ROSS LAKE RAINBOW TROUT STUDY

1993-94 PROGRESS REPORT

by

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ABSTRACT

The Washington Department of Fish and Wildlife conducted a rainbow trout study on Ross Reservoir from June 1, 1993 to May 31, 1994. This investigation was the fourth year of a proposed 5-year study to evaluate the effect of special sport fishing regulations (implemented at the beginning of the 1990 fishing season) on reversing a historic decline in size and numbers of rainbow trout at Ross Lake. Study objectives included estimation of harvest and catch statistics for all species of trout and char, analysis of rainbow trout life history information, estimation of the total size of the overwintering fish population, and evaluation of rainbow trout spawning timing and success in selected tributaries of Ross Lake. A stratified random sampling design was used to develop all effort, catch and harvest estimates.

Ross Lake anglers fished a total of 22,397 hours during the 1993 fishing season, or 5,721 angler days. The total seasonal rainbow trout harvest estimate was 2,208 fish, with a mean seasonal harvest rate of 0.096 fish per hour. Total catch (harvested + released) was estimated at 12,600 rainbow trout, with a mean catch rate of 0.553 fish per hour. Total seasonal dolly varden/bull trout char harvest and catch estimates were 0 and 24 fish, respectively. No other species of trout or char were reported in the 1993 sport catch.

The new angling regulations continue to have significant impacts on angler effort, harvest rates, and harvest at Ross Reservoir. Estimated 1990-93 seasonal angler effort, harvest rates, and harvest remain markedly less than during the the early 1970's and mid-1980's. Compared to 1992 estimates, total 1993 seasonal angler effort declined approximately 5 percent, mean seasonal harvest rates (combined species) decreased 9 percent, and total harvest (combined species) increased 2 percent.

Five hydroacoustic surveys were conducted on the lower portion of Ross Lake during April and May of 1994. These surveys are a continuation of annual index counts that are also used to estimate the total size of the reservoir's fish population (fish larger than six inches). The total combined reservoir species population was estimated at 68,938 fish, while the rainbow trout portion of the population was estimated at 68,812 fish. Index counts and population estimates continue to increase each year, and probably reflect increasing numbers of immature age classes of fish.

Six spawning surveys conducted on the U.S. portion of five Ross Lake tributaries from May to July of 1994 resulted in a total enumeration of 2,279 rainbow trout. Peak spawning occurred on most tributaries during the first two weeks of June, with Roland Creek recording the largest number of spawning fish. Roland Creek and Dry Creek continue to be the most important index tributaries due to fish accessibility, flow,

spawner use, availability of spawning habitat, and visibility and accessibility by survey personnel. Observations of spawning rainbow trout in 1994 indicate that numbers continue to increase each year, but remain much reduced from mid-1980's levels.

Data collected from the 1990-91, 1991-92, 1992-93, and 1993-94 rainbow trout studies at Ross Reservoir indicate the fish population is still suffering from the effects of past overharvest. These studies suggest the present rainbow trout population is increasing, but is still below early 1970's levels. Continued evaluation and monitoring of the fish and fishery in response to the new regulations is necessary to promote recovery of rainbow trout stocks in Ross Reservoir.

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INTRODUCTION

This report summarizes the results of an angler harvest and rainbow trout study conducted on Ross Reservoir from June 1, 1993 to May 31, 1994. This is the fourth year of an ongoing five-year study by the Washington State Department of Fish and Wildlife (WDF&W) to evaluate the effect of special fishery regulations designed to reverse the decline in size and numbers of rainbow trout in Ross Lake (Johnston 1989; Looff 1991, 1992a, 1992b, 1993a, 1993b, 1994b). These regulations were implemented at the beginning of the 1990 sport fishing season by both the WDF&W and the British Columbia Division of Fish and Wildlife (BCF&W), and are identical for both agencies *(Appendix 1)*.

The new fishery regulations are more restrictive than earlier regulations, and are expected to reduce angler harvest (reduced catch limit) and allow fish to spawn at least once before entering the fishery (increased minimum size limit). A bait restriction was necessary to reduce mortality of released fish, and a later season opener was enacted to permit spawning fish more time to ascend tributary streams before the fishery opened, and also to allow both Canadian and American anglers equal access to the lake on opening day. Johnston (1989) gives a complete list of all Washington State fishing regulations on the reservoir since 1933.

This study was funded by the Skagit Environmental Endowment Commission (SEEC). The SEEC solicits, approves, and funds projects from a special fund using money set aside by Seattle City Light as part of a U.S. Federal Energy Regulatory Commission (FERC) permit requirement.

Previous Studies

The present study is a continuation of fisheries studies conducted on Ross Reservoir by the WDF&W and BCF&W in 1985 and 1986 (Scott and Peterson 1986; Johnston 1989). Earlier in-depth fisheries studies were also conducted on Ross Lake by the University of Washington Fisheries Research Institute (FRI) at the time Seattle City Light (SCL) proposed to proceed with the third and final construction phase of Ross dam (High Ross). A number of studies have also been conducted on the upper Skagit River by BCF&W. A complete list of all major fisheries studies related to Ross Reservoir is given in Resident Fisheries Study for Ross, Diablo and Gorge Lakes (Seattle City Light 1989a).

Study Area

Ross Lake is an oligotrophic reservoir located at 49°N latitude and 121°W longitude in the northeastern portion of Whatcom County, Washington and the southeastern portion of Fraser Cheam Regional District, British Columbia *(Figure 1)*. The reservoir is located within

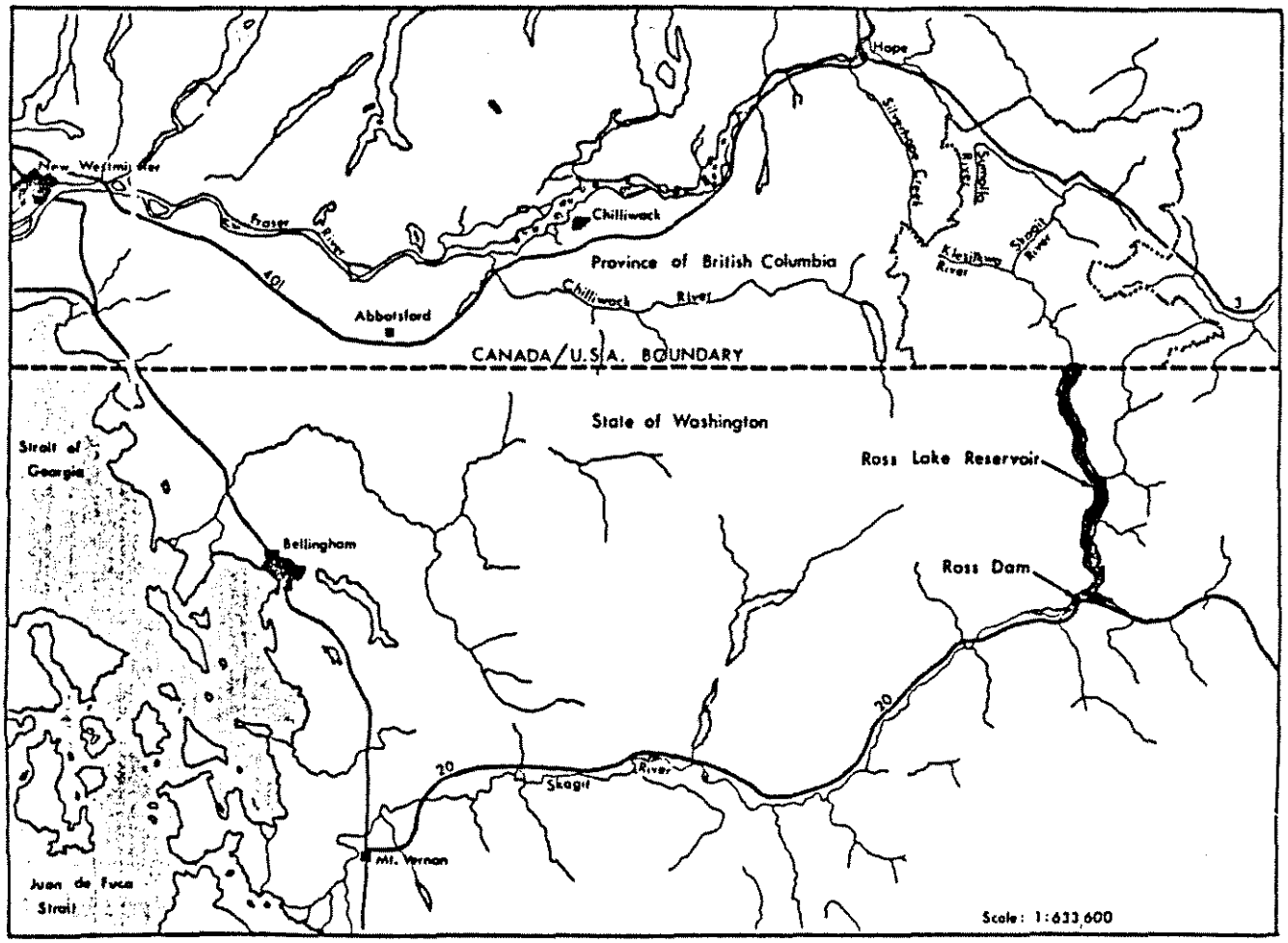

FIGURE 1. Geographic location of Ross Lake in NW Washington and SW British Columbia.

the Skagit River watershed, and was formed by the construction of Ross Dam (1937-49) on the Skagit River. The lake drains approximately 999 square miles of the watershed upstream from the dam. Surface elevation of the lake is 1,602.5 feet mean sea level (msl) at full pool and 1,475 feet msl at maximum drawdown.

Physical characteristics of the reservoir vary seasonally due to winter drawdown by Seattle City Light for power and flood control purposes. Therefore, the following measurements are given for full pool elevation only. The reservoir is approximately 22 miles long, with the northern-most mile extending into Canada. Average width is approximately one mile, and maximum width is two miles. The long axis of the reservoir is oriented in a north-south direction, and is perpendicular to the direction of prevailing winds. Total surface acreage is 11,680 acres, of which 480 acres is located in British Columbia. Total lake volume is estimated at 770,000 acre-ft. The lake basin is predominantly deep and steep-sided, although the northern portion of the lake is relatively shallow. Maximum depth is 400 ft near the base of the dam and mean reservoir depth is 123 ft. A summary of the physical characteristics of Ross Lake is given in *Table 1.*

Ross Reservoir is fed by the upper Skagit River in Canada and several large, perennial streams on the U.S. side of the reservoir *(Figure 2).* Ruby Creek, Lightning Creek, and Big Beaver Creek are the largest American tributaries, followed by Little Beaver, Devils, Silver, Arctic, No Name, Hozomeen, Dry, Pierce, and Roland Creeks. Physical characteristics and spawning habitat summaries of the major tributaries to Ross Lake are summarized in the Ross Lake Tributary Stream Catalog (Seattle City Light 1989b). Numerous small, intermittent streams also drain into the lake. The Skagit River is the only outflow channel present.

Rainbow trout (Oncorhynchus gairdneri) are the predominate sport fish in Ross Lake. A seasonal sport fishery exists on this species from July through October. Also present in the lake are dolly varden (Salvelinus malma)/bull trout (Salvelinus confluentus) char, cutthroat trout (Oncorhynchus clarkii), and brook trout (Salvelinus fontinalis) char.

Objectives

The specific objectives of the 1993-94 Ross Lake study were as follows:

1. Determine angler effort and distribution on the reservoir.

2. Determine angler catch (kept and released), harvest (kept only), catch per unit effort (CPUE), harvest per unit effort (HPUE), and angler distribution on the reservoir.

3. Determine age distribution, age class strength, age versus length, age versus sexual maturity, and length at sexual maturity of rainbow

TABLE 1. Ross Lake physical data. From The Aquatic Environment, Fishes and Fishery: Ross Lake and the Canadian Skagit River (City of Seattle 1972).

	Reservoir Water Levels		
	Max.	Min.	Mean
Annual Flushing Rate[a]	1.84	—	2.35
Drainage Area (mi^2)[b]	999	—	—
Elevation (feet)	1,602.5	1,475	1,575
Length (miles)	22	—	—
Maximum depth (feet)	400	—	—
Mean depth (feet)	122.5	93.6	—
Shoreline development[c]	4.26	4.01	4.07
Shoreline length (miles)	64.5	37.4	51.0
Surface area (acres)	11,680	4,400	10,300
Volume (acre-feet)	1,435,000	412,000	—

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

[a]Based on 1953-69 flushing rates.
[b]Skagit River drainage upstream of Ross dam.
[c]Shoreline development (SD) = $S/(2*((Pi*A)^{-5}))$, where S = shore length and A = lake area.

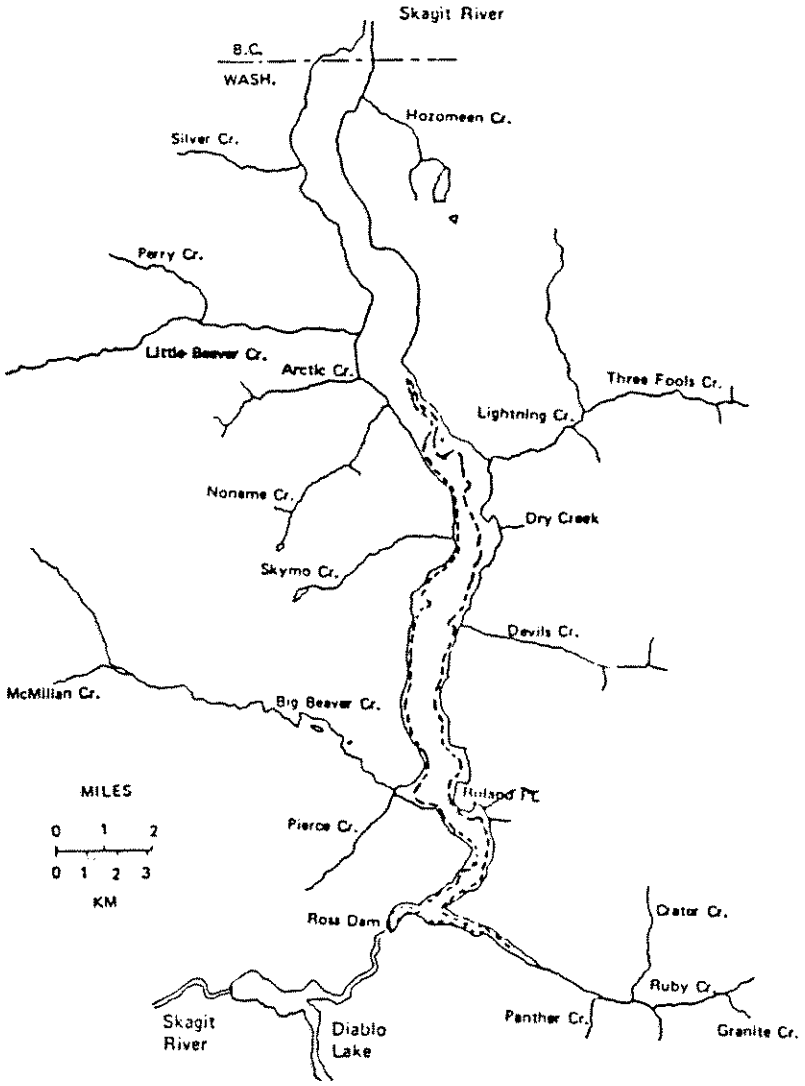

FIGURE 2. Ross Lake and major tributaries. The perimeter of the lake at full pool (1,602.5 feet msl) is shown as a solid line, and the maximum drawdown contour (1,475 feet msl) is depicted as a dotted line.

trout sampled from the angler sport catch.

4. Develop estimates of the reservoir fish population size and conduct index counts from fixed hydroacoustic transects to monitor annual population status.

5. Conduct annual spawner surveys on index streams to determine time of spawning, spawning locations, and effectiveness of (minimum size) catch limits on increasing numbers of spawning fish.

6. Compare results of the 1993-94 study with previous studies.

7. Identify additional data requirements for future studies.

8. Continue development of a long-term management plan for Ross Reservoir in coordination with federal (National Park Service) and international (British Columbia Ministry of Environment) management agencies.

METHODS

Sampling methods and procedures for the 1993-94 rainbow trout study on Ross Reservoir are nearly identical to studies conducted during 1990-91, 1991-92, and 1992-93. Statistical comparisons of data are primarily limited to the first four years of the present five-year study, since different fishing regulations and/or sampling designs were in effect for studies conducted in the mid-1980's and early 1970's.

1993-94 Studies

The 1993-94 sampling program consisted of data and information collected from three different studies. A four-month angler creel survey was conducted from July 1 to October 31, 1993 to determine angler harvest and harvest-related information. A second study involved collection of hydroacoustic transect data from five lake surveys performed during April and May of 1994. The purpose of these surveys was to provide index counts of fish density for use in annual monitoring of population size fluctuations, and to estimate the size of the 1993-94 overwintering reservoir fish population (all species combined). The third study involved enumeration of spawning rainbow trout on selected tributaries of Ross Lake from late May to mid-July of 1994. These surveys were used to provide index counts of spawner density for use in annual monitoring of spawning population fluctuations in each index stream.

Personnel consisted of one full-time biologist that conducted all project-related work. Funding did not permit hiring of a temporary scientific technician (to assist in collection of angler creel survey data) as in the previous three years of the study.

1993 Creel Survey

The 1993 angler creel census was based on a stratified random design that was identical to that used during the 1990-92 creel surveys (Looff 1992a, Looff 1993a, Looff 1994b). Strata were divided into three day-types that reflected intensity of angler use on the reservoir. These day-types included opening day, weekdays, and weekends. Opening day (opening weekend prior to 1990) is treated as a separate strata, since a considerably higher degree of angler effort is generated at this time than at any other time during the fishing season.

Sample days were randomly selected by microcomputer using a Microsoft QuickBASIC program written by the author (Looff 1992a). This program randomly selected four, three-day (continuous) time blocks for each month from July through October, for a total of forty-eight sample days for the 1993 fishing season *(Table 2)*. Logistical and budgetary constraints travelling to and from the lake necessitated the use of continuous three-day time blocks. Two additional constraints on the

TABLE 2. Number of days censused per day type strata during the 1993 sport fishing season at Ross Reservoir.

