain percentage of fish can survive their annual natural mortality rate to reach a larger size, and recent angling mortality rates appear to have been high enough to hold the numbers of 14-inch to a very low level.

The average size of rainbow trout in some years in the 1980's was approximately the same as the 1970's, while in other years it was significantly less. This oscillation in size of fish in the 1980's has been due to extreme variabiliy in different age class abundance. One year the age 3 fish were most abundant, with few age 2 fish available. That condition caused the average size of the fish to be as much as 20 to 30 mm greater than when age 2 fish were dominant the following year. Given their life history and migration patterns in Ross Lake, a healthy rainbow population in that lake should always contain more age 2 than age 3 fish, and that should be reflected in the catch. It was that way each year in the 1970's studies, but not in the 1980's. In the 1970's age 2 fish comprised 50 to 60 percent of the annual harvest. In the 1980's, in some years, their numbers were so low that, as in

1987 on opening day at the north end of the lake, none were caught. This situation is indicative of inadequate numbers of spawners in some years.

The absence or extreme low numbers of age 2 fish places heavy fishing pressure on age 3 and older fish. The majority of age 3 fish have been found to be immature female, one year away from spawning. High angling mortality on these females will hurt the next year's spawning population, which in turn will accentuate the oscilations in dominant age class for a period of time. Eventually mortality will even out the differential abundance between the age classes and the population will reach some very low level from which, even if we close the fishery, natural mortality may never allow it to recover.

Adding to the problem of excessive angling mortality are impacts on the trout population caused by reservoir operations by Seattle City Light. These impacts include, but are not limited to, losses of fish over the dam due to heavy spill, loss of large food organisms and reduced zooplankton abundance due to lake draw-down, loss of recruitment due to stream mouth blockages caused by debris and fluctuating reservoir levels, and spawning bed inundation caused by the reservoir being below full pool as of June 1. Recruitment could be improved if instream barriers such as those in Lightning Creek were removed, the falls at the mouth of Big Beaver made more passable, and, most importantly, the reservoir operating schedule adjusted to require attainment of full pool no later than June 1 and maintenance at that level until October 31.

3. Washington State's and British Columbia's fishing regulations, for their respective portions of Ross Lake and British Columbia's Skagit River need to be complimentary if mutual goals are to be developed and attainable.

There are currently three different sets of management regulations in effect within the Ross Lake drainage basin. British Columbia's regulations on the Canadian Skagit River are aimed at protecting spawning rainbow trout and dolly varden char and building those populations. The added recruitment and survival to older age would produce more recreational opportunity for growing numbers of quality oriented anglers. Their 2 fish, 300 mm fork length minimum size restrictions (12 inches) have begun to show promise --- at least until these fish emigrate back to Ross Lake in mid-September to over-winter. They arrive at the lake only to encounter another set of less restrictive angling regulations (4 fish, 200 mm (8-inch) minimum size). Many of the fish protected while in the river now can be harvested in the lake. If these same fish migrate one mile further down lake (assuming full pool) they enter U.S. waters with an 8 fish limit with no minimum size restriction. The fish Canada is trying to

save are heavily harvested in the fall lake fishery and again the following June on their migration back to the river or as they hold feeding stations off the river mouth. It could be said that these fish are the only thing that stands in the way of total collapse of the north end lake fishery. The heavy angling mortality these fish experience will probably keep Canada from ever attaining its management goals for the river.

Functionally similar management goals for the lake and the river must be set in place soon. The first priority of any management restrictions must be to protect the wild stocks of fish to allow numerical recovery and encourage population stability.

4. Angling pressure can be expected to dramatically increase on Ross Lake in the coming years, especially on the northern half of the reservoir. B.C. Parks Branch is increasing the size and quality of campgrounds at the north end. In addition, the North Cascades National Park is improving boat launching access at the Hozomeen campground, which will allow larger boats to be launched over a longer season. That change will increase fishing pressure on the whole lake. Also major improvements have occurred to the 40 mile long dirt road leading to the north end of the lake, and more can be expected. Easier vehicle access, camping facility improvements and better boat launching access will increase angling pressure on fish stocks already showing the impact of over-fishing. New fishing regulations, more immune to angling pressure increases, must be considered.

FISHERIES MANAGEMENT RECOMMENDATIONS

Need for New Angling Regulations

The Ross Lake fishery can only be expected to become more popular and heavily used in future years, particularly in light of the development of new and enlarged camping facilities at the north end of the lake in Canada. Current fishing regulations do not adequately protect the fish populations from over-harvest at the current angling pressure level.

Based upon significantly reduced CPUE for the 1980's compared to the 1970's (25% seasonal average decline), and a 43 % decline in annual harvest between 1970's and 1980's, over-harvest has already occurred. There are several other indicators, more subtle but just as important, that further support the conclusion that the Ross Lake rainbow trout population has declined and is unstable. Angler over-harvest and reservoir draw-down, are the two most probable causes. Indicators include; 1) wide year to year fluctuation in year class strength of age 2 trout indicating unstable recruitment, most likely due to inadequate numbers of spawning fish or loss of eggs due to inundation, 2) disproportionately high harvest of, and dependency of the fishery at the north and south ends upon, age 3 immature females in the year prior to spawning, especially in years that age 2 fish abundance is low, 3) large drop in CPUE following the first two weeks of the season in the 1980's compared to the 1970's, which indicates the fish population size in the 1980's is insufficiently large to absorb current angling mortality and remain stable, and 4) when the above situations occur simultaneously, overharvest of the future spawners is virtually guaranteed.

The current fishery regulations in effect on Ross Lake do little to prevent further deterioration of the fish population. They: 1) open the lake fishery during the peak spawning period (mid-June) when many shoreline spawners are vulnerable, 2) do not adequately protect nor insure there will be sufficient spawners, particularly females, for the following year, 3) allow harvest of large numbers of Canadian Skagit River fish that were protected under 2 fish, 300 mm minimum fork length regulations while in Canada, but are not protected once they re-enter Ross Lake with its 8 fish, no-minimum-size regulation, and 4) the current regulations have too high a catch limit (8) and too low a minimum size limit (none) considering the need to reverse the rainbow trout population decline, as reflected by CPUE and annual harvest.

The only benefit offered by current regulations is protection of spawning fish in tributaries.