Month	Daytype	Total Days	Days Censused	% Total
Jul	Opener	1	1	100%
	Weekday	21	6	29%
	Weekend	9	5	56%
	Total	31	12	39%
Aug	Weekday	22	8	36%
	Weekend	9	4	44%
	Total	31	12	39%
Sep	Weekday	21	7	33%
	Weekend	9	5	56%
	Total	30	12	40%
Oct	Weekday	21	8	38%
	Weekend	10	4	40%
	Total	31	12	39%
Season	Opener	1	1	100%
	Weekday	85	29	34%
	Weekend	37	18	49%
	Total	123	48	39%

selection process were that four weekend days and eight weekdays had to be sampled each month, and that opening day (July 1), Independence Day (July 4), and Labor Day (September 6) had to be included as sample days. The latter restriction modified the number of (effective) weekend days and weekdays sampled during the months of July and September *(Table 2)*. Sampling dates for the 1993 sport fishing season are listed in *Appendix 2*.

A continuous eight-hour work day was scheduled for each sample day throughout the creel census. The starting time and subsequent eight-hour work period for each sample day was randomly selected by computer (described above) according to the number of daylight hours available each month *(Table 3)*. This work schedule was based on the same design as that used in 1985 (Scott and Peterson 1986), rather than on the 1986 design, which required sampling over the entire daylight period (Lewynsky 1986). The latter design required continuous sampling of <u>all</u> anglers from dawn to dusk in order to develop effort estimates. The design used in the 1985, and 1990–93 studies required a <u>random</u> sampling of returning anglers (although an attempt was made to survey as many anglers as possible).

Restricted access to the reservoir permitted most anglers to be interviewed during the course of any work day (except for a very few heavy use periods such as opening day and holidays). Scott and Peterson (1986) classified five access areas where anglers were intercepted for interviews and biological sampling of catch. These included Canada, three sites on the American portion of the reservoir at the north end of the lake (Winnebago Flats, government dock, and lower launch), and Ross Lake Resort at the south end of the lake. Only three access areas were designated for the present study. These sites included Canada, Hozomeen campground, and Ross Lake Resort. The three launch sites at Hozomeen campground from 1990 to 1993 were considered to be a single access area, since seasonal angler use was significantly lower than in previous years, and the lower launch site was inundated by water most or all of each fishing season. (When late-season drawdown by Seattle City Light does permit use of the lower launch site, the remaining sites at the north end of the lake are not normally accessible due to receding water levels).

Only one employee conducted the angler creel survey on each sample day during 1993. This was similar to the previous season (1992), but differed from the first two years of the study (1990 and 1991), when both ends of the lake were sampled simultaneously. Work days were allocated equally between the north and south end of the lake during 1993, with roving interviews conducted between the Canadian and Hozomeen access areas at the north end.

<u>Angler Interviews</u>

Angler interviews at Ross Reservoir were conducted by contacting anglers returning to the three primary access areas. All anglers were asked to

TABLE 3. Number of daylight hours assumed available to anglers during the 1993 sport fishing season at Ross Reservoir.

Month	Hours	Start	Finish
July	15	0600	2100
August	13	0700	2000
September	11	0800	1900
October	9	0900	1800

volunteer the same information. Anglers were generally interviewed immediately upon returning, but were also interviewed later in the day. To compensate for the reduction in sampling effort at each end, creel information from the previous day was also collected (assuming the angler fished the day before, no data had been collected from that angler, and the previous day was also a sample day). Information was collected from all anglers contacted, regardless of whether they had finished fishing for the day. Two primary reasons for checking incomplete anglers was that a large proportion of anglers did not continue fishing after indicating they were going to, and information would be lost from anglers that continued fishing but did not return before the work day ended.

Interviews consisted of the collection of angler catch and profile data. The following catch information was recorded for each species of trout and char captured:

- time of interview
- time angler started fishing (to the nearest 15 minutes)
- whether angler had finished fishing for the day
- species
- number of fish harvested
- number of fish released
- size range of fish released
- capture location (discussed below)

As in the early 1970's, 1985-86, and 1990-92 studies, the reservoir was arbitrarily divided into seven zones for purposes of determining distribution of angler effort, CPUE (catch per unit effort), HPUE (harvest per unit effort), and catch and harvest information. The location of each of these zones is shown in *Figure 3.* These zones are numbered the same as shown in the 1989 report (Johnston 1989).

The following angler profile information was collected for each angler interviewed:

- age category (adult, juvenile)
- fishing method (boat, shore, float tube)
- angling gear (lure, fly)

The following biological information was collected from a random sample of the angler harvest for rainbow trout only:

- nose to fork length of harvested fish (mm)
- sex
- scales for aging (discussed below)
- sexual maturity (discussed below)

Approximately 20-30 scales were collected from each rainbow trout sampled. Scales were removed from an area formed by an imaginary line drawn from the rear insertion of the dorsal fin to the front insertion

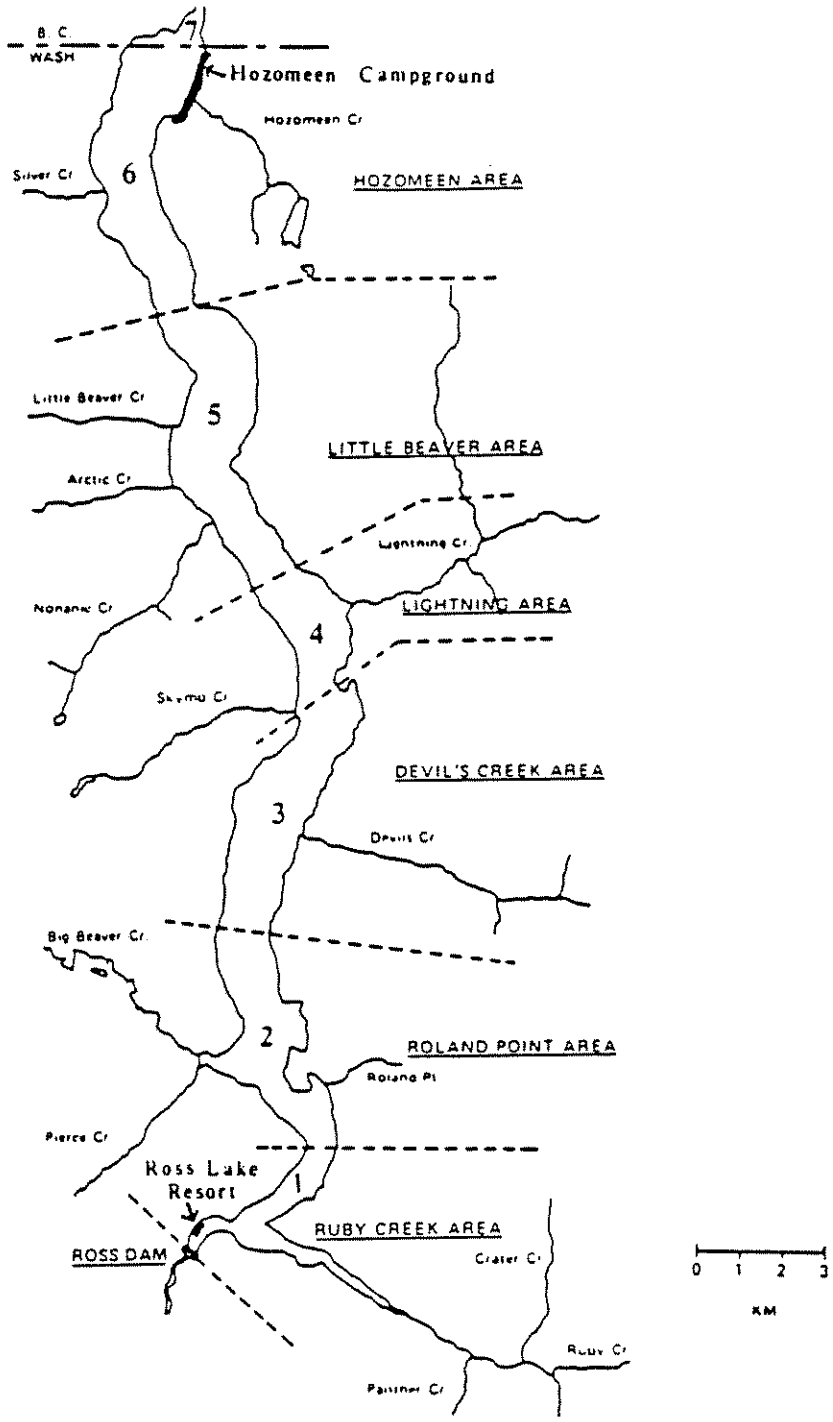

FIGURE 3. Ross Lake survey zones.

of the anal fin approximately 3-5 scale rows above the lateral line. Scales were then placed in scale envelopes and the date, capture area, species, fork length (mm), sex and sexual maturity (if collected) recorded on the outside. Five scales from each sample were later cleaned and mounted on a glass slide using a cover slip and transparent tape. A microfiche reader (35X) was then used to age each sample. Only samples containing at least two good scales that did not exhibit regenerated areas were used. After aging all of the samples once to determine growth patterns and other characteristics, the scales were aged a second time. If the two readings did not agree, a third reading was done. The final result of this third reading was considered to be the age of the sample.

A subset of rainbow trout that were sampled for scale analysis were also examined for sexual maturity on the basis of gonadal development. Sexual maturity information was only collected from trout sampled during the month of July, since newly developing egg skeins and sperm sacs of recently spawned fish appear identical (very small size) to those of immature fish after this time. In addition, sexual maturity determinations are further hindered by the rapid disappearance of secondary external sexual characteristics, and resorption of unspawned gametes following spawning.

Fish were classified as mature if testes were enlarged or contained sperm in males, and if eggs were in an advanced stage of development or freely flowing in females. External spawning characteristics, such as dark color, emaciated condition, and enhanced color of the red side stripe, served as secondary aids to classification of mature fish of both sexes. Fish were classified as immature if male testes and female egg skeins were small and poorly developed.

Separate measurements were collected for dolly varden/bull trout char to assist current WDF&W studies aimed at delineating the geographic ranges of these two species, whose external physical characteristics are visually almost identical. A special linear discriminant function developed by Haas (1988) at the University of British Columbia was used to distinguish between the two species. This equation requires the collection of the following four external physical measurements:

- number of branchiostegal rays (slender bones in the gill membranes) on both right and left sides
- maxillary length
- number of principal anal fin rays
- standard length (nose to last vertebra) in millimeters

The function for species identification is as follows (Haas and McPhail 1991):

1) [(0.629 * branchiostegal ray number) + (0.178 * anal fin number) + (37.310 * (maxillary length/standard length))] - 21.8

where,
dolly varden <0, and
bull trout >0.

Char fork length (mm) was also measured to compare with data collected from earlier studies at Ross Reservoir.

Effort

Effort estimates were generated separate from the angler creel survey. This precluded personnel from having to work over the entire daylight period of each sample day, as described earlier. Effort sampling times were randomly selected by computer *(Appendix 2)* to correspond with sample days and work schedules *(Table 2)*.

Instantaneous effort counts were conducted twice daily by running a boat the length of the reservoir and counting the number of anglers actually fishing in each zone of the lake *(Figure 3)*. An angler was not counted unless a line was visually observed in the water. (This sampling method differed from the 1985 effort survey design in that boats, and not anglers, were counted during the 1985 study. These counts were later expanded to angler counts using average number of anglers per boat data collected by National Park Service personnel during the 1985 season). On average, it required from 40-50 minutes to conduct a single count, depending on weather conditions and number of anglers fishing. The second count was made on the return trip back, after conducting angler interviews for approximately three hours.

Three separate effort estimates (and associated variances) for 1993 were derived by organizing strata into daytypes, lake zones, and access areas. For reasons outlined below and in later portions of the methods section, daytype estimates for all variables (effort, CPUE, HPUE, catch, and harvest) generate the most accurate estimates based on the sampling design utilized in this study, and will be the actual results reported. Zone and access area estimates, which do not accurately reflect one or more of the above variables, are used for comparative purposes only.

Accurate access area effort estimates were not possible using the effort sampling design of the current study (it was not practical to stop and ask each angler where he launched from while conducting effort counts). However, it was assumed that anglers fishing in zone 7 used the Canadian access, anglers fishing in zones 4-6 utilized the Hozomeen access, and anglers fishing in zones 1-3 came from Ross Lake Resort. The small size and low horsepower engines on the resort boats made it difficult for most anglers using these craft to fish north of Ten-Mile Island (zone 3), which was verified through both visual observations during effort counts, and during angler interviews at the resort. Conversely, very few boats originating from Hozomeen fished farther south on the reservoir than Lightning Creek (zone 4). Lastly, very few anglers from either country purchased a second license to fish on the opposite side of the international boundary (zones 6 and 7).

Effort counts for each of the three estimates were converted to monthly and total estimates using simple expansion techniques. However, due to the random sampling of hourly daylight time periods, not all hours were sampled for a particular strata within any monthly time block. Missing hourly effort within a specific strata was estimated using the following proportion:

2) $e = e_h * (n/h)$

where, in any particular strata,

e = total effort,
e_h = sum of the hourly effort counts in a particular strata,
n = total number of available survey hours, and
h = number of hours actually surveyed

The same technique was applied to variance estimates, using the appropriate equation for multiplication of a variance by a constant (Freese 1962).

Catch Rate and Harvest Rate

Catch rate (and harvest rate) estimates and associated variances were generated by expanding data from the creel surveys. The general formula for the catch rate (CPUE) of any particular strata-type is:

3) $r = c / t$

where, in any particular strata,

r = catch rate (CPUE),
c = catch, and
t = time (hours)

The harvest rate (HPUE) of any particular strata-type is found by substituting harvest (h) for catch (c) in (3).

Three separate rainbow trout catch rate (and harvest rate) estimates for daytype, zone, and access areas were generated using the two formulas. Even though total monthly and seasonal catch (and harvest) rates are identical for the three types of estimates, strata estimates are more accurate for daytype calculations. The primary reason for this is that interviewed anglers were asked to identify which one zone they caught and harvested most fish in. Thus, each fish captured or harvested was not traced to the exact zone of capture. Access area catch (and harvest) rate estimates were calculated by arbitrarily dividing the catch identified by zone using the method outlined earlier in the effort section. Daytype estimates consider only the number of fish caught and/or harvested. Thus, zone and access area estimates imply more accuracy than is acceptable, and are given for comparative purposes only. Dolly varden/bull trout char, cutthroat trout, and brook trout

(char) catch rate (and harvest rate) estimates were produced using daytype information only.

Catch and Harvest

Catch (and harvest) estimates and associated variances were generated by expanding data from the two separate creel and effort surveys. The general formula for total catch of any particular strata-type is:

4) $c = e * Q_1$

where, in any particular strata,

c = total catch,
e = total effort, and
$Q_1 = c/t$

The total harvest of any particular strata-type is found by substituting harvest (h) for catch (c) in (4).

Three separate rainbow trout catch (and harvest) estimates for daytype, zone, and access area were generated using this formula. As discussed previously, daytype estimates produce the most accurate results, while zone and access area estimates are given for comparative purposes only. Dolly varden/bull trout char, cutthroat trout, and brook trout (char) catch (and harvest) estimates were produced using daytype information only.

Variance Estimators

Variance estimators were used to generate standard errors for all effort, CPUE, HPUE, catch, and harvest estimates (Freese 1962). The following estimators were used to compute the variance of a ratio (CPUE and HPUE), and product (catch and harvest) of any particular strata type:

(5) $s_{Q_1}^2 = Q_1^2 * ((s_c^2/c^2) + (s_t^2/t^2) - ((2*s_{ct})/ct))$

where,

c = catch,
t = time (hours),
$Q_1 = c/t$, and
s_{ct} = covariance(c,t)

(6) $s_{Q_2}^2 = Q_2^2 * ((s_e^2/e^2) + (s_r^2/r^2) + ((2*s_{er})/er))$

where,

e = effort,
r = c/t, and
$Q_2 = e*r$.

Since effort and catch rate were determined from separate surveys, they were assumed to be independent and the covariance set equal to zero in (6). Thus, the quantity $((2*s_{ct})/ct)$ equaled zero and was dropped from the second equation.

The variance of a harvest rate (HPUE) and total harvest of any particular strata-type is found by substituting harvest (h) for catch (c) in (5) and (6), respectively.

Hydroacoustic Surveys

Hydroacoustic surveys were conducted during April and May of 1994 to estimate the total number of fish (all species) greater than six inches length in the reservoir. Late winter and early spring is the optimal time to conduct these surveys for several reasons. Both the number and length of hydroacoustic transects is reduced at this time of year due to winter reservoir drawdown by Seattle City Light and subsequent decrease in reservoir size *(Figure 2)*. The reservoir fish population is also at a maximum, since fish have not yet ascended tributary streams to spawn and/or feed. Environmental conditions at this time of the year result in more calm, windless days, which are required to keep the sonic cone perpendicular to the lake surface and also eliminate noise interference from boat waves. Lastly, reservoir and environmental conditions also result in less debris in the water column that can create transducer interference.

A modified Ross 600C Straight Line Recorder with a revolving chart recorder was used to collect population data. Power was supplied to the echosounder using two 12-volt DC deep cycle batteries connected in-line to produce 24 volts. One down-scanning and one side-scanning transducer were mounted on a 14' aluminum boat powered by a 25 horsepower outboard motor *(Figure 4)*. Transducer calibration, equipment operation, and development of estimates and associated variances followed echo counting procedures developed by Johnston (1981). However, sampling design was based on fixed transect counts, instead of random selection of transects for each survey, as explained below.