New regulations that should be considered for implementation starting 1990 are as follows:

SEASON CHANGE : Change the current opening day (3rd Saturday in June) to the closest Saturday to July 1. The 1990-1991 proposed seasons are:

June 30, 1990 to October 31, 1990
July 1, 1991 to October 31, 1991

Justification: It is necessary to design fishing seasons to protect spawning fish. Too early a fishing season opening date in Ross Lake would not only cause a loss of late spawners and result in an overall population decline, but could remove from the population the genetic component for late spawning. Were that to happen, eventually there would be no late spawners. In the case of Ross Lake, with its Seattle City Light controlled draw-down, that would result in dependence upon early spawners that lay their eggs in stream channels that are later inundated by a rising reservoir. The majority of those eggs would die. Regulations, the fish life history and the environment must work hand in hand. A better regulation would be to set the fishing season late enough to ensure adequate numbers of early and late spawners contribute to the genetic diversity of the stock. Such an opening day would be the closest Saturday to July 1 each year. The current June 14 to June 20 opening date range occurs at the very peak of spawning. While few anglers keep the spawners they catch, these ripe fish are caught in good numbers by bait anglers fishing off the mouths of the creeks and over the inundated Skagit River channel. The spawners are released alive, for the most part, but the stress of hooking and releasing and loss of eggs from the ripe females during the landing process takes its toll. In 1985, 18 percent of the fish caught were released, and a significant percentage of the fish released between opening day and July 6 were spawners. In 1985, approximately 5000 fish were harvested in that time period. If 15 percent more were released because they were spawners (750 rainbow) and if 20 percent of those fish die from hooking mortality (150) and if 60 percent of those fish were females (90) each carrying 2000 eggs, that means a minimum loss of 180,000 eggs. This estimate of loss does not even include the number of sexually mature, unspawned females kept by some anglers during this time period. Put in another perspective, the loss of eggs is at least equal to the annual deposition of eggs in some of Ross Lake's smaller tributaries.

MINIMUM SIZE LIMIT: Change the current no minimum size limit to 13-inch (total length) minimum size

Justification: To re-establish the stability in recruitment and increase the total population of the Ross Lake rainbow stock we must enact regulations that will protect the immature age 2 females and males and the immature age 3 females in the year before they will spawn. The only way to do that is to place a minimum size restriction on the harvest that will be effective for the whole season of growth. This regulation must consider the size of the age 2 and 3 fish at the first of the fishing season and their size by the last of the season and considered differences in size of fish at the north and south ends of the lake. For example, in 1987 at the south end of the lake on opening day, 30 percent of the harvest was age 2 fish averaging 273 mm (fork length), and 43 percent of the harvest was age 3 immature females averaging 287 mm (fork length). That same year on opening day at the north end there were no age 2 fish caught, however 40 percent of the harvest was age 3 immature females with an average size of 296 mm (fork length). While a 12 inch (fork length) mimimum size limit (305 mm) would protect the majority of age 2 and 3 fish on opening day, summer growth of 20 to 30 mm is common, and as a result, 49% of the 1987 south end opening day harvest (those fish between 280 and 305 mm) potected by a 12-inch (fork length) minimum size on the opener would exceed that size by September, and would likely be harvested in the intensive fall fishery. The same situation applied to the north end fishery in 1987; 21 percent of the opening day harvest was between 280 and 305 mm and could be expected to exceed a 12-inch minimum length limit by September. These same circumstances applied to the 1988 findings disclose; at the south end 29 percent of the opening day harvest that would have been protected by a 12-inch (fork length) minimum size limit would exceed 12 inches by September. The north end opening day harvest in 1988 was comprised of 40 percent rainbow that, while protected on opening day by a 12-inch minimum would exceed that size by September. Obviously then, a 12-inch (fork length) minimum size limit applied for the full season does little to achieve the goal of increasing the following year's spawning population. This is especially true since the September/October trout harvest is up to one-half of the annual harvest.

The preferred and best regulation to control mortality of immature fish prior to spawning is a season long minimum size limit of 13 inches TOTAL length. All length data in this report has been in fork length measurements, not total length. While fork length is a standard measurment in scientific studies, and used by British Columbia in all its fishing regulations, Washington sets all of its length regulations in terms of total length. Total length measurement is taken from the tip of the fish's snout to the tip of its tail, while fork length is from the tip of the

snout to the fork of the tail. A 12.5 inch fork length is equivalent to a 13-inch total length. A 13-inch total length fish is approximately 320 mm in fork length, and could be matched by B.C. for their portion of the lake with a 320 mm fork length minimum size restriction.

One final point needs to be emphasized: a 13-inch minimum size limit, is the only regulation that will allow adequate numbers of fish to survive from season to season and ensure that a majority of rainbow females will spawn at least one time before being legal to harvest. Minimum size restrictions are much more effective in preventing overharvest than are restrictions on the number of fish that can be harvested in a day or have in possession. The latter does little to prevent overharvest if significant increases in numbers of anglers occurs, as is expected to happen at Ross Lake in the next few years.

ANGLING GEAR RESTRICTION: Bait Prohibited.

Justification: A minimum total length restriction of 13 inches will require the releasing of large numbers of fish. Literature indicates that as many as 50 percent of the fish hooked and released using bait die, whereas fish hooked and released using artificial lures have a hooking mortality ranging from 5 to 20 percent. These mortalilty rates were derived from experiments conducted under a wide variety of conditions, not all of which apply to Ross Lake, but the survival ratio between gear types should still apply. In the early 1970's when tagging studies were conducted the test fish were captured with a variety of gear but mostly flies and lures. The fish were retained in capture boxes to evaluated post-hooking mortality and it was found that 10 percent died. It would appear then that Ross lake hook and release mortality rates are similar to those reported in the literature. For this reason a bait restriction should be applied to Ross Lake to ensure maximum survival of released fish.

One question that must be raised is; would such a bait restriction significantly reduce harvest or are other fishing gear types just as effective in catching Ross Lake rainbow?

Table 50 contains a comparison of the gear used by the Ross Lake anglers in 1986 (season), 1987 (opening day only), and 1988 (opening day only), the percent of anglers using a particular type of terminal tackle, and the percent of harvest taken with that gear type. Tackle preference has changed little since the 1970's when 2 percent of the anglers used flies, 5 percent used lures, 16 percent used bait only, and 77 percent used a combination of flashers and lures or worms (note: compare these percentages for 1971-73 with the 1986 season data in Table 50).