Preliminary hydroacoustic surveys conducted on March 29-30, 1991, indicated that the upper portion of the reservoir north of Rainbow Point was unsuitable for echosounding due to the presence of large numbers of trees just below the lake surface. The reservoir was only partially logged prior to inundation in the late 1940's and early 1950's, with most of the logging having occurred north of Lightning Creek (Pitzer 1978). Both fish and tree parts trace identically on the chart recorder, making it impossible to conduct population estimates in this portion of the lake. Furthermore, other areas south of Rainbow Point, including areas adjacent to May Creek, Big Beaver Creek, and Roland Point, also have large numbers of standing trees close to the surface. Based on the above information, eleven fixed transects south of Rainbow Point were selected for annual index counts and subsequent calculation

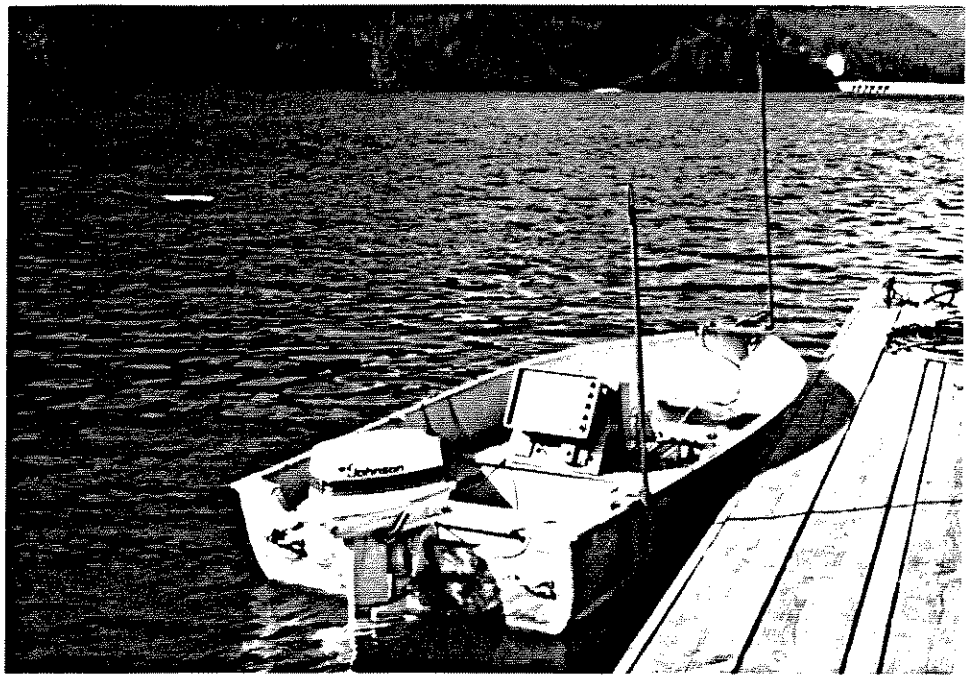

FIGURE 4. Hydroacoustic equipment used in reservoir trout population estimates and index counts.

of reservoir population density. Transects were almost or entirely devoid of standing trees, and were selected to encompass as many geographic features of the lake as possible. Each transect was surveyed with the down-scanning transducer using a 0-100 foot setting. It was not necessary to scan deeper than 100 feet, since very few fish were present below 60 feet. Additionally, three of the eleven transects were randomly selected for sampling with the side-scanning transducer (transects 1, 6, and 8). Approximately four hours were required to survey all eleven transects.

Five estimates were conducted on April 27-28 and May 3. Three estimates were conducted in the morning between 0800 and 1200 hours (April 27-28, and May 3), and two estimates were conducted in the afternoon between 1200 and 1600 hours (April 27-28).

Population estimates were calculated from index count data, and are based on the assumption that fish are randomly distributed in the reservoir during early spring. Visual inspection of transect data did not indicate clumping of fish in any of the areas surveyed. Relatively rapid water level fluctuations probably inhibit establishment of territories along shallow littoral areas of the lake, possibly enhancing random dispersion into pelagic zones. Also, the absence of terrestrial and aquatic invertebrates due to seasonal timing and/or reservoir fluctuations, probably entice fish to disperse and feed on zooplankton throughout the upper water column of the lake.

The development of reservoir population estimates required the calculation of lake strata volumes. Lake volumes were estimated at (even) 25-foot contour intervals from 1600 feet down to 1375 feet using a set of 1933 topographic maps supplied by Seattle City Light. Johnston (1981) lists the methods and procedures for determining lake strata volumes from topographic maps. It was necessary to first locate the appropriate 25-foot contour intervals used in the lake volume estimates on the down-scan transect echograms before making any initial fish counts. This was necessary since the reservoir was at a different elevation on each survey date. Fish counts were then made between these intervals. Volume adjustments (linear interpolation) were necessary for the upper and lower portion of each echogram, since the echogram did not precisely match the 25-foot volume contour intervals.

Population estimates and variances for each complete survey were calculated using statistical procedures developed by Johnston (1981). These procedures utilize simple expansion techniques to estimate density within each 25-foot depth strata.

Spawning Surveys

Six rainbow trout spawning surveys were conducted from late May to early July of 1994 on each of five index streams. Tributaries were selected for annual enumeration of spawning fish on the basis of size, flow,

availability of spawning habitat, historic spawner usage, and accessability by personnel. Streams surveyed included Dry, Lightning, Pierce, Roland, and Thursday Creeks *(Figure 2)*.

Each stream was surveyed upstream from the mouth to either the first total migration barrier, or the limit of available spawning habitat. Survey frequency from 8-12 days throughout the spawning period, averaging approximately ten days. Survey dates included May 24, June 2, 10, 22, and 30, and July 12. High water flows precluded surveys above the mouth of Lightning Creek on May 24, and above the drawdown on all other survey dates.

RESULTS

1993-94 Lake Levels

The opening day lake elevation was 1,599.98 feet msl on July 1, 1993. The reservoir reached a maximum elevation of 1,602.44 feet msl on August 5, 1993, and a minimum elevation of 1,536.67 feet msl on February 28, 1994.

1993 Opening Day Creel Survey - (post-1990 regulation change)

A total of 34 anglers were checked at Ross Lake on opening day, July 1, 1993 *(Table 4)*. These anglers fished a total of 163.25 hours and caught 175 rainbow trout (harvest and release) for a catch per unit effort (CPUE) of 1.072 fish per hour. Catch per unit effort was higher at the south end of the lake (1.243 fish per hour) than at the north end (0.889 fish per hour). The fish per angler average was 5.1 for a combination of complete and incomplete anglers, while completed trip anglers caught an average of 6.2 fish per person. Two dolly varden/bull trout char were the only other species reported in the catch on opening day, both of which were released by two anglers fishing at the south end of the lake.

1993 Opening Day - Harvest

Opening day harvest totalled 37 rainbow trout for interviewed anglers *(Table 4)*. A total of 138 fish (79%) were released. Harvest per unit effort (HPUE) was 0.227 fish per hour, and was markedly higher at the north end of the lake (0.355 fish per hour) than at the south end (0.089 fish per hour). The fish per angler average was 1.1 for a combination of complete and incomplete anglers, while completed trip anglers harvested an average of 1.8 fish per person.

1993 Opening Day - Methods and Gear

All anglers checked at Ross Lake used boats on opening day. The only angling method utilized by these anglers was trolling with flashers and lures.

1993 Opening Day - Age, Length, Sex, and Sexual Maturity

An extremely small sample size (n=2) precluded analysis of rainbow trout life history information from the opening day harvest.

A complete list of the 1993 opening day creel data for Ross Lake is given in *Appendix 1* of the Ross Lake Rainbow Trout Study: 1993-94 Data Appendix (Looff 1994a).

TABLE 4. Comparison of 1993 opening day rainbow trout catch statistics between different access areas at Ross Reservoir.

			Rainbow Trout					
						Fork Length (mm)		
Access	Anglers	Hours	Catch	CPUE[a]	F/A[b]	Min	Max	Avg
COMBINED TRIPS[c] - Harvest Only								
Hozomeen	21	85	30	0.355	1.4	—	—	—
Resort	13	79	7	0.089	0.5	320	333	327
Total	34	163	37	0.227	1.1	320	333	327
COMBINED TRIPS[c] - Harvest + Released								
Hozomeen	21	85	105	1.243	5.0			
Resort	13	79	70	0.889	5.4			
Total	34	163	175	1.072	5.1			
COMPLETE TRIPS - Harvest Only								
Hozomeen	6	28	16	0.582	2.7	—	—	—
Resort	3	13	0	0.000	0.0	—	—	—
Total	9	40	16	0.400	1.8	—	—	—
COMPLETE TRIPS - Harvest + Released								
Hozomeen	6	28	49	1.782	8.2			
Resort	3	13	7	0.560	2.3			
Total	9	40	56	1.400	6.2			

[a]Catch per unit effort (fish/hour).

[b]Fish per angler.

[c]Includes data from fishermen that were not finished fishing for the day (complete + incomplete trips).

1993 Season Creel Survey

A total of 1,035 anglers were interviewed during the July 1 to October 31, 1993 creel census at Ross Reservoir. During the interviews 243 rainbow trout were sampled for life history information.

1993 Season - Angler Effort

From July 1, 1993 to October 31, 1993 anglers fished an estimated 22,397 ± 54 hours, or 5,721 angler days *(Table 5*, daytype estimate*)*. Angling decreased steadily as the season progressed *(Figure 5* and *Appendix 3)*, with 41 percent of the seasonal effort total occurring in July, 27 percent in August, 18 percent in September, and 14 percent in October.

A total seasonal estimate of 23,764 ± 5 hours was calculated for effort data that was partitioned into zones *(Table 5* and *Appendix 4)*. From *Figure 6*, it can be seen that most effort was expended in zones 2-Big Beaver (23%) and 6-Hozomeen (22%). Zones 7-Canada (15%), 5-Little Beaver (13%), 1-Ruby (11%), 3-Devils (9%), and 4-Lightning (7%) comprised the remaining effort.

Effort data that was partitioned into access areas resulted in a total seasonal estimate of 25,659 ± 28 hours *(Table 5* and *Appendix 5)*. An estimated total of 13,520 hours (53%) was calculated for anglers utilizing the resort, 8,570 hours (33%) for anglers at Hozomeen, and 3,569 hours (14%) for anglers in Canada.

1993 Season - Angler Catch and Harvest Rates

The mean seasonal catch rate (combination of harvested and released) for rainbow trout was 0.553 ± <0.001 fish per hour *(Table 6*, daytype estimate*)*. Rainbow trout catch rates declined markedly from July to August, then increased slightly in September and October *(Figure 7* and *Appendix 6)*. Catch rates were highest in July (0.744 CPUE) and October (0.467 CPUE), and lowest in August (0.423 CPUE) and September (0.453 CPUE).

The mean seasonal harvest rate for rainbow trout was 0.096 ± <0.001 fish per hour *(Table 6*, daytype estimate*)*. As shown in *Figure 7*, harvest rates for rainbow trout decreased from a seasonal high in July (0.145 HPUE) to a seasonal low in August (0.055 HPUE), then increased in September (0.069 HPUE) and October (0.086 HPUE).

Mean seasonal capture rates for zone and access area estimates are identical to daytype estimates *(Table 6)*, since all three estimates were calculated from the same creel data. As shown in *Table 6* and *Figure 8*, the highest seasonal catch rates for rainbow trout (zone estimate) occurred in zones 7-Canada (0.921 CPUE) and 6-Hozomeen (0.767 CPUE). Intermediate catch rates occurred in zones 3-Devils (0.560 CPUE) and 5-Little Beaver (0.479 CPUE), while zones 2-Big Beaver (0.444 CPUE),

TABLE 5. Estimated total seasonal angler effort in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Type[a]	Strata	Angler Hours[b]		Mean Hours Fished per Day[c]	Total Angler Days[d]
Daytype	Opener	840	(0)	4.80	175
	Weekday	11300	(75)	3.89	2904
	Weekend	10257	(55)	3.88	2642
	Total	22397	(54)	3.91	5721
Zone[e]	1 Rby	2549	(5)	3.78	674
	2 Bbv	5571	(10)	4.27	1306
	3 Dev	2095	(5)	5.10	411
	4 Lit	1638	(5)	5.27	311
	5 Lbv	3109	(5)	5.14	605
	6 Hoz	5282	(8)	3.32	1592
	7 Can	3519	(8)	2.83	1242
	Total	23764	(5)	3.87	6140
Access	Resort	13520	(64)	4.27	3169
	Hozomeen	8570	(44)	3.62	2368
	Canada	3569	(34)	2.91	1226
	Total	25659	(28)	3.79	6763

[a]Type of estimate. Daytype estimates are the most accurate based on sample design, and are the values reported for this study (see text).

[b]Ninety-five percent confidence interval of estimated total angler-hours given in parentheses.

[c]Mean hours calculated using data from all anglers, including those that indicated they had not finished fishing for the day (see text).

[d]Total angler days = angler hours/mean hours fished per day.

[e]See *Figure 3* for location of lake survey zones.

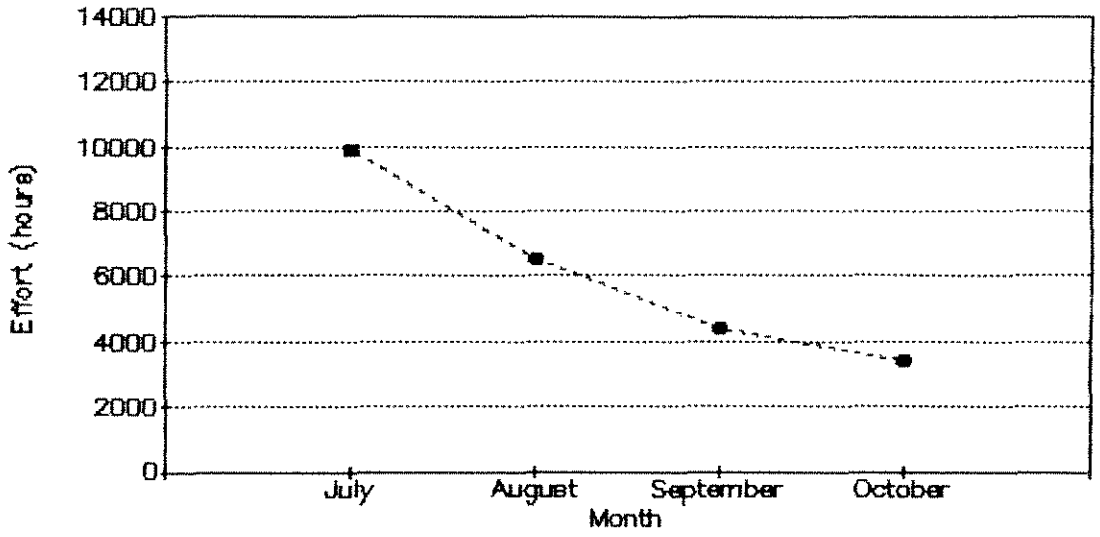

FIGURE 5. Monthly distribution of seasonal angler effort (daytype estimate) during the 1993 Ross Reservoir sport fishery. Range intervals denote 95% confidence limit of each estimate.

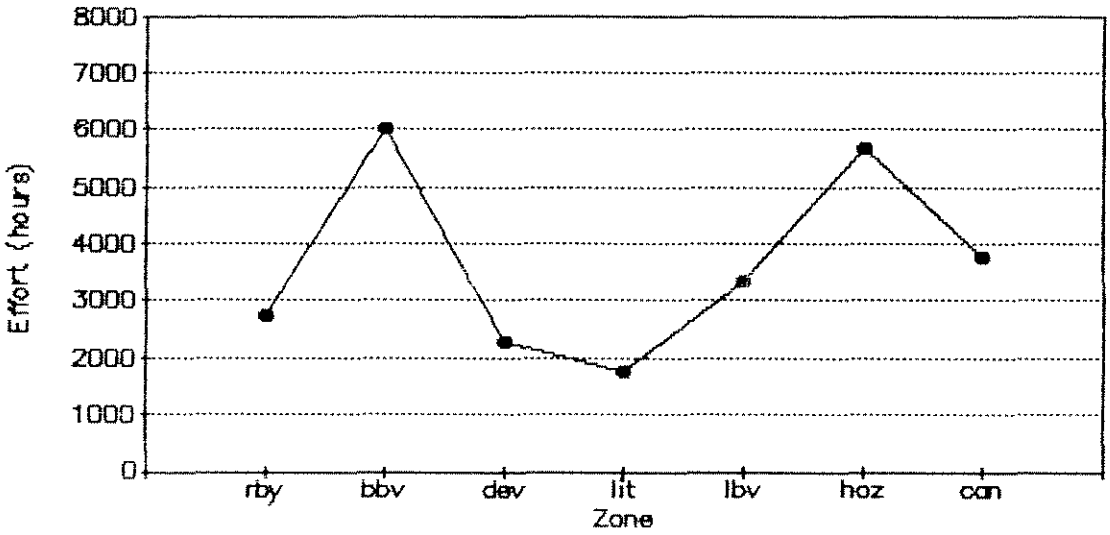

FIGURE 6. Distribution of seasonal angler effort (zone estimate) among lake zones during the 1993 Ross Reservoir sport fishery. Zone abbreviations are as follows: rby = ruby (zone 1), bbv = big beaver (zone 2); dev = devils (zone 3); lit = lightning (zone 4); lbv = little beaver (zone 5); hoz = hozomeen (zone 6); and can = canada (zone 7). Range intervals denote 95% confidence limit of each estimate.

TABLE 6. Estimated mean seasonal catch and harvest rates for rainbow trout in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

			Rainbow Trout Captures per Hour[a]		
Type[b]	Strata	N[c]	Harvested	Released	Total
Daytype	Opener	34	.227 (.003)	.845 (.004)	1.072 (.006)
	Weekday	506	.086 (.000)	.420 (.000)	.506 (.000)
	Weekend	495	.094 (.000)	.464 (.000)	.558 (.000)
	Mean		.096 (.000)	.458 (.000)	.553 (.000)
Zone[d]	1 Rby	164	.053 (.000)	.352 (.001)	.405 (.001)
	2 Bbv	369	.091 (.000)	.353 (.000)	.444 (.000)
	3 Dev	85	.085 (.000)	.475 (.002)	.560 (.002)
	4 Lit	47	.059 (.001)	.365 (.003)	.423 (.003)
	5 Lbv	33	.060 (.001)	.419 (.004)	.479 (.004)
	6 Hoz	194	.142 (.000)	.625 (.001)	.767 (.001)
	7 Can	143	.143 (.000)	.778 (.002)	.921 (.002)
	Mean		.096 (.000)	.458 (.000)	.553 (.000)
Access	Resort	664	.079 (.000)	.366 (.000)	.445 (.000)
	Hozomeen	233	.129 (.000)	.614 (.000)	.743 (.000)
	Canada	138	.144 (.000)	.783 (.002)	.927 (.002)
	Mean		.096 (.000)	.458 (.000)	.553 (.000)

[a]Ninety-five percent confidence interval of estimated mean captures per hour given in parentheses.

[b]Type of estimate. Daytype estimates are the most accurate based on sample design, and are the values reported for this study (see text).

[c]Number of anglers surveyed.

[d]See *Figure 3* for location of lake survey zones.