TABLE 50. Fishing gear (terminal tackle) and percent of total harvest taken with that gear, 1986, 1987, and 1988, at Ross Lake.

Terminal Tackle	1986 Season Anglers(%)	1986 Season Harvest(%)	1987 Opener (S.End) Anglers(%)	1987 Opener (S.End) Harvest(%)	1987 Opener (N.End) Anglers(%)	1987 Opener (N.End) Harvest(%)	1988 Opener (S.End) Anglers(%)	1988 Opener (S.End) Harvest(%)	1988 Opener (N.End) Anglers(%)	1988 Opener (N.End) Harvest(%)
Bait-Only	21.3	19.8	0.0	0.0	41.0	38.0	0.0	0.0	42.0	51.0
Lure-Only	0.4	0.0	0.0	0.0	0.0	0.0	3.0	2.0	0.0	0.0
Fly-Only	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flasher & Worm	49.1	54.7	85.0	73.0	31.0	35.0	87.0	87.0	30.0	34.0
Flasher & Lure	26.9	24.8	15.0	27.0	28.0	27.0	10.0	11.0	28.0	15.0

It is important to note that for the 3 main fishing methods, (1) boat, still-fishing with bait, (2) boat, trolling with flashers and bait, and (3) boat, trolling with flashers and lures, the percent of fish harvested by a particular gear type is nearly the same as the percentage of people using that gear type. For example, if 30 percent of the anglers fish flashers with lures attached, they can be expected to catch approximately 30 percent of the fish. The implication of this is that the fish can be taken by any of the three gear types in direct proportion to the number of anglers using that gear type. Where regulations are necessary to restrict bait, anglers currently fishing with bait could shift their gear to flashers with lures and catch would not significantly decline. Any decline in harvest from a bait restriction would probably result from anglers chosing not to change and therefore not participate in the fishery.

DAILY AND POSSESSION LIMIT: Daily catch limit -- 3 fish
Possession limit -- 6 fish

Justification: Catch limits and possession limits mainly function to spread the harvestable surplus of the fish population among the anglers. Ross Lake anglers are not different in terms of fishing skills than most other anglers -- 10 to 20 percent of the anglers still catch the majority of the fish. The current catch and possession limit of 8 fish for Ross Lake is attained by very few anglers over the course of the season. The average angler catches 4 to 6 fish per day on opening day in some years. Catch/day then drops to as low as 1 to 2 per day in the summer months of July and August. To have a fish limit reduce overall

harvest or , as it works in most cases, to spread the catch to more anglers, the limit must be set below the average daily catch. Obviously Ross Lake's current 8 fish limit does not do that. In the case of Ross Lake, the use of daily catch limits and possession limits need to be aimed at ensuring annual harvest is spread among as many anglers as possible, not only on opening day but for the season. Contrary to popular belief most number limits do not guarantee the fish are safe from over-harvest. All it takes is to dramatically increase the number of anglers fishing, catching the same number of fish per angler, and too many fish will be killed. Only when daily catch limits are combined with minimum size limits (such as 13-inch) do we see harvest rates brought in line with the needs of the fish.

Impact of New Regulations on Harvest

If the proposed regulations recommended above had been in place during the 1987 and 1988 seasons what would have happened to the opening day harvest in those years?

1987, South End. In 1987 the completed trip anglers fishing the south end of the lake on opening averaged 5 fish for the day. Forty-eight percent of the anglers caught more than 3 fish. Had a three fish limit been in place the harvest would have been reduced by 35% assuming unharvested fish would not be caught by other anglers. Out of every 100 fish the anglers caught on that day, 23 were large enough to have been kept under a 13-inch total length minimum size restriction. Therefore it would have been necessary for the anglers to have each caught 13 fish to sort out 3 fish large enough to keep. Since the average catch per angler was 5 fish for the day, and only 23% of those equalled or exceeded 13 inches, the average harvest per angler would have dropped from 5 fish to 1.15 fish for the day; or a 77 percent reduction in catch for the day at the south end of the lake. The 13-inch minimum size limit would have controlled the harvest, not the 3 fish daily bag limit.

1987, North End: At the north end of Ross Lake on opening day, 1987 the average completed trip catch per day was 6 fish. Seventy-four percent of the anglers caught more than 3 fish. Had a 3 fish limit alone been in place the harvest would have been reduced 50 percent. Under a 13-inch total length minimum size restriction, out of every 100 fish caught 58 were equal to or larger than 13 inches. Since the average catch per day was 6 fish, then of the 6 fish, an average of 3.5 would have exceeded the 13-inch minimum, and the majority of anglers would have been able to catch their 3 fish per day limit. In this case the numbers limit, not size limit, controlled harvest.

1988, South End: In 1988, at the south end of Ross Lake on opening day, completed trip anglers caught an average of 6.5 fish per day. Eighty-five percent of the anglers caught more than 3 fish. If a 3 fish limit had been in place the total harvest for the day would have been reduced by 53 percent (again assuming the catch was not redistributed). On that day, out of every 100 fish, 11 were equal to or greater than 13 inches. Since the catch per day was 6.5 fish only 0.7 fish out of that catch would be kept under a 13-inch total length minimum size regulation (89 percent harvest reduction). Anglers would have had to catch 9 fish to find one large enough to keep. The 13-inch minimum size regulation governed the harvest, not the 3 fish daily limit.

1988, North End: At the north end of Ross Lake on opening day 1988, the average catch per completed trip angler day was 4.3 fish. Thirty-nine percent of the anglers caught more than 3 fish and a three fish limit would have reduced the harvest by 32 percent. Out of every 100 fish caught at the north end 12 were equal to or greater than 13 inches. Since the average daily catch was 4.3 fish only 0.5 of those fish could be expected to exceed the minimum size limit. The average angler would have had to catch 9 fish to sort out one equal to or greater than 13-inches in total length. A 0.5 catch/day would have reduced total harvest by 88 percent. Again it was the 13-inch minimum length that saved fish for the next year's spawning population, not the 3 fish limit.

In the 4 cases cited above it can be readily seen that under current conditions at Ross Lake a 13-inch total length minimum size limit, not a daily catch limit offers the best hope in helping the population of rainbow trout in the lake to recover. The harvest reductions in these examples are drastic but it will take that type of action to increase the spawning population sufficiently to reverse the downward trend. Without these regulations, the state's finest native trout fishery will collapse and the lake will need to be closed.

As to the future, if these regulations are in place for the 1990 season, good recovery should start to be seen within 3 to 5 years of that date. Recovery will be in the form of increased numbers of age 2 and 3 fish evident in the fishery (most all still being released alive) and increased numbers of larger/older fish that should enable more anglers to achieve a 3 fish daily limit of fish larger than 13 inches, and fish over 14 inches should become much more common.

If the regulations proposed in this report are enacted, the only additional regulations needed for Ross Lake must be enacted by Fisheries Branch, of the B.C. Ministry of Environment. British Columbia regulations, complimentary to Washington State Department of Wildlife regulations, are currently being considered by the B.C. Fisheries Branch.

FUTURE STUDIES AND DATA COLLECTION

The studies completed to date, including this one, do not give fisheries managers all the information needed to fully protect the wild stocks of the Ross Lake system from over-harvest, or from losses due to manipulation of their environment. Even if the regulations proposed in this document are adopted, it will be necessary to monitor the fish populations to determine the adequacy of the restrictions. In addition, the environmental impacts of reservoir operations need to be more carefully monitored, defined, and adjusted to ensure that, first of all, fish population stability is achieved, and secondly, that recreational opportunity is not further degraded.

One major study that needs to be undertaken concerns the dolly varden of the Ross Lake system. Data collected on dolly varden during this study were inadequate to develop a good understanding of the life history of that species. A new study, specifically aimed at answering questions regarding migrations, spawning time and locations, age structure, growth, sexual maturity, etc., needs to be initiated. There is no question that the dolly varden in Ross Lake have experienced the same over-exploitation as the rainbow trout. Fortunately, the proposed new regulations will protect the dolly varden in the system as they too come under the 13-inch minimum size, 3/6 daily/possession limit, bait prohibited regulations. That is the minimum protection this species needs; certainly not the optimum. The optimum regulation proposal must await further work.

Evaluation of the new regulations needs to be done annually, at least on opening day. Minimum data collection should include: angler effort, catch, fish scales and lengths. This information needs to be gathered at the Ross Lake Resort and Hozomeen boat launch. Additional NCNP data on car counts, campers, boats, etc., and Ross Lake Resort data on boat rentals, need to be collected for the full fishing season to estimate annual fishing effort. Similar data to the above needs to be collected by British Columbia Ministry of Environment's Fisheries and Parks Branches for the Canadian portion of Ross Lake, the Canadian Skagit River, and the associated campgrounds/boat launches.

Full season studies, similar to the ones detailed in this report, also need to be undertaken in the future. The next major study should be scheduled for 1995-97, to evaluate recovery of Ross Lake fish and the fishery.

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APPENDICES

Appendix 1. Ross Lake 1986 creel census design.

CREEL SURVEY DESIGNS FOR THE SKAGIT RIVER AND ROSS RESERVOIR SPORT FISHERIES

Prepared for

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Fish and Wildlife Management
Surrey, B.C.

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By

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WESTERN RENEWABLE RESOURCES

January, 1986

ROSS RESERVOIR FISHERY

Description

Ross Reservoir is a large "international" body of water utilized by both Canadian and American anglers. Because of its relative remoteness (travel distance) anglers tend to camp overnight in the area, and thus angler use is much higher during weekends. The reservoir can only be reached from two general locations; from the Silver-Skagit road at the north end or from the Diablo Resort at the south west end. A National Park campsite is located on the northeast end near the Canadian border. However, as indicated, the majority of anglers, whether Canadian or American, access the reservoir via British Columbia.

Virtually all angling occurs from boats. Access is obtained from a maximum of five launch sites (Fig. 2): site A on the Canadian section of the Reservoir, site B1 and site B2 at Hozomeen Campground, site C just south of the campground, and site D the Diablo Resort. All sites are utilized throughout the season except site C which is closed between early July and early October. The two B sites from early September onward can be surveyed by a single person, but not otherwise. Also, site B2 is closed by the Park Service during the month of October. The odd occurrence of shore angling (other than that subsequent to boat launcing) is restricted to the immediate area of the launch sites.

In 1985, daily fishing activity through summer tended to be bimodal, with many anglers making two (or more) boat trips per day. Afternoon winds and length of daylight hours were often responsible for the observed decline in midday fishing activity.

Recommended Sampling Design

The limited number of boat launch sites through which all anglers must pass and the absence of shore angling (beyond the launch sites) makes the access point creel survey (Malvestuto 1983) the most suitable approach to estimate effort, CPUE and total catch. Using this procedure, survey worker(s) stationed at a boat launch will enumerate all boats returning to the site and