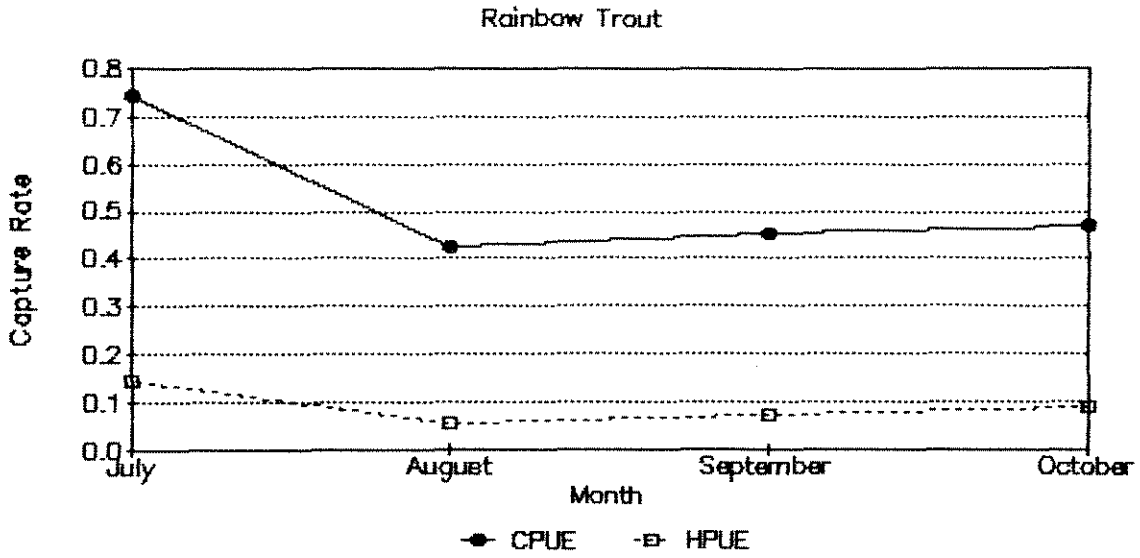

FIGURE 7. Monthly distribution of seasonal rainbow trout catch and harvest rates (daytype estimate) during the 1993 Ross Reservoir sport fishery.

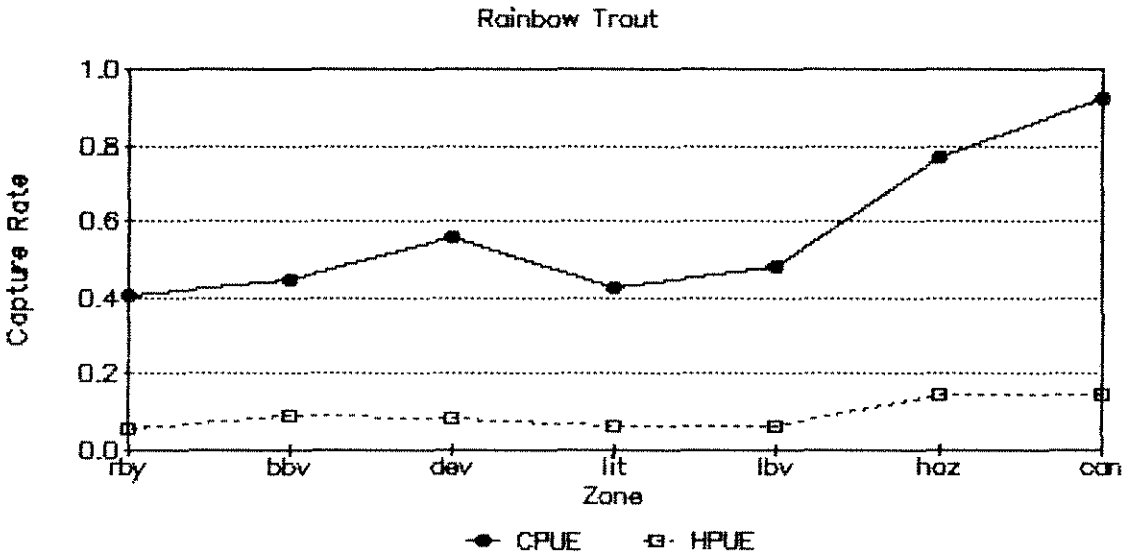

FIGURE 8. Distribution of seasonal rainbow trout catch and harvest rates (zone estimate) among lake zones during the 1993 Ross Reservoir sport fishery. Zone abbreviations are as follows: rby = ruby (zone 1), bbv = big beaver (zone 2); dev = devils (zone 3); lit = lightning (zone 4); lbv = little beaver (zone 5); hoz = hozomeen (zone 6); and can = canada (zone 7).

4-Lightning (0.423 CPUE), and 1-Ruby (0.405 CPUE) exhibited the lowest catch rates. Rainbow trout harvest rates followed a similar pattern as catch rates for the different zones, being highest at the north end of the lake, and lowest at the south end. Monthly and seasonal capture rate estimates for the different zone strata can be found in *Appendix 7.*

As shown in *Table 6*, anglers fishing in Canada had the highest seasonal catch rate (access area estimate) for rainbow trout (0.927 CPUE). An intermediate catch rate was returned by anglers utilizing the Hozomeen access (0.743 CPUE), while resort anglers experienced the lowest catch rate (0.445 CPUE). Rainbow trout harvest rates followed the same pattern as catch rates, being highest at the north end of the lake, and lowest at the south end. Monthly and seasonal capture rate estimates for the different access area strata can be found in *Appendix 8.*

Angler catch and harvest rate estimates for dolly varden/bull trout char were low during the 1993 sport fishing season at Ross Lake *(Table 7* and *Appendix 9).* The mean seasonal catch rate was 0.001 fish per hour, while the mean seasonal harvest rate was less than 0.001 fish per hour (daytype estimate). No cutthroat trout or eastern brook trout (char) were reported by anglers during the 1993 season.

Mean seasonal catch and harvest rate estimates for all species of trout and char combined are given in *Table 7* and *Appendix 10.* The mean seasonal catch rate of all species combined was 0.554 fish per hour, while the seasonal harvest rate was 0.096 fish per hour (daytype estimate).

1993 Season - Angler Catch and Harvest

The total seasonal catch (combination of harvested and released) of rainbow trout was 12,600 ± 25 fish *(Table 8,* daytype estimate*).* Total catch dropped sharply from a seasonal high of 6,894 fish in July to 2,510 in August, then declined more slowly to 1,840 fish in September, and 1,354 in October *(Figure 9* and *Appendix 11).*

The total seasonal harvest of rainbow trout was 2,208 ± 4 fish *(Table 8,* daytype estimate*).* As shown in *Figure 9*, harvest of rainbow trout followed the same pattern as catch. Total harvest decreased markedly as the season progressed, with 60 percent of the seasonal harvest occurring in July, 15 percent in August, 13 percent in September, and 12 percent in October.

A total seasonal catch estimate of 15,265 ± 24 rainbow trout were calculated for data separated into zones *(Table 8* and *Appendix 12).* As shown in *Figure 10*, the greatest catch of rainbow trout occurred near the north end of the lake in zones 6-Hozomeen (28%) and 7-Canada (25%). An intermediate catch total occurred in zone 2-Big Beaver (16%), while zones 5-Little Beaver (10%), 1-Ruby (9%), 3-Devils (8%), and 4-Lightning (5%) recorded the lowest totals. A total seasonal harvest estimate of 2,588 ± 4 rainbow trout was distributed similar to catch for the

TABLE 7. Estimated mean seasonal catch and harvest rates for all trout and char species in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Species	Strata*	Harvest	Release	Total
Rainbow	Opener	0.227	0.845	1.072
	Weekday	0.086	0.420	0.506
	Weekend	0.094	0.464	0.558
	Mean	0.096	0.458	0.553
Dolly Varden	Opener	0	0.012	0.012
	Weekday	0	0	0
	Weekend	0	0.001	0.001
	Mean	0	0.001	0.001
Cuttroat Trout	Opener	0	0	0
	Weekday	0	0	0
	Weekend	0	0	0
	Mean	0	0	0
Brook Trout	Opener	0	0	0
	Weekday	0	0	0
	Weekend	0	0	0
	Mean	0	0	0
All Species	Opener	0.227	0.858	1.084
	Weekday	0.086	0.420	0.506
	Weekend	0.094	0.465	0.559
	Mean	0.096	0.459	0.554

*Daytype estimate.

TABLE 8. Estimated total seasonal catch and harvest of rainbow trout in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

		Rainbow Trout Captures[a]					
Type[b]	Strata	Harvested		Released		Total	
Daytype	Opener	190	(3)	710	(5)	900	(7)
	Weekday	963	(5)	4658	(22)	5621	(27)
	Weekend	1054	(3)	5024	(17)	6078	(20)
	Total	2208	(4)	10392	(21)	12600	(25)
Zone[c]	1 Rby	187	(1)	1115	(7)	1302	(8)
	2 Bbv	499	(5)	1940	(20)	2439	(25)
	3 Dev	207	(2)	1047	(12)	1255	(14)
	4 Lit	117	(2)	569	(9)	687	(11)
	5 Lbv	185	(3)	1393	(16)	1578	(18)
	6 Hoz	863	(7)	3395	(30)	4258	(37)
	7 Can	529	(8)	3217	(44)	3747	(52)
	Total	2588	(4)	12677	(20)	15265	(24)
Access	Resort	1104	(4)	4959	(20)	6064	(25)
	Hozomeen	1250	(8)	5540	(36)	6790	(44)
	Canada	540	(8)	3157	(45)	3698	(53)
	Total	2895	(5)	13657	(26)	16552	(31)

[a]Ninety-five percent confidence interval of estimated captures given in parentheses.

[b]Type of estimate. Daytype estimates are the most accurate based on sample design, and are the values reported for this study (see text).

[c]See *Figure 3* for location of lake survey zones.

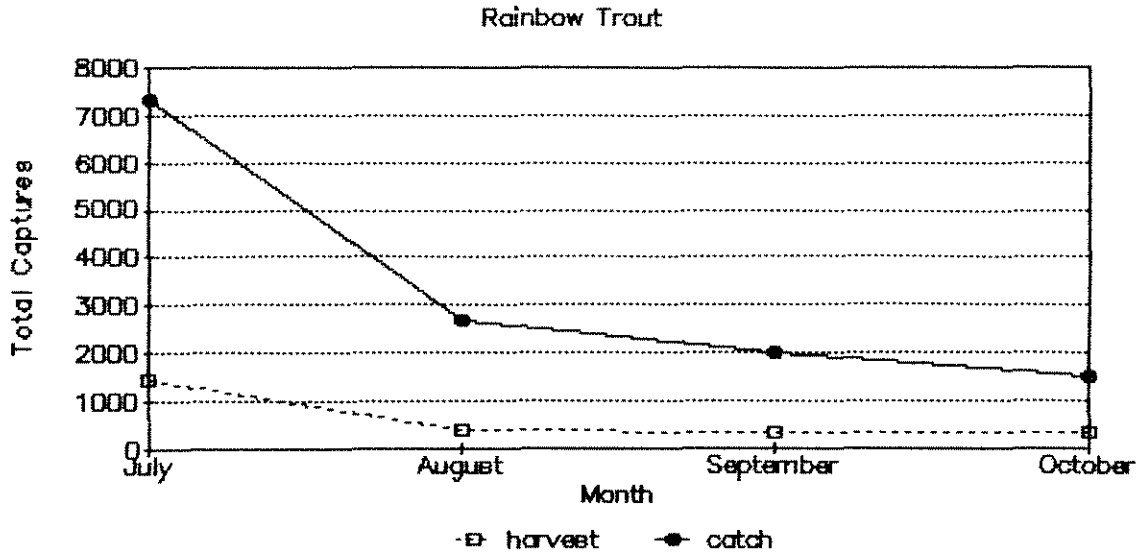

FIGURE 9. Monthly distribution of seasonal rainbow trout catch and harvest (daytype estimate) during the 1993 Ross Reservoir sport fishery.

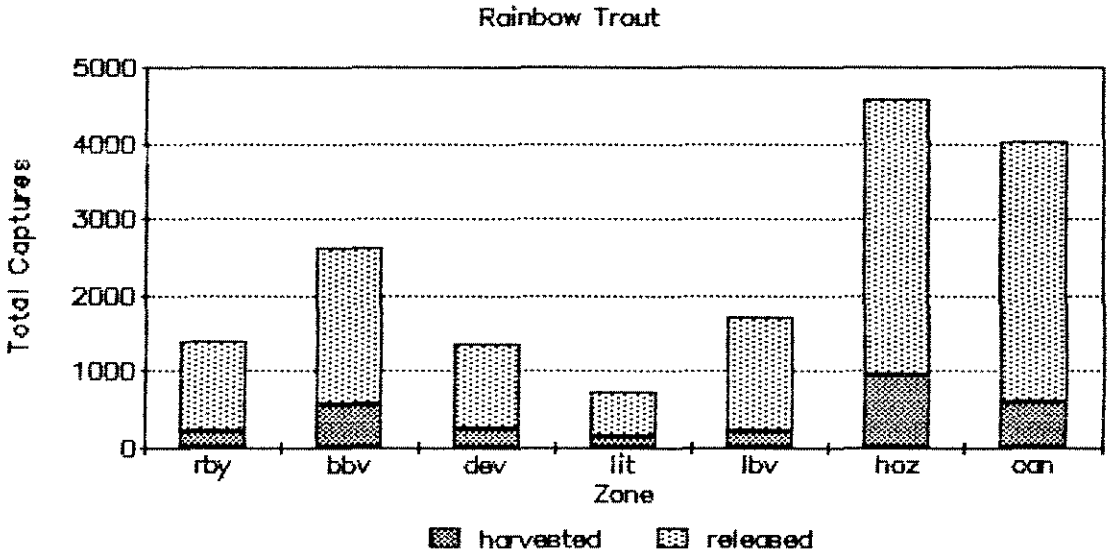

FIGURE 10. Distribution of seasonal rainbow trout catch and harvest (zone estimate) among lake zones during the 1993 Ross Reservoir sport fishery. Zone abbreviations are as follows: rby = ruby (zone 1), bbv = big beaver (zone 2); dev = devils (zone 3); lit = lightning (zone 4); lbv = little beaver (zone 5); hoz = hozomeen (zone 6); and can = canada (zone 7).

different zones. The greatest numbers were harvested at the north end of the lake in zones 6-Hozomeen (33%) and 7-Canada (20%), while lower numbers were harvested at the south end in zones 2-Big Beaver (19%), 3-Devils (8%), 1-Ruby (7%), 5-Little Beaver (7%), and 4-Lightning (5%).

A total seasonal catch estimate of 16,552 ± 31 rainbow trout were calculated for data separated into access areas *(Table 8* and *Appendix 13)*. Anglers utilizing the Hozomeen access caught the largest numbers of rainbow trout (41%). Anglers originating from Ross Lake Resort also caught a large proportion of the catch (37%), while anglers using the Canadian access caught the fewest fish (22%). A total seasonal harvest estimate of 2,895 ± 5 rainbow trout followed the same distribution pattern as catch. More fish were harvested by anglers originating from Hozomeen (43%) and the resort (38%), than by anglers fishing in Canada (19%).

Catch and harvest estimates for dolly varden/bull trout char were low during the 1993 sport fishing season at Ross Lake *(Table 9* and *Appendix 14)*. Total seasonal catch was 24 ± <1 dolly varden/bull trout, while seasonal harvest was zero. No cutthroat trout or eastern brook trout (char) were reported by anglers during the 1993 season.

Total seasonal catch and harvest estimates for all species of trout and char combined are given in *Table 9* and *Appendix 15*. The total seasonal catch of all species combined was 12,623 ± 25 fish, while the seasonal harvest was 2,208 ± 4 fish (daytype estimate).

1993 Season - Angling Methods and Gear

The majority of anglers (97%) interviewed at Ross Lake fished from boats during 1993 *(Table 10)*. Only twenty-six shore anglers (3%) were interviewed the entire season. The most popular angling method was trolling with flashers and lures (83%), followed by casting or trolling flies from a boat (15%), and casting flies (2%) and lures (1%) from shore. Bait fishing is no longer permitted under the new regulations (implemented at the beginning of the 1990 sport fishing season).

Anglers trolling lures caught eighty-four percent of the total harvest, and experienced a HPUE of 0.093 fish per hour *(Table 10)*. Anglers trolling flies harvested an additonal fourteen percent of the seasonal total, and returned a HPUE of 0.115 fish per hour. The remaining harvest was caught by shore anglers utilizing lures (1%) and flies (1%), and having respective HPUE rates of 0.061 and 0.222 fish per hour.

1993 Season - Age

A total of 40 rainbow trout scale samples from the 1993 angler sport harvest were analyzed for age determination. Age 5 fish were the most abundant age class throughout the entire season, comprising forty-eight percent of the total sample *(Table 11)*. Age 4 fish also comprised a large proportion of the harvest (33%), while the remaining harvest

TABLE 9. Estimated total seasonal catch and harvest of all species of trout and char in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Species	Strata*	Harvest	Release	Total
Rainbow	Opener	190	710	900
	Weekday	963	4658	5621
	Weekend	1054	5024	6078
	Total	2208	10392	12600
Dolly Varden	Opener	0	10	10
	Weekday	0	0	0
	Weekend	0	13	13
	Total	0	24	24
Cutthroat	Opener	0	0	0
	Weekday	0	0	0
	Weekend	0	0	0
	Total	0	0	0
Brook Trout	Opener	0	0	0
	Weekday	0	0	0
	Weekend	0	0	0
	Total	0	0	0
All Species	Opener	190	720	911
	Weekday	963	4658	5621
	Weekend	1054	5037	6091
	Total	2208	10415	12623

*Daytype estimate.

TABLE 10. Harvest, harvest rates, and number of anglers fishing for rainbow trout using different types of gear and methods during the 1993 sport fishing season[a].

Geartype[b]	Resort	Hozomeen	Canada	Total	Percent
ANGLERS					
bl	600	214	43	857	83
bf	62	16	74	152	15
sl	1		7	8	1
sf	1	3	14	18	2
Total	664	233	138	1035	100
HARVEST					
bl	212	100	18	330	84
bf	14	6	36	56	14
sl	0		3	3	1
sf	0	0	3	3	1
Total	226	106	60	392	100
HPUE					
bl	0.080	0.130	0.140	0.093	
bf	0.069	0.130	0.152	0.115	
sl	0.000		0.240	0.222	
sf	0.000	0.000	0.081	0.061	
Mean	0.079	0.129	0.144	0.096	

[a]Data compiled from combined (complete + incomplete) trip anglers.

[b]bl = boat, trolling lure
bf = boat, trolling fly

TABLE 11. Percent age composition of rainbow trout sampled from the 1993 sport harvest at Ross Reservoir.

	MONTH									
	Jul		Aug		Sep		Oct		Total	
AGE	n	%	n	%	n	%	n	%	n	%
FOUR:	8	25			5	83			13	33
FIVE:	16	50	1	100	1	17	1	100	19	48
SIX:	6	19							6	15
SEVEN:	2	6							2	5
TOTAL:	32	100	1	100	6	100	1	100	40	100

consisted of age 6 (15%), and age 7 (5%) fish.

Small sample sizes precluded analysis of occurrence trends for each age class *(Table 11)*.