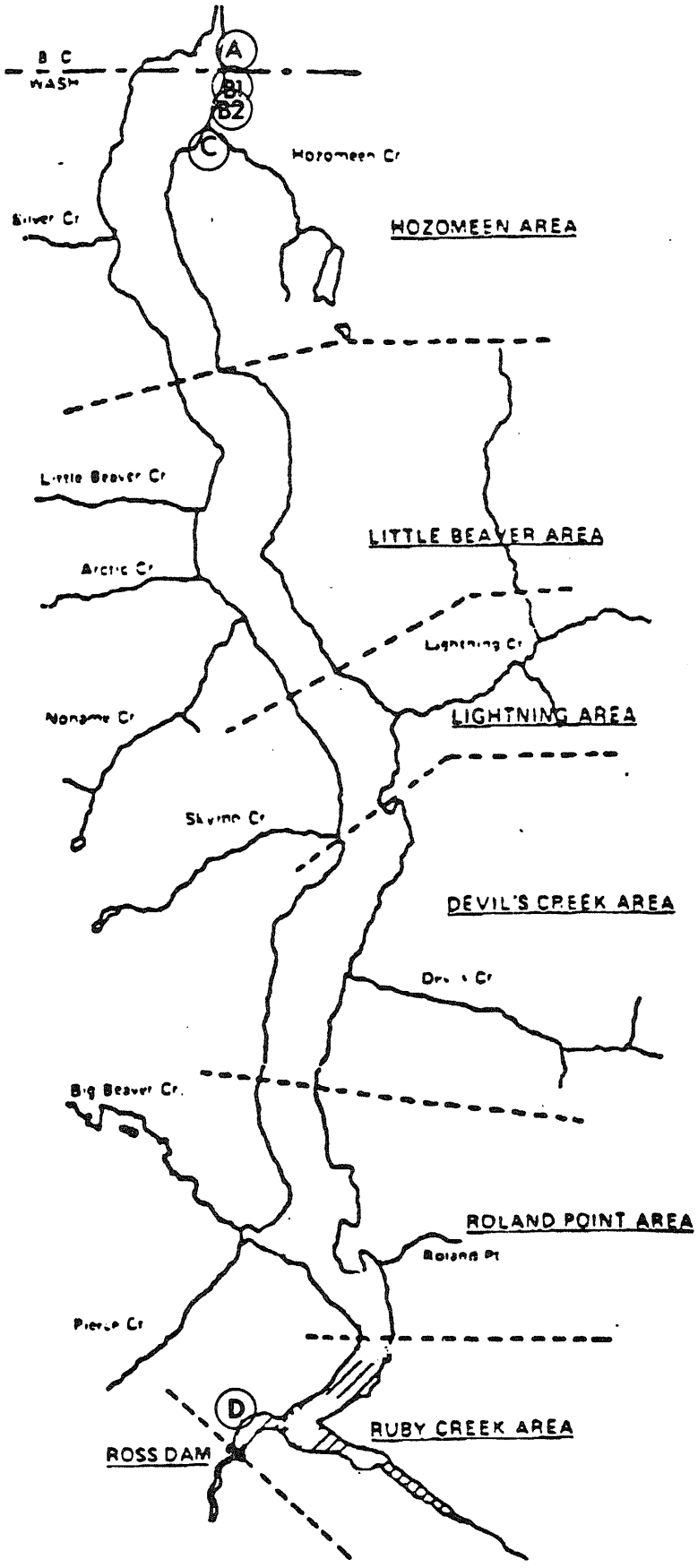

Figure 2. Ross Reservoir with approximate locations of the five launch sites.

interview as many boat parties as possible. Boat trip counts will be used to estimate monthly effort, and the interviews will be used to estimate mean CPUE and to obtain other pertinent data (anglers per boat, hours fished, catch/person, lengths of fish, scales, otoliths, sex of fish, etc.). Total effort estimates are then applied to CPUE estimates to generate estimates of total catch.

The above is a simplification of the procedure that abstracts from stratification levels and sampling stages. A detailed documentation follows. The accurate estimation of effort is the key consideration in the prescribed design (see Skagit River design for rational).

It would be ideal to interview every boat party returning to each of the four (five) launch sites during a sample day, but due to logistical and budget constraints this will not be possible. The high volume of boats returning throughout the day (particularly on weekends in the early season) along each beach-type launch site (launch sites are not narrow restrictions) can be readily enumerated. As well, the 10 (man) days per month allocation using a single survey worker as set by WDG, does not allow concurrent sampling of all launch sites during a sample day. Thus, sampling days will be randomized with respect to launch sites and day-type (weekend vs midweek).

A sample day will vary in total hours between June and October according to daylight hours, ranging from 15 hours in June to 9 hours in October:

June	7:00 - 22:00
July	7:00 - 22:00
August	7:00 - 22:00
September	8:00 - 21:00
October	9:00 - 18:00

The prescribed design requires complete and continuous attendance during these hours of a sample day. The day can be sampled by two consecutive interviewers or by a single interviewer working exceptionally long days. An alternate solution would be to split the day into two interview periods and randomize interview periods with repect to launch sites and day-type. However, because of the additional cost and time required to travel to these remote areas (i.e. from Bellingham / Seattle) the longer working day is the more feasible option.

Although the 1985 survey did not identify boat trips to individual launch sites, use apparently differed considerably between sites (Jim Scott, pers.

com.). Thus, unless the proportion of daily boat trips for each launch site is accurately estimated with appropriate variance estimates for each temporal strata (as opposed to arbitrary point estimates of the proportions without respect to variance as reported by Malvesuto et al. 1978; see comments in Skagit Design), sites should be treated as strata as opposed to a secondary sampling stage. Treating sites as strata, requires that each of the four or five sites be surveyed a minimum of two times within each day-type strata during each time block (i.e. one or two months, season, etc.) to calculate sample variances of boat trips per launch site. Any increase in sampling effort above the minium of two samples should be chosen in proportion to boat-angler use (assuming heteroscedastic variances and sampling costs are equal among launch sites; see Cochran 1977).

Because angler use in 1985 was significantly higher on weekends (Canadian and American holidays are considered weekend days) than during midweek, days will be partitioned into the two day-type strata. Fishing effort also varied through the season, with effort highest during the early season, particularly in June, declining gradually thereafter. Therefore the fishing season will also be divided into time blocks. Thus, the multiple statification will be time block x day-type x launch site.

The minimum of two sample days per site per day-type required for the estimation of effort to be valid exceeds the limit of 50 sampling days set by WFG if the season is divided into monthly time blocks (5 x 2 x 4(5) x 2 = 80(100) sample days). The season is therefore divided into wider time blocks corresponding with changing effort and number of access points as follows:

Time Block	Period	Approximate percentage of 1985 effort	Number of launch sites	Minimum Sampling days	
				Weekend	Midweek
1	June 14-July 11	40%	5	10	10
2	July 12-August 29	34%	4	8	8
3	August 30-October 31	26%	4	8	8

This allocation results in 52 sample days. The additional 2 days plus the long working days in June through September will be compensated by using additional interviewers during June/July (Jim Johnston, pers. comm. as per meeting of December 9, 1985).

Estimation of total effort requires complete enumeration of all boat trips at the particular site during the sample day and thus the site-day is the sampling unit and the five launch sites and days between June 14 and October 31, 1986 constitute the sampling frames. To estimate CPUE and other fishery statistics, the boat trip is the sampling unit (second sampling stage). A boat trip is not a boat day; the boat trip was chosen as the unit of measure because many Ross Reservoir anglers take more than one trip per day (primarily due to mid-day winds). Thus, CPUE is catch (harvested / released) of a particular species per completed boat trip. Total boat trips (effort) multiplied by the mean catch per boat trip (CPUE) yields total catch. Therefore the unit of measure for the prescribed design is the boat trip as opposed to the angler trip.

If during the interview additional data for each individual angler is also obtained, then boat trips can be converted to angler hours, and catch per boat trip to catch per angler hour. However, hours per trip and anglers per boat are random variables and thus have associated variances which, if converted, will yield lower precision of estimates, particularly total catch.

Sampling Schedule. The sampling schedule for 1986 is given in Table 7. A simple random sample of two days for each day-type strata within each time block was drawn without replacement using a a uniform number generator (i.e., as commonly given in random number tables), subject to the following restrictions:

1) only one site could be sampled during a day (i.e., there will only be only survey worker;

2) once a sample day was drawn for a particular site, one of the remaining sites was selected to be sampled on an adjoining day of the same day-type (to reduce frequency of travel to and from the reservoir).

This procedure departs from pure simple random sampling of sites within day-types, but it is not considered a serious violation. Parameter estimation is therefore assumed to be based on simple random sampling.

Table 7. Sampling schedule for the five launch sites of Ross Reservoir, 1986.

	TIME BLOCK 1 (June 14 - July 11)		TIME BLOCK 2 (July 12 - August 30)		Time Block 3 (August 31 - October 31)	
Launch	Weekend	Midweek	Weekend	Midweek	Weekend	Midweek
Site A	Jun 28, Jul 1	Jun 18, Jul 3	Aug 3, Aug 23	Jul 29, Aug 21	Sep 6, Sep 13	Sep 5, Sep 18
Site B1	Jun 15, Jul 4	Jun 19, Jul 7	Aug 10, Aug 24	Jul 28, Aug 13	Sep 7, Sep 27	Sep 17, Oct 8
Site B2	Jun 29, Jul 5	Jun 20, Jul 8	Jul 12, Aug 9	Jul 14, Aug 14	" "	" "
Site C	Jun 21, Jun 22	Jun 30, Jul 9	closed	closed	Sep 28, Oct 11	Oct 7, Oct 21
Site D	Jun 14, Jun 6	Jul 2, Jul 10	Jul 13, Aug 2	Aug 4, Aug 22	Sep 14, Oct 12	Sep 4, Oct 22

Data Collection

Interviewers will be stationed at the randomly selected launch site for the extent of the randomly selected day to tally all boats landing and to interview boating parties at the end of the just-completed boat trip. The interviewer will use two data sheets:

1) a tally sheet to record the number of boats landing (boat trips);
2) an interview sheet to record information obtained by interviewing boat parties.

To facilitate accurate enumeration of boat trips, number of boats returning should be record in 30 minute or one hour intervals. Because their is a (unlikely) possibility that some boats could have landed before the interviewer arrived at the launch site (e.g., before 7:00 am), the interviewer should ask any persons in the vacinity if any boats had returned prior to his/her arrival. Because of floating debris (dead heads) throughout the reservoir, few if any boating parties return after dusk (sampling is scheduled to dusk).

An attempt should be made to interview <u>all</u> boat parties returning during the sample day, and the most knowledgable party member should be interviewed to obtain the boat trip characteristics for the total boating party. On the occassion that more boats arrive than can be interviewed then a "representative" sample should be taken. To avoid any potential (unconscious) bias, every "1 in K" boat should be chosen, where "K" is determined by the interviewer based on the likely number of boats that can be interviewed. This procedure will prevent unequal selection of large vs small boat parties, family oriented vs serious adults, unfriendly vs those eager to talk, etc.

Principle information obtained will be the number of fish kept and released by species (inspected and verified by the interviewer). Additional information may also include number of anglers per boat, hour of arrival, trip length, gear type, residence, and any other desired information of importance. At this time the number of tagged and untagged fish can be determined and biological samples taken (scales, length, weight).

Because some boat parties may be returning from overnight camping trips, boat trip characteristics refer only to that activity since midnight of the interview day. In the same context, data should only be obtained from the

just-completed trip, and should not include information from a previous trip earlier that day or otherwise.

Estimation

From the complete counts of boat trips to each launch site during an entire day, one gets a mean daily count of boat trips. To estimate total effort as measured in boat trips, this mean is multiplied by the total number of possible days. From the interviews, mean catch per boat trip is calculated. Multiplying total effort by mean catch per effort yields total catch.

This is a simplification of the estimation procedure that does not account for the sum of all launch sites or the day-type and seasonal stratification level. A detailed procedure follows. To simplify the following presentation, subscripts referring to seasonal time block are omitted (i.e., final estimates refer to a time block).

Let Y_{dsi} = number of boat trips counted on sample day i at launch site s on day-type d;

n_{ds} = number of days sampled at launch site s of day-type d;

S = number of possible sites in the seasonal time block (common accross day-type);

N_d = total number of possible sample days of day-type d in the seasonal time block (common accross launch sites).

Then $\bar{Y}_{ds}$ = mean number of boat trips per day at site s of day-type d,

$$= \frac{\sum_{i=1}^{n_{ds}} Y_{dsi}}{n_{ds}}$$

with v^2_{ds} = the sample variance

$$= \frac{\sum_{i=1}^{n_{ds}} (Y_{dsi} - \bar{Y}_{ds})^2}{n_{ds} - 1} \quad .$$

Now,

T_d = total number of boat trips for day-type d,

$$= N_d \sum_{s=1}^{S} \bar{Y}_{ds}$$

with $V(T_d) = \sum_{s=1}^{S} N^2_{ds}[1-(N_{ds}/n_{ds})][v^2_{ds}/n_{ds}]$.

Thus, the estimated total effort for a particular seasonal time block is

$$T = \sum_{d=1}^{2} T_d$$

with $V(T) = \sum_{d=1}^{2} V(T_d)$.

Let F_{dsib} = catch by boat party b on sample day i at launch site s in day-type d;

n_{dsi} = number of boat parties interviewed on sample day i at launch site s in day-type d;

n_d = number of boat parties interviewed during day-type d.