1993 Season - Length

A total of 243 rainbow trout were measured during the 1993 fishing season *(Table 12)*. The minimum size regulations restrict angler harvest to fish longer than 13 inches (330 mm) total length. A fork length of 317 mm is an approximate equivalent to the 330 mm (total length) minimum size restriction. The average fork length of angler harvested rainbow trout during the 1993 season was 332 mm. Sizes ranged from a low of 280 mm (illegally harvested) to a high of 406 mm. Average size of fish harvested during the first half of the season was slightly larger than those harvested during the second half. Life history characteristics that may be responsible for the apparent temporal decrease in average size of specific age classes will be presented in a later section of this report.

Length at age information for the rainbow trout harvest is shown in *Table 13*. As expected, average fork length increases with each successive age class. Age 4 fish averaged 323 mm, age 5 fish averaged 331 mm, age 6 fish averaged 352 mm, and age 7 fish averaged 395 mm.

Small sample sizes precluded analysis of summer growth of rainbow trout in Ross Lake, as reflected by the size of fish in the angler sport harvest *(Table 14* and *Figure 11)*.

Monthly and seasonal length-frequency histograms of angler harvested rainbow trout at Ross Reservoir are shown in *Figure 12*. The abscissa scale values are standardized to facilitate comparison. All five histograms (monthly and seasonal) closely resemble the standard normal curve, and are predominantly centered around the 310-320 mm (July and September) and 330-340 mm (August and October) fork length intervals. The legal size limit is 330 mm total length or approximately 317 mm fork length.

1993 Season - Sex

A total of 41 rainbow trout were sampled from the seasonal sport harvest for sex determination. Males constituted 44 percent of the total sample (n=18), while females accounted for 56 percent (n=23). The south end sample (n=39) was composed of 44 percent males and 56 percent females, while only two fish (one male and one female) were sampled from the north end.

1993 Season - Sexual Maturity

A random sample of 32 rainbow trout from the seasonal sport harvest were checked for gonadal development *(Table 15)*. Mature fish comprised

TABLE 12. Trout and char length information, by month, from the 1993 sport fishing season at Ross Reservoir.

Month	Number	Percent	Fork Length (mm) Average	Minimum	Maximum
RAINBOW					
July	132	54	333	294	406
August	38	16	337	280	401
September	35	14	328	290	377
October	38	16	327	283	368
Season	243	100	332	280	406

TABLE 13. Rainbow trout length information, by age, from the 1993 sport harvest at Ross Reservoir.

Age	Number	Percent	Fork Length (mm) Average	Minimum	Maximum
4	13	33	323	312	333
5	19	48	331	318	346
6	6	15	352	340	361
7	2	5	395	394	395

TABLE 14. Average fork length (mm) of rainbow trout, grouped by month and age class, from the 1993 sport harvest at Ross Reservoir.

AGE		JUL	AUG	SEP	OCT	SEASON
FOUR:	n	8	—	5	—	13
	avg	325	—	319	—	323
FIVE:	n	16	1	1	1	19
	avg	330	332	340	330	331
SIX:	n	6	—	—	—	6
	avg	352	—	—	—	352
SEVEN:	n	2	—	—	—	2
	avg	395	—	—	—	395

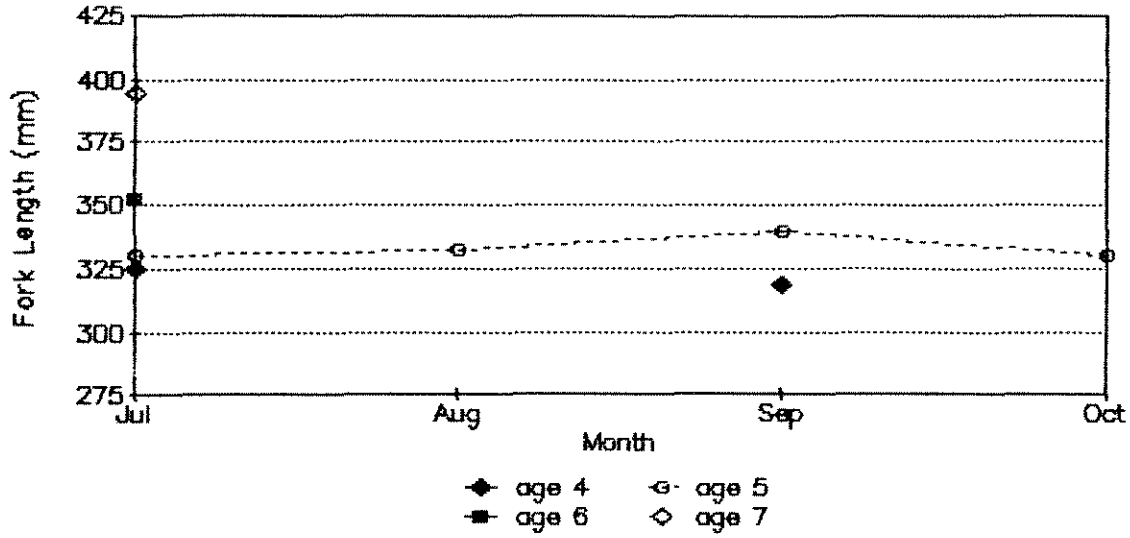

FIGURE 11. Average lengths of age 4 - age 7 rainbow trout, by month, from the 1993 Ross Lake sport harvest.

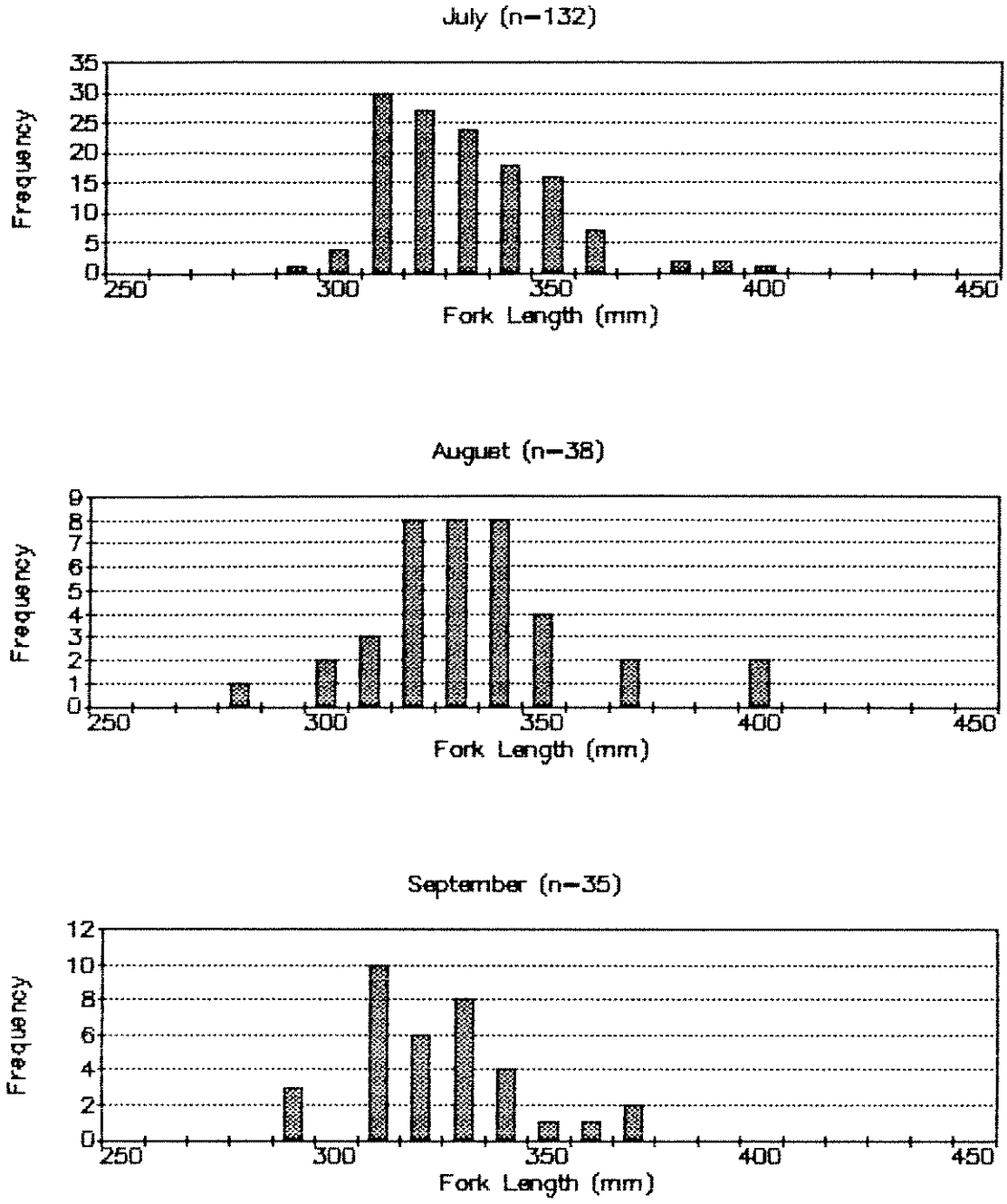

FIGURE 12. Length-frequency distribution of rainbow trout sampled from the 1993 Ross Lake sport harvest. Minimum legal size limit is approximately 317 mm fork length. Abscissa values indicate lower limit of length interval.

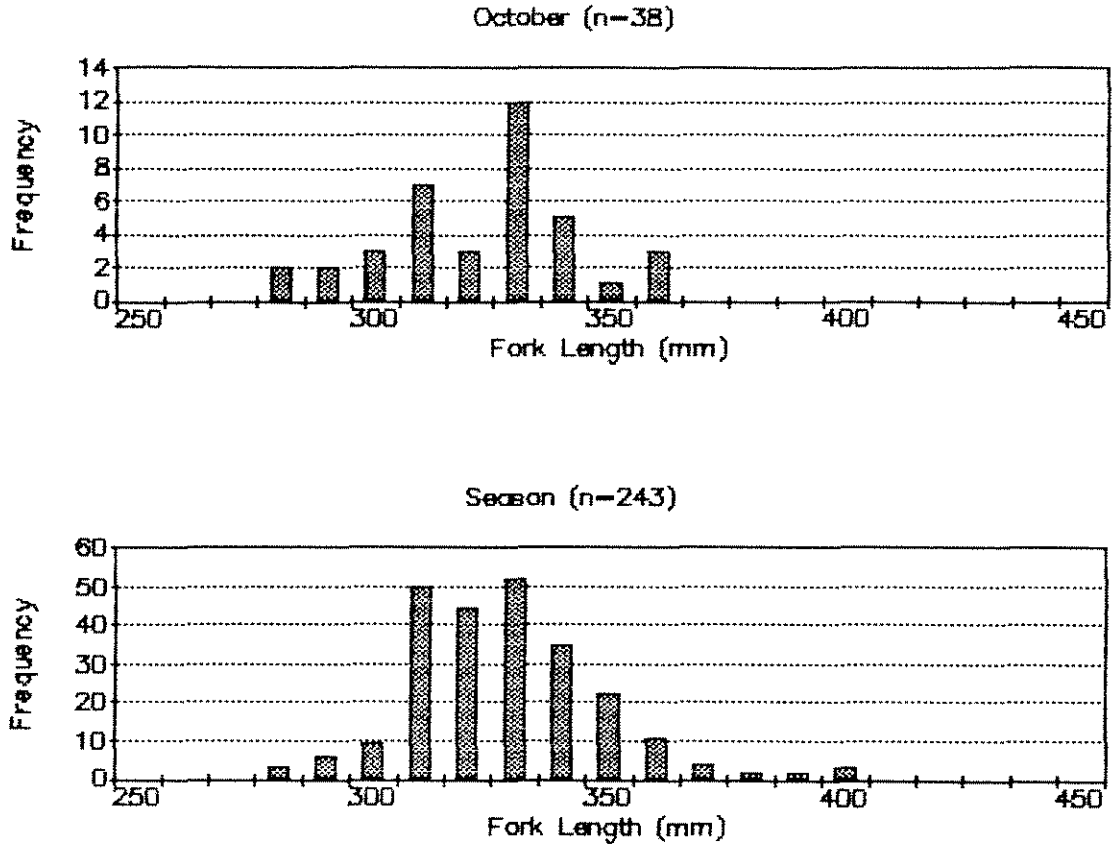

FIGURE 12. (Continued).

TABLE 15. Rainbow trout length information, grouped by sex and maturity, from the 1993 sport harvest at Ross Reservoir.

Sex	Maturity	N	%	Fork Length (mm) Avg	Min	Max
Male	Mature	13	93	340	321	395
	Immature	1	7	320	320	320
Female	Mature	18	100	335	316	394
	Immature	0	0	—	—	—

97 percent of the sample, while the remaining 3 percent were immature. Males consisted of 93 percent mature and 7 percent immature fish, while the female sample was composed entirely of mature fish.

Table 16 shows the average fork length and size range of a random sample of 32 rainbow trout from the seasonal sport harvest, separated by access, sex, sexual maturity, and age. All fish were sampled at the south end of the lake, and had a sexual maturity composition as listed above. The average length of immature (n=1) and mature (n=13) males was 320 mm and 340 mm, respectively, while mature females (n=18) averaged 335 mm.

1993 Season - Additional Data

Thirty-nine percent of the interviewed anglers that were fishing for rainbow trout during the 1993 sport fishing season at Ross Reservoir were unsuccessful at catching a fish *(Figure 13)*. The remaining anglers (61%) were successful at catching from one to twenty-seven fish. Seventy-four percent of the anglers were unsuccessful in harvesting a legal rainbow trout, while the remaining anglers harvested one (17%), two (6%), and three (3%) fish.

Only one of the three remaining species of trout and char were caught and/or harvested by interviewed anglers during the season *(Figure 14)*. Four anglers each reported catching one dolly varden char, none of which were harvested.

1993 Season - Dolly Varden/Bull Trout Char

No dolly varden/bull trout char were measured for (possible future) species classification during the 1993-94 study at Ross Lake. A 20-inch minimum size restriction (implemented at the beginning of the 1992 sport fishing season) resulted in anglers reporting no harvest of this species in 1993 *(Appendix 1)*.

Hydroacoustic Surveys

Five hydroacoustic surveys were conducted on Ross Lake between April 27 and May 3, 1994. A total of 239 fish were recorded for the five surveys, resulting in an average of 48 fish per survey *(Table 17)*. Index counts varied as much as 254 percent between surveys, ranging from 26 to 66 fish per survey. There was no appreciable difference between the average number of fish recorded between morning and afternoon surveys (AM average = 50, PM average = 44).

Population estimates for the five hydroacoustic surveys are given in *Table 18*. Based on the assumption that percent species occurrence in the sport catch reflects species occurrence in the reservoir, rainbow trout population estimates for the five surveys ranged from a high of 97,976 fish to a low of 29,941. The total reservoir rainbow trout

TABLE 16. Rainbow trout age and length information, grouped by access area, sex and maturity, from the 1993 sport harvest at Ross Reservoir.

					Fork Length (mm)		
Access	Sex	Maturity	Age	N	Avg	Min	Max
Hozomeen	Male	Mature					
		Immature					
	Female	Mature					
		Immature					
Resort	Male	Mature	4	3	325	321	333
			5	6	334	324	346
			6	3	351	340	360
			7	1	395	395	395
		Immature	5	1	320	320	320
	Female	Mature	4	5	325	316	330
			5	9	329	318	341
			6	3	353	346	361
			7	1	394	394	394
		Immature					

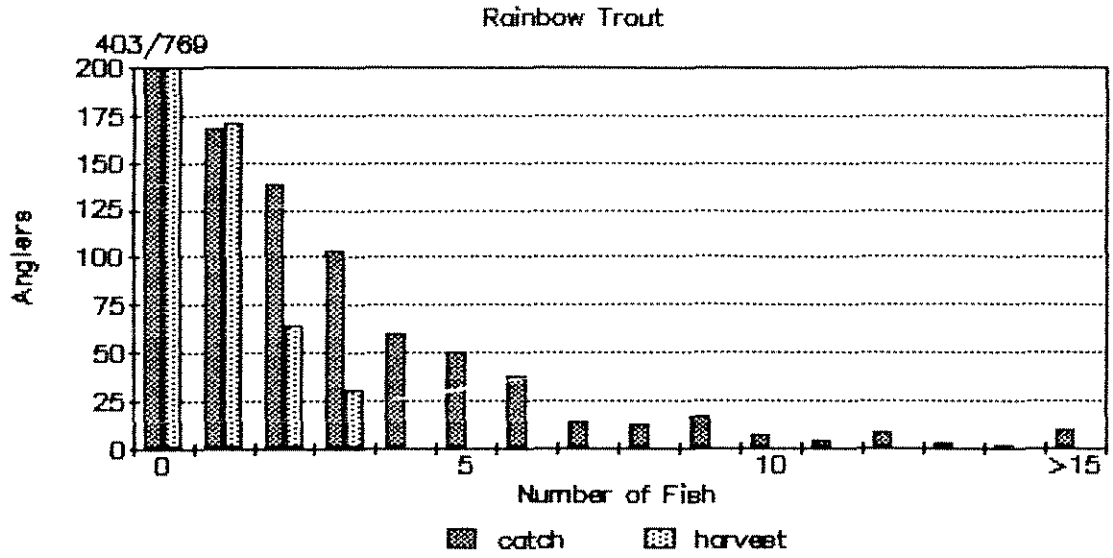

FIGURE 13. Reported angler success at catching rainbow trout during the 1993 sport fishing season at Ross Reservoir.

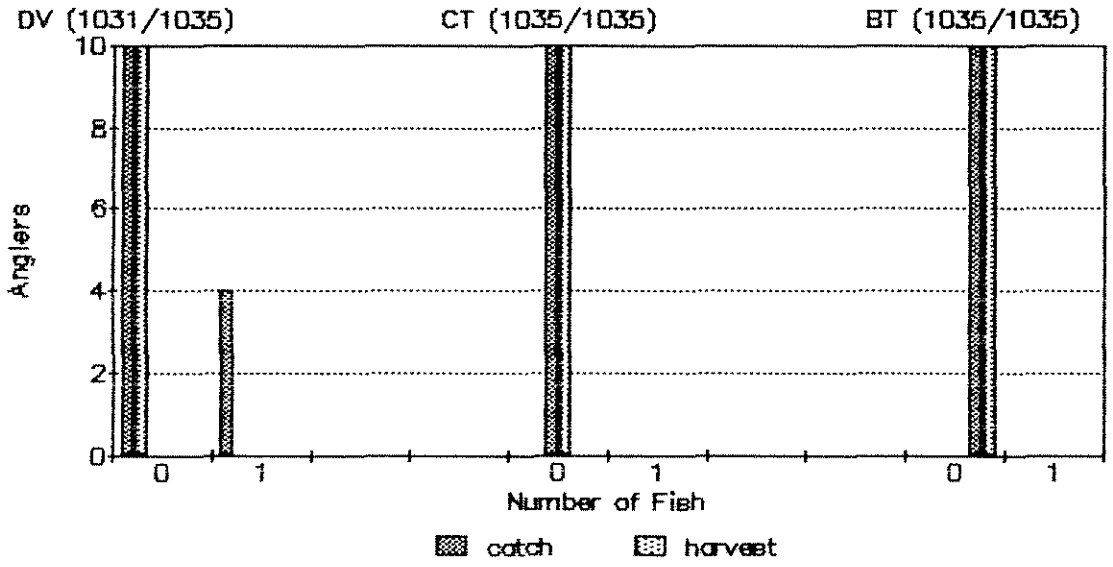

FIGURE 14. Reported angler success at catching dolly varden/bull trout char, cutthroat trout, and brook trout (char) during the 1993 sport fishing season at Ross Reservoir.

TABLE 17. Hydroacoustic index counts of trout and char[a] from the lower end of Ross Lake (Ross Dam to Rainbow Point) from five surveys conducted between April 27 and May 3, 1994.

		Transect											
Date	Elev	1	2	3	4	5	6	7	8	9	10	11	Total
04/27[b]	1548	9	7	4	5	22	0	7	0	11	0	1	66
04/27[c]	1548	6	3	3	6	4	7	8	3	8	0	4	52
04/28[b]	1549	7	4	1	3	6	6	11	3	14	2	2	59
04/28[c]	1549	3	2	2	3	1	0	6	10	3	5	1	36
05/03[b]	1552	1	0	4	1	3	0	5	1	10	0	1	26
Mean		5	3	3	4	7	3	7	3	9	1	2	48

[a]Fish larger than 152 mm (6 in).

[b]AM (0800–1200) count.

[c]PM (1200–1600) count.

TABLE 18. Population estimates of Ross-Skagit system trout and char[a] from five hydroacoustic surveys conducted between April 27 and May 3, 1994.

	Trout and Char		Rainbow Trout[b]	
Date	Estimate	95% C.I.	Estimate	95% C.I.
04/27[c]	98,155	± 27,203	97,976	± 27,153
04/27[d]	80,586	± 16,154	80,440	± 16,124
04/28[c]	86,305	± 17,577	86,148	± 17,545
04/28[d]	49,645	± 13,070	49,555	± 13,046
05/03[c]	29,996	± 7,821	29,941	± 7,807
Mean	68,938	± 17,561	68,812	± 17,529

[a]Fish larger than 152 mm (6 in).

[b]Estimates using proportion of rainbow trout in 1993 sport harvest (0.9982).

[c]AM (0800-1200) count.

[d]PM (1200-1600) count.

population was estimated at 68,812 ± 17,529, while the total combined species (trout and char) population was estimated at 68,938 ± 17,561. Confidence limits are within ± 26 percent of both estimates, indicating poor precision.

The values shown may eventually be modified for the final completion report, since an accurate bottom contour map of sufficiently large scale has not yet been obtained from Seattle City Light. An accurate, large-scale map is needed for precise calculation of lake strata volumes and transect lengths. Estimates should also be viewed with caution for reasons outlined earlier in the methods section of this report.

Spawning Surveys

Six rainbow trout spawning surveys were conducted on Dry, Lightning, Pierce, Roland, and Thursday Creeks between May 24 and July 12, 1994 *(Table 19)*. A total of 2,279 rainbow trout were counted during the six surveys *(Table 20)*. Surveys did not commence until May 24, due to adverse weather conditions during the preceding several weeks. Spawning fish were observed on all survey dates, with the largest numbers of rainbow trout occurring on June 10, when a total of 688 fish were recorded on the five tributaries. Roland Creek recorded the highest spawner total (1,067 fish), and because of size, accessibility, and available spawning habitat, is the best spawning indicator stream of those surveyed. Lightning Creek recorded the second largest spawner total for the season (604 fish), although the vast majority of these fish were observed adjacent to the stream mouth. Dry Creek also reported a large number of spawners (436 fish), followed by smaller numbers on Pierce Creek (137 fish) and Thursday Creek (35 fish).

Peak spawning probably occurred during the first second or third week of June on most of the tributaries surveyed. Spawning counts gradually declined on most survey streams after June 10, and surveys concluded on July 12 when 207 fish were observed in Dry, Roland, Lightning, and Thursday Creeks. Of this total, 158 fish were milling off the mouth of Dry, Lightning, and Thursday Creeks, and were probably kelts that had recently completed spawning.

TABLE 19. Elevations and distances surveyed* on Ross Reservoir index tributaries during rainbow trout spawning surveys from May 24 to July 12, 1994.

Tributary Name	Distance (ft)	Elevation (ft)	
		Minimum	Maximum
Dry Creek	1200	1602	1800
Lightning Creek	1000	1602	1675
Pierce Creek	85	1602	1615
Roland Creek	1500	1602	1835
Thursday Creek	25	1602	1610

*Baseline elevations and distances are measured from full pool upstream, and do not include drawdown elevation distances surveyed.

TABLE 20. Number of spawning rainbow trout observed in selected tributaries of Ross Reservoir from May 24 to July 12, 1994.

	Number of Rainbow Trout						
	May	Jun				Jul	
Tributary	24	02	10	22	30	12	Total
Dry	44	78	78	162	52	22	436
Lightning*	20	30	203	100	100	151	604
Pierce	0	5	53	75	4	0	137
Roland	123	196	340	243	139	26	1067
Thursday	0	4	14	6	3	8	35
Total	187	313	688	586	298	207	2279

*High water flows prevented surveys of one or more areas of stream (ie. drawdown and/or upstream of pool elevation) on all dates.

DISCUSSION

The fish and fishery of Ross Lake (and the Canadian Skagit River) are dependent upon wild, naturally produced trout and char. Historically, direct hatchery introductions have not occurred in the reservoir and upper Skagit River, although BCF&W did conduct two plants in the Sumallo River (tributary to the upper Skagit River) in the late 1980's. A resident strain of wild-origin Skagit River rainbow trout and a strain of Blackwater River rainbow trout were introduced into the Sumallo River in 1987 and 1988, respectively, in an attempt to increase fish production in that section of the Canadian Skagit River drainage (Slaney and Godin 1989; Rosenau and Slaney 1991). These introductions were subsequently determined by BCF&W to be unsuccessful, and plans for further plants discontinued.

Analysis of historic data (Johnston 1989) indicates that the stability of the Ross Reservoir and Skagit River fish population appears to be largely dependent on restricting the harvest to only surplus fish above that required to maintain the population. This surplus is not a static number, since annual variability in environmental conditions, production, survival, and other factors can cause this number to change from year to year. It is desirable, therefore, to establish and implement a harvestable surplus value that represents a realistic worst case scenario.

Johnston (1989) discusses the factors affecting optimum population numbers and angler harvest levels at Ross Reservoir, and discusses the importance of monitoring annual harvest levels to help evaluate fluctuations in the lake fish population. However, it is difficult to estimate optimum harvest levels unless the annual variability in size of the fish population is also known. Annual fluctuations in total population size can be used to find total annual mortality rates, and depending on annual recruitment and survival rates, used to establish optimum harvest rates. Regulations can then be adjusted to achieve harvest and spawning escapement goals.

Through comparisons of current effort, HPUE, CPUE, harvest, catch, population size, and spawner numbers with data collected in previous years, it is possible to determine the effectiveness of the new regulations in achieving current management goals.

Effort

Total estimated 1993 seasonal angler effort remained markedly less than in years prior to the new restrictive fishing regulations implemented in 1990. The 1993 estimated angler effort was 22,397 hours, while estimated angler effort was 74,098, 65,673, and 65,797 hours in 1971, 1985 and 1986, respectively *(Table 21)*. This represents an effort decline of approximately 66 percent from the mid-1980's, and 70 percent

TABLE 21. Estimated seasonal angler effort[a] at Ross Reservoir in 1971, 1985–86, and 1990–93.

Year	Effort (hours)	± CI[b]	Source
1971	74,098[c]	—	City of Seattle (1972) City of Seattle (1973)
1985	65,673[d]	—	Scott and Peterson (1986)
1986	65,797[e]	—	Johnston (1989)
1990	30,894[f]	81	Looff (1992a)
1991	33,418[f]	27	Looff (1993a)
1992	23,453[f]	68	Looff (1994b)
1993	22,397[f]	54	

[a]Season length approximately two weeks shorter in 1990–93 than in previous years. See Johnston (1989) and *Appendix 1*.

[b]Ninety-five percent confidence interval of estimated total angler-hours.

[c]Effort estimated from interview data and boat rental information (south end), and vehicle counts (north end).

[d]Effort estimated from reservoir boat counts.

[e]Effort estimated from interview data.

[f]Effort estimated from reservoir pole counts.

from the early 1970's. Total 1993 estimated angler effort also declined approximately 5 percent from the 1992 estimate of 23,453 hours, 33 percent from the 1991 estimate of 33,418 hours, and 28 percent from the 1990 estimate of 30,894 hours.

The new regulations appear to be more of a deterrent to anglers utilizing the north end of the lake than to anglers fishing from the south end. In 1971, anglers from the south end accounted for 22 percent of the total seasonal effort (16,572 hours), while north end anglers accounted for 78 percent (57,526 hours). From 1990–93, approximately 59 percent (20,073 hours), 54 percent (18,444 hours), 67 percent (16,915 hours), and 53 percent (13,520 hours) of the seasonal effort totals were contributed by south end anglers, respectively. North end anglers contributed 41 percent (14,201 hours), 46 percent (15,912 hours), 33 percent (8,417 hours), and 47 percent (12,139 hours) of the seasonal effort totals during the same time period. Effort estimates for the different access areas are not available for the 1985 and 1986 study years.

Harvest Rates

Mean overall (all species combined) harvest rates also remained considerably lower than in years prior to the 1990 regulation changes. The mean seasonal HPUE from 1990–93 was 0.12, 0.10, 0.11, and 0.10 respectively, while HPUE was 0.48 in 1971, 0.52 in 1972, 0.33 in 1985, and 0.41 in 1986 *(Table 22)*. The observed 1990–93 harvest rate declines are due primarily to the 13-inch minimum size limit imposed at the beginning of the 1990 season. However, the decline may also be influenced by decreasing numbers of fish in the reservoir (as indicated by the HPUE decline from the early 1970's to the mid-1980's).

Mean overall monthly harvest rates tend to decline (July–August) and then increase (August–October) as the season progresses *(Table 22 and Figure 15)*. Factors affecting the initial HPUE decline probably include harvest-related mortality and movement of mature rainbow trout into tributary streams to spawn. In addition, some fish may also be removed from the fishery when they enter streams on midsummer feeding runs (Johnston 1989). Subsequent HPUE increases in September and October may be due to migration patterns and/or recruitment. Studies of rainbow trout migration patterns in the Sumallo River suggest that trout may migrate to the lake when water temperatures drop below 10°C (Slaney and Godin 1989; Rosenau and Slaney 1991). Summer growth of previously undersized fish also recruits new numbers into the fishery. Very little increase in HPUE occurred at the end of the 1991–93 seasons, with HPUE remaining below July levels.

Mean seasonal harvest rates for the different lake zones show contrasting patterns between the 1971–74, 1986, and 1990–93 fishing seasons *(Table 23)*. Overall harvest rates remained relatively high throughout the different lake zones in the early 1970's, but were lower

TABLE 22. Mean overall (all species combined) opening day, monthly, and seasonal harvest rates for the 1971–72, 1985–86, and 1990–93 fishing seasons[a] at Ross Reservoir.

	Trout and Char HPUE						
Year	Opener	Jun	Jul	Aug	Sep	Oct	Season
1971	0.56	0.53	0.49	0.43	0.49	0.62	0.48
1972	0.52	0.49	0.76	0.63	0.66	0.68	0.52
1985	0.83	0.47	0.21	0.27	0.37	0.45	0.33
1986	0.81	0.45	0.29	0.23	0.37	0.49	0.41
1990[b]	0.15	——	0.12	0.09	0.11	0.15	0.12
1991[b]	0.15	——	0.13	0.10	0.09	0.10	0.10
1992[b]	0.26	——	0.15	0.06	0.09	0.11	0.11
1993[b]	0.23	——	0.15	0.06	0.07	0.09	0.10

[a]Fishing regulations differed between 1971–72, 1985–86, and 1990–93. See Johnston (1989) and *Appendix 1*.

[b]Opening day of the 1990–93 fishing seasons was July 1.

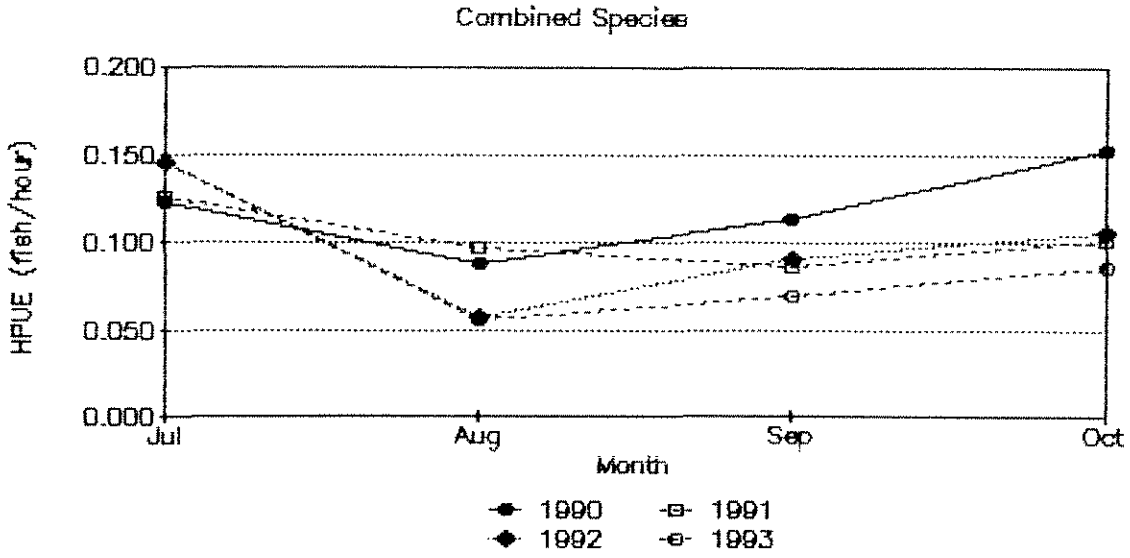

FIGURE 15. Mean overall (all species combined) monthly harvest rates for the 1990–93 fishing seasons at Ross Reservoir.

TABLE 23. Mean overall (all species combined) seasonal harvest rates[a] for zones 1 through 7 on Ross Reservoir during the 1971-74, 1986, and 1990-93 fishing seasons.

	Trout and Char HPUE								
Zone[b]	1971	1972	1973	1974	1986	1990[c]	1991[c]	1992[c]	1993[c]
1 (Ru)	0.50	0.57	0.54	0.53	0.29	0.06	0.07	0.11	0.05
2 (BB)	0.47	0.70	0.45	0.50	0.42	0.08	0.11	0.11	0.09
3 (De)	0.49	0.72	0.45	0.49	0.48	0.10	0.10	0.09	0.09
4 (Li)	0.44	0.43	0.36	0.48	0.45	0.09	0.10	0.10	0.06
5 (LB)	0.43	0.52	0.43	0.39	0.46	0.12	0.10	0.09	0.06
6 (Ho)	0.53	0.46	0.36	0.39	0.35	0.24	0.12	0.12	0.14
7 (Ca)	0.46	0.53	0.35	0.44	0.28	0.15	0.08	0.00	0.14

[a]Fishing regulations differed between 1971-74, 1986, and 1990-93. See Johnston (1989) and *Appendix 1*.

[b]See *Figure 3* for location of lake zones.

[c]Zone estimates for rainbow trout only.

at the north end (zones 6 and 7) and south end (zones 1 and 2) of the lake in 1986. Johnston (1989) attributes the latter declines to excessive fishing mortality in zones adjacent to the two major access areas. In contrast, 1990 rainbow trout harvest rates were markedly higher at the north end of the lake (zones 5-7) than at the south end (zones 1-4), due primarily to the marked decrease in angler effort at the north end. From 1990-93, annual harvest rates remained generally similar in zones 1-4, even though effort decreased annually at the south end. In addition, 1993 harvest rates remain below 1990 levels in zones 5-7, even though seasonal effort declined at the north end during the same time period. This suggests that the reservoir fish population is still suffering the effects of past overharvest.

Harvest

The 1990-93 overall (all species combined) and rainbow trout harvest estimates are greatly reduced from previous years *(Table 24)*. Rainbow trout harvest levels in the early 1970's (average = 36,153) and mid-1980's (average = 20,514) are approximately thirteen and seven times larger, respectively, than the 1990-93 (average = 2,855) levels. The dramatic reduction in harvest is due primarily to the reduced daily catch limit (eight fish reduced to three), minimum size restriction (no size limit changed to 13-inch minimum size), shorter season (mid-June opener changed to July 1 opener) and reduced reservoir fishing effort. In addition, a reduction of the reservoir fish population also contributed to the decline. The small (combined species) harvest increase (2 percent) in 1991 compared to 1990 is primarily the result of increased effort (8 percent) on the reservoir in 1991. Similarly, the harvest decrease (40 percent) from 1991 to 1992 is primarily due to decreased effort (30 percent) in 1992. A slight harvest increase (2 percent) and corresponding effort decrease (5 percent) in 1993 compared to 1992, may indicate increasing numbers of harvestable fish in the reservoir.

The greater proportion of rainbow trout in the overall 1990-93 harvests (99.5, 99.1, 99.6, and 100.0 percent, respectively) is due to fewer numbers of dolly varden/bull trout char being caught. The 1990 bait fishing restriction (with a resultant decrease in anglers fishing with live and/or scented bait off stream mouths), and the 1992 dolly varden/bull trout char size restriction of twenty inches, is primarily responsible for the observed harvest reduction of this species.

Age

The 13-inch (317 mm fork length) minimum size restriction resulted in a greater percentage of older rainbow trout in the 1990-93 harvests than in previous studies *(Table 25)*. The 1990 harvest consisted primarily of age 3 (47 percent) and age 4 (32 percent) fish, while the 1991 and 1992 harvests comprised mostly age 4 (48 and 61 percent, respectively) and

TABLE 24. Combined species and rainbow trout harvest* estimates for the 1971-74, 1985-86, and 1990-93 fishing seasons at Ross Reservoir.