Assuming that interviewed boat parties are a simple random sample of all boats landing, then

$\bar{F}_d$ = mean catch per boat trip for day-type d

$$= \frac{\sum_s \sum_i \sum_b K_{dsib}}{\sum_s \sum_i n_{dsi}}$$

with variance $V(\bar{F}_d) = \dfrac{\sum_{i=1}^{n_d} (Y_{dsib} - \bar{F}_d)^2}{n_d - 1}$

Thus, the estimated total catch for day-type d of a particular time block is

$$C_d = \bar{F}_d T_d$$

and the total catch estimate for the time block is

$$C = \sum_{d=1}^{2} C_d = \sum_{d=1}^{2} \bar{F}_d \cdot T_d$$

and variance of the total catch estimate is (Bohrnstedt and Goldberger 1969):

$$V(C) = \sum_{d=1}^{2} V(C_d) = \sum_{d=1}^{2} \left[\bar{F}_d^2 V(T_d) + T_d^2 V(\bar{F}_d) + V(T_d)V(\bar{F}_d)\right]$$

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APPENDIX 2. The proposed and actual 1986 sampling schedule.

PROPOSED SCHEDULE

	TIME BLOCK 1 (June 14 - July 11)	
Launch	Weekend	Midweek
Site A	Jun 28, Jul 1	Jun 18, Jul 3
Site B1	Jun 15, Jul 4	Jun 19, Jul 7
Site B2	Jun 29, Jul 5	Jun 20, Jul 8
Site C	Jun 21, Jun 22	Jun 30, Jul 9
Site D	Jun 14, Jul 6	Jul 2, Jul 10

	TIME BLOCK 2 (July 12 - August 30)	
Launch	Weekend	Midweek
Site A	Aug 3, Aug 23	Jul 29, Aug 21
Site B1	Aug 10, Aug 24	Jul 28, Aug 13
Site B2	Jul 12, Aug 9	Jul 14, Aug 14
Site C	-----	-----
Site D	Jul 13, Aug 2	Aug 4, Aug 22

ACTUAL SCHEDULE

	TIME BLOCK 1 (June 14 - July 11)	
Launch	Weekend	Midweek
Site A	Jun 28	Jun 18, Jul 3
Site B1	Jun 14, Jul 4 Jun 21	Jun 19, Jul 7
Site B2	Jun 29, Jul 5	Jun 20, Jul 8
Site C	NOT OPEN AT BEGINNING OF SEASON	
Site D	Jun 14, Jul 6 Jun 22	Jul 2, Jul 10

	TIME BLOCK 2 (July 12 - August 30)	
Launch	Weekend	Midweek
Site A	Aug 3, Aug 23	Jul 29, Aug 21
Site B1	Aug 10, Aug 24	Jul 28, Aug 13
Site B2	Jul 12, Aug 9	Jul 18, Aug 14
Site C	-----	-----
Site D	Jul 13, Aug 2	Aug 4, Aug 22

Launch	TIME BLOCK 3 (August 31 - October 31) Weekend	Midweek
Site A	Sep 6, Sep 13	Sep 5, Sep 18
Site B1	Sep 7, Sep 27	Sep 17, Oct 8
Site B2	"	"
Site C	Sep 28, Oct 11	Oct 7, Oct 21
Site D	Sept 14, Oct 12	Sep 4, Oct 22

Launch	TIME BLOCK 3 (August 31 - October 31) Weekend	Midweek
Site A	Sep 6, Sep 13	Sep 5, Sep 18
Site B1	Sep 7, Sep 27	Sep 17, Oct 8
Site B2	"	"
Site C	Oct 18, Oct 19	Oct 7, Oct 21
Site D	Sept 14, Sep 28	Sep 4, Oct 20

Appendix 3. Ross Lake 1986 creel census data form.

ANGLER SURVEY FORM

TARGET SPECIES CODES:

SH = STEELHEAD, GEN	WW = WARMWATER, GEN.	YP = PERCH	ANY = ANY SPECIES (NO SPECIFIC TARGET)
SAL = SALMON, GEN.	B = BASS, GEN.	CF = CATFISH, GEN.	CYP = CYPRINID, GEN. (CARP, SUCKER, ETC.)
TR = TROUT, GEN.	C = CRAPPIE, GEN.	WAL = WALLEYE	BUR = BURBOT (LING)
WF = WHITEFISH, GEN.	S = SUNFISH, GEN.	STU = STURGEON, GEN.	AMS = SHAD

WATER NAME (24 COL. MAX.) | SECTION (12 COL. MAX.) | PCNO | CO

DATE (MM DD YY) | TIME | INITIALS | WRIA | BASIN | WATER CODE | WAT TYPE

EFFORT COUNTS	TIME	BOAT COUNT	ANGLER COUNTS		COMPLETE	
			BOAT	SHORE	Y	N

EACH PARTY			EACH ANGLER									WHAT EACH ANGLER CAUGHT															
				"AGE"								CATCH							TOTAL LENGTHS IN CENTIMETERS								
														NO. FISH			MARK CODE										
PARTY NO.	PARTY SIZE	MILITARY TIME CHECKED	ANGLER NO.	ADULT	JUVENILE	TOTAL HOURS FISHED	COMPLETE Y-N	SATISFIED Y-N	ANGLER TYPE	GEAR CODE	TARGET SPECIES	SPECIES CAUGHT	ORIGIN	KEPT	REL	REL CODE	1	2	#1	#2	#3	#4	#5	#6	#7	#8	

B=BOAT, S=SHORE, T=TUBE, C=ICE (D=DRIFT, P=PLUNK) ↑ | ↑ B=BAIT, L=LURE, F=FLY (COMB=BL, BF, LF) | ↑ S=SUBLEGAL, L=LEGAL, O=OVERLEGAL

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Appendix 4. Summary of 1986 creel census data.