Year	Combined	% Rb	Rainbow
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	88.1	18,503
1986	23,054	97.7	22,524
1990	3,524	99.5	3,508
1991	3,587	99.1	3,553
1992	2,160	99.6	2,151
1993	2,208	100.0	2,208

*Fishing regulations differed between 1971-74, 1985-86, and 1990-93. See Johnston (1989) and *Appendix 1*.

TABLE 25. Percent age class contribution* of rainbow trout to the 1971-73, 1985-86, and 1990-93 seasonal sport harvest at Ross Reservoir.

	Percent of Season Harvest								
Age	1971	1972	1973	1985	1986	1990	1991	1992	1993
2	55	49	62	36	28	10	0	0	0
3	26	39	29	29	40	47	5	4	0
4	7	8	6	13	19	32	48	61	33
5	1	2	1	4	4	10	43	29	48
6	0	0	0	1	1	1	4	5	15
7	0	0	0	0	0	<1	0	<1	5

*Fishing regulations differed between 1971-73, 1985-86, and 1990-93. See Johnston (1989) and *Appendix 1*.

age 5 (43 and 29 percent, respectively) fish. The 1993 harvest consisted mostly of age 5 (48 percent) and age 4 (33 percent) fish. This is in contrast to earlier years, when small numbers of age 1 and large numbers of age 2 fish were present in the harvest. Except for 1986, when age 3 fish comprised the majority of the harvest, age 2 fish were the age class harvested in greatest numbers by anglers prior to 1990. Johnston (1989) attributes the increase in percentage of older age classes (age 3 and age 4) in the harvest from the early 1970's to the mid-1980's to anglers targeting older Canadian Skagit River rainbow trout (that enter the reservoir fishery in June and again in September and October) at the north end of the lake, and to selectively "high-grading" their catch to retain the largest and brightest rainbow trout (predominantly age 3, immature females).

The ratio of age 4 to age 3 rainbow trout also increased from previous years *(Table 25)*. The 1990-93 age 4:age 3 harvest ratios were 68, 960, and 1,525 percent (no age 3 fish were sampled in 1993), respectively, compared to 27 percent in 1971, 21 percent in 1972, 21 percent in 1973, 45 percent in 1985, and 48 percent in 1986. The 13-inch minimum size restriction is designed to increase the percentage of age 4 and older age classes of rainbow trout harvested. This appears to have occurred from 1990-93, with 43, 95, 96, and 100 percent of the harvest comprising age 4 and older fish, respectively. Sexual maturity and spawning or post-spawning of Ross Lake rainbow trout occurs primarily at age 4 for females (age 3 for males), generally before opening day of the fishing season (July 1). Theoretically, fish should then be able to spawn at least once before becoming available to the fishery.

Length

The average size of most rainbow trout age classes have declined annually since 1990 (*Table 26* and *Figure 16)*. Since 1990, average size of age 3 to age 6 fish has declined 18 mm (1990-92 only), 16 mm, 21 mm, and 16 mm, respectively. In addition, all 1993 age classes average smaller in size than 1985-86 age classes. This could indicate that a larger number of fish are competing for limited food resources in the reservoir, or that environmental factors are decreasing the available food supply.

Sexual Maturity

A very small proportion (3 percent) of the 1993 rainbow trout harvest was composed of immature fish *(Table 27)*. Thus, the 13-inch minimum size restriction appeared to protect immature fish during 1993. (However, the 1993 sample size was approximately one-third smaller than in previous years). This was not the case from 1990-92, when a much larger proportion of immature age 3 - age 5 fish were harvested than in 1993. However, total percentage of immature fish harvested (all age classes combined) has declined markedly since 1990. Exceptionally good

TABLE 26. Seasonal rainbow trout age and length data* from the 1985-86 and 1990-93 sport harvests at Ross Reservoir.

			Fork Length (mm)		
Year	Age	N	Avg	Min	Max
1985	2	216	260	183	337
	3	169	302	207	369
	4	76	334	275	378
	5	23	347	307	384
	6	5	394	374	424
	7	0	—	—	—
1986	2	207	257	157	328
	3	251	302	218	380
	4	146	333	286	403
	5	32	349	295	395
	6	3	380	365	409
	7	0	—	—	—
1990	2	36	313	270	330
	3	172	326	271	370
	4	115	339	300	460
	5	36	352	300	400
	6	5	368	350	395
	7	1	380	380	380
1991	2	0	—	—	—
	3	15	310	292	332
	4	145	325	301	371
	5	128	350	315	385
	6	13	378	325	411
	7	0	—	—	—
1992	2	0	—	—	—
	3	12	308	290	318
	4	167	324	295	370
	5	78	343	306	373
	6	14	366	340	402
	7	1	365	365	365

TABLE 26. (Continued)

Year	Age	N	Fork Length (mm) Avg	Min	Max
1993	2	0	—	—	—
	3	0	—	—	—
	4	13	323	312	333
	5	19	331	318	346
	6	6	352	340	361
	7	2	395	394	395

*Fishing regulations differed between 1985–86 and 1990–93. See Johnston (1989) and *Appendix 1*.

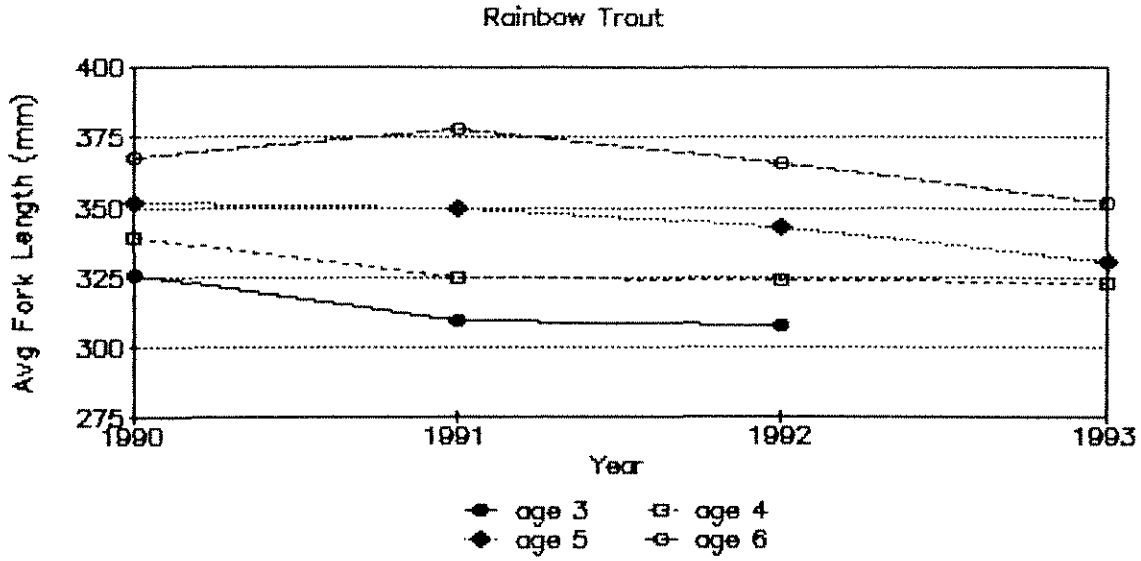

FIGURE 16. Average lengths of age 3 - age 6 rainbow trout from the 1990-93 Ross Lake sport harvests.

TABLE 27. Percent immature rainbow trout sampled, by age, from the 1990–93 sport harvests at Ross Reservoir.

	Percent Immature*						
Year	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1990	86	83	62	38	0	———	70
	(7)	(53)	(37)	(13)	(1)	———	(111)
1991	———	80	62	38	0	———	52
	———	(10)	(34)	(39)	(1)	———	(84)
1992	———	50	26	19	0	0	23
	———	(2)	(58)	(36)	(3)	(1)	(100)
1993	———	———	0	6	0	0	3
	———	———	(8)	(16)	(6)	(2)	(32)

*Sample size of each age class given in parentheses.

growth conditions during the winter and early spring of 1990 may have resulted in larger size at age of rainbow trout, resulting in a large proportion of immature fish available for harvest *(Table 26)*.

Population Size

Ross Lake rainbow trout mark-recapture population estimates from the early 1970's are substantially higher than hydroacoustic estimates conducted during the first four years of the current study *(Table 28)*. Mark-recapture studies estimated reservoir rainbow trout population sizes of 153,580, 206,185, and 191,480 fish in 1971, 1972, and 1973, respectively. These estimates are much larger than the 1991-94 hydroacoustic estimates of 19,733, 37,080, 59,320, and 68,812 fish, respectively. A possible explanation for this large discrepancy is that mark-recapture efforts in the early 1970's may have focused at stream mouths, where fish concentrations are typically high. In contrast, hydroacoustic surveys conducted on the reservoir between December 1970 and June 1973 ranged in size from 26,000-90,000 fish with a mean of 49,000 (Thorne 1976). These values are similar to, though average lower than, the 1994 hydroacoustic estimates. (The 1973 estimate of 31,000 rainbow trout listed in *Table 28* is the only year that a specific hydroacoustic date and estimate were reported).

The 1991-94 hydroacoustic estimates suggest that the reservoir trout population has increased approximately 88 percent, 60 percent, and 16 percent annually over the past four years *(Table 28)*. In addition, the 1994 estimate is approximately forty percent larger than the 1973 hydroacoustic average. (It should be noted that the fairly large confidence intervals associated with the 1991-94 hydroacoustic estimates should be treated with caution, while any future measurements should incorporate a larger number of sample transects to reduce variance associated with the estimate). Catch rate information also tends to support an increase in the reservoir trout population. Overall HPUE shows a slight decrease from 1990-93 of 0.12, 0.10, 0.11, and 0.10, respectively *(Table 22)*, while CPUE indicates an increase of 0.39 (Looff 1992a), 0.37 (Looff 1993a), 0.43 (Looff 1994b), and 0.55 *(Table 6)*. Overall 1993 CPUE is also larger than the 1971-72 and 1985-86 HPUE of 0.48, 0.52, 0.33, and 0.41, respectively. (The 1993 overall CPUE estimate is used for comparison with the overall 1971-72 and 1985-86 HPUE estimates, since 1993 catch would be roughly equivalent to 1971-72 and 1985-86 harvest). This suggests that expanding numbers of younger (non-harvestable) age classes (age 2 and age 3) may be occurring in the reservoir.

Spawning Surveys

Spawning survey data conducted on selected tributary streams of Ross Reservoir from 1991 to 1994 continue to show an increase in the number of spawning rainbow trout *(Table 29)*. Spawning numbers increased from a

TABLE 28. Population estimates of Ross-Skagit system rainbow trout in 1971-73, and 1991-94.

Year	Estimate	95% CI	Method	Source
1971	153,580	± 33,317	Mark-Recapture	Johnston (1989)
1972	206,185	± 31,685	Mark-Recapture	Johnston (1989)
1973	191,480	± 20,729	Mark-Recapture	Johnston (1989)
1973	31,000*	———	Hydroacoustic	Thorne (1976)
1991	19,733	± 6,509	Hydroacoustic	Looff (1992a)
1992	37,080	± 10,636	Hydroacoustic	Looff (1993a)
1993	59,320	± 12,095	Hydroacoustic	Looff (1994b)
1994	68,812	± 17,529	Hydroacoustic	

*One estimate. See text for explanation.

TABLE 29. Number of spawning rainbow trout observed in selected tributaries of Ross Reservoir from 1991 to 1994.

Tributary	Number of Rainbow Trout[a]							
	1991[b]		1992[c]		1993[d]		1994[e]	
Dry	8	(8)	155	(126)	345	(305)	436	(380)
Lightning	51	(0)	1554	(29)	963	(15)	604	(4)
Pierce	5	(2)	30	(30)	95	(42)	137	(37)
Roland	107	(107)	597	(447)	1012	(897)	1067	(926)
Thursday	3	(3)	64	(28)	49	(35)	35	(22)
Total	174	(120)	2400	(660)	2464	(1294)	2279	(1369)

[a]Counts include fish observed milling in the immediate vicinity of mouth to upstream migration barrier. Counts from drawdown elevation to upstream migration barrier (instream counts only) given in parentheses.

[b]1991 = eight surveys.

[c]1992 = seven surveys

[d]1993 = seven surveys

[e]1994 = six surveys

total of 120 fish in 1991 (n=8 surveys), to 660, 1,294, and 1,369 fish in 1992 (n=7 surveys), 1993 (n=7 surveys), and 1994 (n=6 surveys), respectively (instream counts only). However, this is still well below a single estimate of 2,500 to 3,000 fish that were observed spawning in Roland Creek by a National Park Service employee on June 13, 1986 (National Park Service letter from Gary Mason to Washington Department of Wildlife area fisheries biologist Jim Johnston). Excessive and prolonged spring and early summer runoff during 1991 may have prevented most fish from ascending tributary streams to spawn that year, as well as reducing survival of any eggs that may have been deposited. However, very few fish were observed milling off stream mouths during the 1991 surveys, suggesting a depressed rainbow trout spawning population.

All five tributaries recorded increases in numbers of spawning rainbow trout from 1991 to 1994 *(Table 29)*. Roland Creek recorded the largest number of (instream) spawners during all four annual surveys, and continues to be the best index stream based on spawner use, flow, available spawning habitat, and accessibility. Dry Creek is another excellent index stream that should continue to be included in future surveys. As well as recording the second highest spawner totals, Dry Creek registered the greatest percentage increase (4,750 percent) over the four year survey period. Pierce and Thursday Creeks also recorded marked spawning increases, even though total numbers remain low due to migration barriers located near the mouth of each tributary. Total (instream) numbers on Lightning Creek are difficult to determine due to stream size and flow. In addition, a substantial number of fish probably spawn in the lake immediately adjacent to the stream mouth.

Continuation of the 1990-91, 1991-92, 1992-93, and 1993-94 reservoir studies, as well as concurrent monitoring of the Canadian Skagit River, are necessary to evaluate the effectiveness of the new restrictive angling regulations. With adequate data and analysis, appropriate management responses can be used to promote recovery of the Ross Lake rainbow trout population from the effects of past overharvest.

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APPENDIX 1. Summary of 1989-1993 Ross Lake fishing regulations.

	1990-1993	
	Washington State	British Columbia
Season:	07/01 - 10/31	
Catch limit:	three	
Size limit[a]:	thirteen inch minimum size for all species[b]	same as Washington State
Possession limit:	six	
Gear restriction:	no bait	

	1989	
	Washington State	British Columbia
Season:	06/17 - 10/31	07/01 - 10/31
Catch limit:	eight	four
Size limit[c]:	no more than three over 14 inches	
Possession limit:	eight	four
Gear restriction:	none	none

[a]Size limits measured using total length in both Washington State and British Columbia.

[b]Twenty-inch minimum size restriction for dolly varden/bull trout char in 1992 and 1993.

[c]Size limits were measured using total length in Washington State, and fork length in British Columbia.

APPENDIX 2. Creel and effort sampling schedule for the 1993 sport fishing season at Ross Reservoir.

Month	Day[a]	Daytype[b]	Work Period Start	Work Period Finish	Effort Count 1	Effort Count 2
July	1	OD	0800	1600	1200	1500
	3	WE	0700	1500	0700	1100
	4	WE	1100	1900	1300	1700
	15	WD	1100	1900	1400	1800
	16	WD	1200	2000	1200	1600
	17	WE	0600	1400	0800	1000
	20	WD	1100	1900	1200	1600
	21	WD	0600	1400	0900	1300
	22	WD	1300	2100	1300	1700
	24	WE	1300	2100	1500	1900
	25	WE	0700	1500	1000	1400
	26	WD	1000	1800	1300	1700
August	1	WE	0700	1500	0800	1200
	2	WD	1200	2000	1300	1700
	3	WD	1200	2000	1500	1900
	13	WD	1000	1800	1000	1400
	14	WE	1100	1900	1400	1800
	15	WE	0900	1700	0900	1300
	23	WD	1100	1900	1400	1800
	24	WD	1200	2000	1500	1900
	25	WD	0800	1600	0900	1300
	29	WE	1100	1900	1100	1500
	30	WD	1200	2000	1200	1600
	31	WD	1200	2000	1500	1900
September	1	WD	1100	1900	1300	1700
	2	WD	0800	1600	1100	1200
	3	WD	0900	1700	0900	1300
	6	WE	1100	1900	1100	1500
	7	WD	0800	1600	1100	1200
	8	WD	1000	1800	1200	1600
	18	WE	0900	1700	1200	1600
	19	WE	1100	1900	1100	1500
	20	WD	0800	1600	1200	1300
	25	WE	0900	1700	1100	1500
	26	WE	1000	1800	1300	1700
	27	WD	1100	1900	1100	1500

APPENDIX 2. (Continued)

Month	Day[a]	Daytype[b]	Work Period Start	Work Period Finish	Effort Count 1	Effort Count 2
October	1	WD	0900	1700	1200	1600
	2	WE	1000	1800	1100	1500
	3	WE	1000	1800	1300	1700
	8	WD	0900	1700	0900	1300
	9	WE	0900	1700	1000	1100
	10	WE	0900	1700	1100	1500
	18	WD	1000	1800	1100	1500
	19	WD	1000	1800	1000	1400
	20	WD	0900	1700	1200	1600
	26	WD	0900	1700	1100	1500
	27	WD	0900	1700	0900	1300
	28	WD	1000	1800	1100	1500

[a]Two holidays, July 4 (Independence Day) and September 6 (Labor Day), were treated as weekend days, even though Labor Day was observed during midweek in 1993 (see text).

[b]OD=opening day
WD=weekday
WE=weekend day

APPENDIX 3. Estimated monthly and seasonal angler effort by daytype in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Month	Daytype	Angler Hours[a]		Mean Hours Fished per Day[b]	Total Angler Days[c]
Jul	Opener	840	(0)	4.80	175
	Weekday	4253	(254)	4.25	1002
	Weekend	4193	(193)	4.19	1002
	Total	9285	(171)	4.26	2178
Aug	Weekday	3871	(63)	3.49	1108
	Weekend	2208	(0)	3.57	619
	Total	6079	(44)	3.52	1727
Sep	Weekday	2126	(45)	4.00	532
	Weekend	1870	(53)	4.22	444
	Total	3996	(34)	4.10	976
Oct	Weekday	1051	(69)	4.01	262
	Weekend	1986	(59)	3.43	579
	Total	3037	(49)	3.61	841
Ssn	Opener	840	(0)	4.80	175
	Weekday	11300	(75)	3.89	2904
	Weekend	10257	(55)	3.88	2642
	Total	22397	(54)	3.91	5721

[a]Ninety-five percent confidence interval of estimated total angler-hours given in parentheses.