TIME PERIOD ONE
JUNE 14, 1986 - JULY 11, 1986

LOC/TIME	# TRIPS	# ANGLERS	# RB	AVG RB/TRIP	AVG RB/ANGLER	AVG TRIP TIM	CPUE
CANWE1	14	25	31	2.21	1.24	2.89	0.42
CANWK1	9	22	22	2.44	1.00	3.39	0.29
CANWK2	9	17	16	1.78	0.94	4.17	0.22
GOVWE1	10	25	50	5.00	2.00	2.95	0.70
GOVWE2	10	26	42	4.20	1.62	5.10	0.27
GOVWK1	5	13	27	5.40	2.08	4.50	0.45
GOVWK2	5	11	10	2.00	0.91	3.60	0.24
HOZWE1	75	194	565	7.53	2.91	3.38	0.83
HOZWE2	15	37	57	3.80	1.54	3.53	0.44
HOZWE3	33	76	76	2.30	1.00	3.12	0.30
HOZWK1	11	29	41	3.73	1.41	3.18	0.46
HOZWK2	9	20	27	3.00	1.35	4.28	0.31
RESWE1	42	93	295	7.02	3.17	4.17	0.76
RESWE2	17	39	67	3.94	1.72	4.15	0.40
RESWE3	8	18	22	2.75	1.22	3.56	0.34
RESWK1	11	25	42	3.82	1.68	4.30	0.42
RESWK2	13	28	52	4.00	1.86	3.92	0.48

TIME PERIOD TWO
July 12, 1986 - August 30, 1986

TIME/LOC	# TRIPS	# ANGLERS	# RB	AVG RB/TRIP	AVG RB/ANGLER	AVG TRIP TIME	CPUE
CANWE1	17	36	20	1.18	0.56	3.18	0.16
CANWE2	19	61	26	1.37	0.43	2.46	0.29
CANWK1	19	27	14	0.74	0.52	2.58	0.20
CANWK2	11	20	11	1.00	0.55	2.18	0.26
GOVWE1	3	8	17	5.67	2.12	5.50	0.31
GOVWE2	2	6	0	0.00	0.00	2.00	0.00
GOVWK1	8	23	16	2.00	0.70	2.97	0.24
GOVWK2	0	0	0	0	0	0	0
HOZWE1	30	69	42	1.40	0.61	3.42	0.17
HOZWE2	21	48	30	1.43	0.63	2.77	0.23
HOZWK1	12	28	20	1.67	0.71	4.19	0.17
HOZWK2	19	37	22	1.16	0.59	2.26	0.25
RESWE1	14	32	27	1.93	0.84	4.25	0.20
RESWE2	32	76	80	2.50	1.05	4.48	0.24
RESWK1	27	62	62	1.47	1.00	4.41	0.22
RESWK2	21	41	51	2.43	1.24	4.46	0.27

TIME PERIOD THREE

August 31, 1986 - October 31, 1986

TIME/LOC	# TRIPS	# ANGLERS	# RB	AVG RB/TRIP	AVG RB/ANGLER	AVG TRIP TIM	CPUE
CANWE1	38	70	47	1.24	0.67	2.80	0.23
CANWE2	13	23	16	1.23	0.70	2.81	0.25
CANWK1	18	33	23	1.28	0.70	2.47	0.27
CANWK2	9	10	12	1.33	1.20	2.86	0.43
CWE1	19	45	82	4.32	1.82	5.01	0.36
CWE2	15	34	77	5.13	2.26	4.63	0.47
CWK1	10	24	72	7.20	3.00	4.55	0.71
CWK2	6	14	43	7.17	3.07	5.83	0.52
HOZWE1	33	62	19	0.58	0.31	2.75	0.11
HOZWE2	41	107	216	5.27	2.02	3.08	0.64
HOZWK1	8	15	38	4.75	2.53	5.63	0.46
HOZWK2	13	23	45	3.46	1.96	3.56	0.54
RESWE1	20	41	36	1.80	0.88	3.79	0.23
RESWE2	25	50	79	3.16	1.58	3.17	0.49
RESWK1	33	71	102	3.09	1.44	4.09	0.35
RESWK2	4	8	28	7.00	3.50	5.94	0.54

Appendix 5. Observations of fish during 1974 stream spawning surveys.

Stream	Date	Observations
Roland Creek	16 May	No fish from lake (1537 ft) to 1602 ft elev. Very low stream flow.
	28 May	No fish from 1540 to 1605 ft elev. Ripe fish caught in lake at stream mouth.
	30 May	2 fish between 1541 and 1602 ft elevation.
	4 June	7 fish between 1547 and 1610 ft elev. Zero fish from 1610 ft elev. to 200 yds upstream.
	11 June	29 fish from 1555 to 1602 ft elev. 12 fish from 1602 to 1615 ft elev.
	19 June	10 spawners from about 1584 to 1602 ft elevation.
	20 June	13 fish 1588 to 1602 ft elev. 66 fish in stream to 50 yds above east bank trail.
	27 June	47 fish in stream up to east bank trail.
	27 June	6 female and 5 male spawners dipped out of Creek for egg incubation box.
	28 June	4 female and 3 male spawners shocked and used for egg incubation box.
	2 July	20 spawners in stream up to east bank trail.
	11 July	31 fish in stream up to east bank trail.
Dry Creek	8 May	No fish from about 1535 to 1602 ft elevation.
	28 May	No fish in North fork from 1540 to 1585 ft elev. One spawner in south fork at 1602 ft elev.
	4 June	3 fish from 1547 to 1602 ft elev. 13 fish above 1602 ft elev. Many fish very red.
	11 June	11 fish from 1555 to 1602 ft elev. 10 fish in pool at 1603 ft elev. Zero fish for 100 yds upstream but water very dirty and poor light conditions.
	20 June	2 fish in drawdown near 1602 ft elev. 23 fish in stream. Stream flow very high.
	25 June	3 fish from 1592 to 1602 ft elev. 79 spawners up in stream.
	2 July	One fish in north fork. 53 spawners in south fork.
	11 July	15 fish in stream up to migration block.
Lightning Creek	16 May	No fish from 1537 ft elev. to 200 yds upstream (Park Service personnel said they saw some fish from the footbridge that morning).

Appendix 5 . Observations of fish during 1974 stream spawning surveys.

Stream	Date	Observations
Lightning Creek (cont'd)	17 May	One ripe male shocked about 150 yds upstream from 1537 ft elev.
	7 June	One fish at site #2. Surveyed from 1550 to site #3.
	25 June	No fish up to spawning site #2.
	28 June	No fish up to 50 yds above spawning site #2. High stream flow.
	2 July	3 female and 1 male spawners caught by angling at mouth.
	17 July	3 female and 2 male spawners caught angling at site #2. Used for egg incubation box.
	29 Aug.	9 dead rainbow in dry pool at Migration block. At least 2 were spawned out.
Pierce Creek	17 May	No fish from 1538 to 1602 ft elev.
	11 June	No fish from 1555 to 1602 ft elev.
Noname Creek	29 May	Spawning pair of rainbows seen digging at about 1570 ft elevation.
Thursday Creek	6 June	No fish from 1548 to 1602 ft elev. 2 ripe fish caught in lake at mouth.

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