[b]Mean hours calculated using data from all anglers, including those that indicated they had not finished fishing for the day (see text).

[c]Total angler days = angler hours/mean hours fished per day.

APPENDIX 4. Estimated monthly and seasonal angler effort by lake zone[a] in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Month	Daytype	Angler Hours[b]		Mean Hours Fished per Day[c]	Total Angler Days[d]
Jul	1 Rby	1514	(9)	4.27	354
	2 Bbv	2394	(18)	4.73	506
	3 Dev	897	(6)	5.96	151
	4 Lit	987	(7)	6.34	156
	5 Lbv	1699	(8)	5.21	326
	6 Hoz	3431	(14)	3.19	1075
	7 Can	1312	(13)	3.02	435
	Total	12233	(7)	4.07	3002
Aug	1 Rby	546	(6)	3.24	168
	2 Bbv	1931	(12)	3.91	494
	3 Dev	688	(8)	4.12	167
	4 Lit	336	(5)	3.93	85
	5 Lbv	621	(7)	3.71	167
	6 Hoz	663	(7)	3.23	206
	7 Can	1587	(12)	2.91	545
	Total	6372	(5)	3.48	1832
Sep	1 Rby	117	(5)	3.72	31
	2 Bbv	484	(8)	3.84	126
	3 Dev	194	(6)	5.72	34
	4 Lit	167	(7)	4.61	36
	5 Lbv	444	(7)	6.75	66
	6 Hoz	416	(10)	4.25	98
	7 Can	407	(11)	3.11	131
	Total	2229	(5)	4.27	522
Oct	1 Rby	372	(7)	3.10	120
	2 Bbv	763	(10)	4.24	180
	3 Dev	316	(7)	5.37	59
	4 Lit	149	(6)	4.42	34
	5 Lbv	344	(7)	7.50	46
	6 Hoz	772	(8)	3.62	214
	7 Can	214	(7)	1.63	132
	Total	2930	(5)	3.74	784
Ssn	1 Rby	2549	(5)	3.78	674
	2 Bbv	5571	(10)	4.27	1306
	3 Dev	2095	(5)	5.10	411
	4 Lit	1638	(5)	5.27	311
	5 Lbv	3109	(5)	5.14	605
	6 Hoz	5282	(8)	3.32	1592
	7 Can	3519	(8)	2.83	1242
	Total	23764	(5)	3.87	6140

[a]See *Figure 3* for location of lake survey zones.
[b]Ninety-five percent confidence interval of estimated total angler-hours given in parentheses.
[c]Mean hours calculated using data from all anglers, including those that indicated they had not finished fishing for the day (see text).
[d]Total angler days = angler hours/mean hours fished per day.

APPENDIX 5. Estimated monthly and seasonal angler effort by access area[a] in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Month	Daytype	Angler Hours[b]		Mean Hours Fished per Day[c]	Total Angler Days[d]
Jul	Resort	5792	(193)	4.89	1184
	Hozomeen	5130	(132)	3.43	1496
	Canada	1312	(82)	3.02	435
	Total	12233	(80)	3.93	3115
Aug	Resort	4024	(70)	3.77	1068
	Hozomeen	1069	(35)	3.32	322
	Canada	1335	(71)	2.91	458
	Total	6428	(34)	3.48	1849
Sep	Resort	1889	(51)	4.18	452
	Hozomeen	1357	(58)	4.90	277
	Canada	798	(58)	3.11	256
	Total	4043	(31)	4.11	985
Oct	Resort	1816	(78)	3.91	464
	Hozomeen	1014	(51)	3.72	273
	Canada	125	(27)	1.63	77
	Total	2954	(31)	3.63	814
Ssn	Resort	13520	(64)	4.27	3169
	Hozomeen	8570	(44)	3.62	2368
	Canada	3569	(34)	2.91	1226
	Total	25659	(28)	3.79	6763

[a]See *Figure 3* for location of access areas.

[b]Ninety-five percent confidence interval of estimated total angler-hours given in parentheses.

[c]Mean hours calculated using data from all anglers, including those that indicated they had not finished fishing for the day (see text).

[d]Total angler days = angler hours/mean hours fished per day.

APPENDIX 6. Estimated monthly and seasonal mean captures per hour for rainbow trout by daytype in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

			Rainbow Trout Captures per Hour[a]		
Month	Daytype	N[b]	Harvested	Released	Total
Jul	Opener	34	.227 (.003)	.845 (.004)	1.072 (.006)
	Weekday	167	.127 (.000)	.496 (.001)	.623 (.001)
	Weekend	145	.143 (.000)	.654 (.001)	.797 (.001)
	Mean		.145 (.000)	.600 (.000)	.744 (.000)
Aug	Weekday	149	.050 (.000)	.315 (.000)	.365 (.001)
	Weekend	115	.061 (.000)	.436 (.001)	.497 (.002)
	Mean		.055 (.000)	.368 (.000)	.423 (.000)
Sep	Weekday	101	.069 (.000)	.414 (.001)	.483 (.002)
	Weekend	162	.069 (.000)	.366 (.000)	.435 (.000)
	Mean		.069 (.000)	.384 (.000)	.453 (.000)
Oct	Weekday	89	.078 (.000)	.425 (.001)	.504 (.001)
	Weekend	73	.096 (.001)	.319 (.002)	.415 (.002)
	Mean		.086 (.000)	.382 (.001)	.467 (.001)
Ssn	Opener	34	.227 (.003)	.845 (.004)	1.072 (.006)
	Weekday	506	.086 (.000)	.420 (.000)	.506 (.000)
	Weekend	495	.094 (.000)	.464 (.000)	.558 (.000)
	Mean		.096 (.000)	.458 (.000)	.553 (.000)

[a]Ninety-five percent confidence interval of estimated mean captures per hour given in parentheses.

[b]Number of anglers surveyed.

APPENDIX 7. Estimated monthly and seasonal mean captures per hour for rainbow trout by lake zone[a] in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Month	Zone	N[c]	Rainbow Trout Captures per Hour[b] Harvested		Released		Total	
Jul	1 Rby	42	.100	(.001)	.563	(.004)	.663	(.004)
	2 Bbv	130	.141	(.000)	.449	(.001)	.590	(.001)
	3 Dev	22	.160	(.003)	.817	(.020)	.977	(.021)
	4 Lit	16	.079	(.004)	.463	(.016)	.542	(.019)
	5 Lbv	12	.064	(.007)	.544	(.028)	.608	(.030)
	6 Hoz	90	.198	(.001)	.658	(.002)	.856	(.002)
	7 Can	34	.185	(.003)	1.298	(.017)	1.483	(.017)
	Mean		.145	(.000)	.600	(.000)	.744	(.000)
Aug	1 Rby	45	.027	(.001)	.274	(.004)	.301	(.004)
	2 Bbv	95	.035	(.000)	.234	(.001)	.269	(.001)
	3 Dev	25	.039	(.001)	.204	(.005)	.243	(.006)
	4 Lit	7	.073	(.021)	.036	(.013)	.109	(.020)
	5 Lbv	7	.000		.346	(.046)	.346	(.046)
	6 Hoz	30	.041	(.001)	.496	(.008)	.537	(.009)
	7 Can	55	.150	(.001)	.855	(.007)	1.005	(.007)
	Mean		.055	(.000)	.368	(.000)	.423	(.000)
Sep	1 Rby	30	.018	(.001)	.296	(.007)	.314	(.007)
	2 Bbv	94	.072	(.000)	.319	(.001)	.391	(.001)
	3 Dev	25	.049	(.002)	.455	(.015)	.503	(.015)
	4 Lit	18	.024	(.002)	.398	(.009)	.422	(.010)
	5 Lbv	13	.068	(.003)	.365	(.014)	.433	(.014)
	6 Hoz	37	.095	(.001)	.528	(.004)	.623	(.004)
	7 Can	46	.119	(.001)	.391	(.004)	.510	(.005)
	Mean		.069	(.000)	.384	(.000)	.453	(.000)
Oct	1 Rby	47	.048	(.001)	.213	(.002)	.261	(.003)
	2 Bbv	50	.076	(.001)	.340	(.002)	.416	(.003)
	3 Dev	13	.086	(.008)	.272	(.018)	.358	(.020)
	4 Lit	6	.075	(.034)	.226	(.032)	.302	(.033)
	5 Lbv	1	.133		.267		.400	
	6 Hoz	37	.150	(.002)	.763	(.008)	.912	(.008)
	7 Can	8	.000		.000		.000	
	Mean		.086	(.000)	.382	(.001)	.467	(.001)
Ssn	1 Rby	164	.053	(.000)	.352	(.001)	.405	(.001)
	2 Bbv	369	.091	(.000)	.353	(.000)	.444	(.000)
	3 Dev	85	.085	(.000)	.475	(.002)	.560	(.002)
	4 Lit	47	.059	(.001)	.365	(.003)	.423	(.003)
	5 Lbv	33	.060	(.001)	.419	(.004)	.479	(.004)
	6 Hoz	194	.142	(.000)	.625	(.001)	.767	(.001)
	7 Can	143	.143	(.000)	.778	(.002)	.921	(.002)
	Mean		.096	(.000)	.458	(.000)	.553	(.000)

[a]See *Figure 3* for location of lake survey zones.
[b]Ninety-five percent confidence interval of estimated mean captures per hour given in parentheses.
[c]Number of anglers surveyed.

APPENDIX 8. Estimated monthly and seasonal mean captures per hour for rainbow trout by access area[a] in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Month	Zone	N[c]	Rainbow Trout Captures per Hour[b] Harvested		Released		Total	
Jul	Resort	211	.127	(.000)	.490	(.000)	.617	(.000)
	Hozomeen	101	.186	(.000)	.720	(.002)	.906	(.002)
	Canada	34	.185	(.003)	1.298	(.017)	1.483	(.017)
	Mean		.145	(.000)	.600	(.000)	.744	(.000)
Aug	Resort	169	.034	(.000)	.229	(.000)	.263	(.000)
	Hozomeen	40	.039	(.001)	.456	(.005)	.495	(.005)
	Canada	55	.150	(.001)	.855	(.007)	1.005	(.007)
	Mean		.055	(.000)	.368	(.000)	.423	(.000)
Sep	Resort	168	.057	(.000)	.363	(.001)	.420	(.001)
	Hozomeen	54	.078	(.001)	.451	(.002)	.529	(.003)
	Canada	41	.122	(.002)	.394	(.005)	.516	(.005)
	Mean		.069	(.000)	.384	(.000)	.453	(.000)
Oct	Resort	116	.068	(.000)	.282	(.001)	.351	(.001)
	Hozomeen	38	.149	(.002)	.736	(.007)	.885	(.008)
	Canada	8	.000		.000		.000	
	Mean		.086	(.000)	.382	(.001)	.467	(.001)
Ssn	Resort	664	.079	(.000)	.366	(.000)	.445	(.000)
	Hozomeen	233	.129	(.000)	.614	(.000)	.743	(.000)
	Canada	138	.144	(.000)	.783	(.002)	.927	(.002)
	Mean		.096	(.000)	.458	(.000)	.553	(.000)

[a]See *Figure 3* for location of access areas.

[b]Ninety-five percent confidence interval of estimated mean captures per hour given in parentheses.

[c]Number of anglers surveyed.

APPENDIX 9. Estimated monthly and seasonal mean captures per hour for dolly varden/bull trout char by daytype in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

			Dolly Varden/Bull Trout Captures per Hour[a]			
Month	Daytype	N[b]	Harvested	Released	Total	
Jul	Opener	34	0	.012 (.001)	.012	(.001)
	Weekday	167	0	0	0	
	Weekend	145	0	0	0	
	Mean		0	.001 (.000)	.001	(.000)
Aug	Weekday	149	0	0	0	
	Weekend	115	0	.002 (.000)	.002	(.000)
	Mean		0	.001 (.000)	.001	(.000)
Sep	Weekday	101	0	0	0	
	Weekend	162	0	0	0	
	Mean		0	0	0	
Oct	Weekday	89	0	0	0	
	Weekend	73	0	.004 (.000)	.004	(.000)
	Mean		0	.002 (.000)	.002	(.000)
Ssn	Opener	34	0	.012 (.001)	.012	(.001)
	Weekday	506	0	0	0	
	Weekend	495	0	.001 (.000)	.001	(.000)
	Mean		0	.001 (.000)	.001	(.000)

[a]Ninety-five percent confidence interval of estimated mean captures per hour given in parentheses.

[b]Number of anglers surveyed.

APPENDIX 10. Estimated monthly and seasonal mean captures per hour for all trout and char species by daytype in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

			Trout and Char Captures per Hour[a]					
Month	Daytype	N[b]	Harvested		Released		Total	
Jul	Opener	34	.227	(.003)	.858	(.005)	1.084	(.006)
	Weekday	167	.127	(.000)	.496	(.001)	.623	(.001)
	Weekend	145	.143	(.000)	.654	(.001)	.797	(.001)
	Mean		.145	(.000)	.601	(.000)	.746	(.000)
Aug	Weekday	149	.050	(.000)	.315	(.000)	.365	(.001)
	Weekend	115	.061	(.000)	.438	(.001)	.499	(.002)
	Mean		.055	(.000)	.369	(.000)	.424	(.000)
Sep	Weekday	101	.069	(.000)	.414	(.001)	.483	(.002)
	Weekend	162	.069	(.000)	.366	(.000)	.435	(.000)
	Mean		.069	(.000)	.384	(.000)	.453	(.000)
Oct	Weekday	89	.078	(.000)	.425	(.001)	.504	(.001)
	Weekend	73	.096	(.001)	.323	(.002)	.419	(.002)
	Mean		.086	(.000)	.383	(.001)	.469	(.001)
Ssn	Opener	34	.227	(.003)	.858	(.005)	1.084	(.006)
	Weekday	506	.086	(.000)	.420	(.000)	.506	(.000)
	Weekend	495	.094	(.000)	.465	(.000)	.559	(.000)
	Mean		.096	(.000)	.459	(.000)	.554	(.000)

[a]Ninety-five percent confidence interval of estimated mean captures per hour given in parentheses.

[b]Number of anglers surveyed.

APPENDIX 11. Monthly and seasonal estimates of rainbow trout captured by daytype in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

		Rainbow Trout Captured*					
Month	Daytype	Harvested		Released		Total	
Jul	Opener	190	(3)	710	(5)	900	(7)
	Weekday	540	(11)	2111	(43)	2651	(53)
	Weekend	601	(9)	2742	(42)	3343	(51)
	Total	1331	(10)	5563	(43)	6894	(54)
Aug	Weekday	193	(2)	1220	(9)	1413	(10)
	Weekend	134	(1)	963	(4)	1097	(5)
	Total	328	(1)	2183	(8)	2510	(9)
Sep	Weekday	148	(2)	880	(10)	1027	(11)
	Weekend	129	(1)	684	(6)	813	(7)
	Total	276	(1)	1564	(7)	1840	(8)
Oct	Weekday	82	(3)	447	(16)	530	(19)
	Weekend	190	(3)	634	(9)	825	(11)
	Total	273	(3)	1082	(12)	1354	(15)
Ssn	Opener	190	(3)	710	(5)	900	(7)
	Weekday	963	(5)	4658	(22)	5621	(27)
	Weekend	1054	(3)	5024	(17)	6078	(20)
	Total	2208	(4)	10392	(21)	12600	(25)

*Ninety-five percent confidence interval of estimated captures given in parentheses.

APPENDIX 12. Monthly and seasonal estimates of rainbow trout captured by lake zone[a] in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Month	Zone	Rainbow Trout Captured[b] Harvested		Released		Total	
Jul	1 Rby	152	(4)	852	(19)	1004	(22)
	2 Bbv	339	(12)	1074	(37)	1413	(49)
	3 Dev	144	(4)	733	(23)	877	(26)
	4 Lit	78	(4)	457	(20)	535	(23)
	5 Lbv	109	(9)	924	(44)	1033	(47)
	6 Hoz	681	(13)	2257	(44)	2938	(56)
	7 Can	243	(15)	1702	(101)	1945	(115)
	Total	1745	(9)	7999	(37)	9744	(46)
Aug	1 Rby	15	(1)	150	(4)	164	(5)
	2 Bbv	68	(2)	452	(10)	520	(12)
	3 Dev	27	(2)	140	(7)	167	(9)
	4 Lit	24	(4)	12	(3)	37	(4)
	5 Lbv	0		215	(19)	215	(19)
	6 Hoz	27	(1)	329	(12)	356	(13)
	7 Can	238	(9)	1357	(49)	1594	(57)
	Total	399	(2)	2655	(13)	3054	(15)
Sep	1 Rby	2	(0)	35	(4)	37	(4)
	2 Bbv	35	(2)	154	(7)	189	(8)
	3 Dev	9	(1)	88	(9)	97	(10)
	4 Lit	4	(1)	66	(11)	71	(12)
	5 Lbv	30	(2)	162	(10)	192	(12)
	6 Hoz	40	(4)	219	(24)	259	(28)
	7 Can	48	(6)	159	(19)	207	(25)
	Total	169	(2)	884	(12)	1053	(14)
Oct	1 Rby	18	(1)	79	(4)	97	(5)
	2 Bbv	58	(3)	259	(14)	317	(18)
	3 Dev	27	(3)	86	(10)	113	(12)
	4 Lit	11	(3)	34	(6)	45	(7)
	5 Lbv	46		92		138	
	6 Hoz	115	(4)	589	(20)	704	(24)
	7 Can	0		0		0	
	Total	275	(3)	1139	(12)	1414	(14)
Ssn	1 Rby	187	(1)	1115	(7)	1302	(8)
	2 Bbv	499	(5)	1940	(20)	2439	(25)
	3 Dev	207	(2)	1047	(12)	1255	(14)
	4 Lit	117	(2)	569	(9)	687	(11)
	5 Lbv	185	(3)	1393	(16)	1578	(18)
	6 Hoz	863	(7)	3395	(30)	4258	(37)
	7 Can	529	(8)	3217	(44)	3747	(52)
	Total	2588	(4)	12677	(20)	15265	(24)

[a]See *Figure 3* for location of lake survey zones.

[b]Ninety-five percent confidence interval of estimated captures given in parentheses.

APPENDIX 13. Monthly and seasonal estimates of rainbow trout captured by access area[a] in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Month	Access	Rainbow Trout Captured[b] Harvested		Released		Total	
Jul	Resort	735	(11)	2839	(42)	3574	(53)
	Hozomeen	953	(15)	3693	(60)	4646	(75)
	Canada	243	(15)	1702	(101)	1945	(115)
	Total	1931	(12)	8234	(50)	10165	(61)
Aug	Resort	138	(1)	922	(8)	1060	(9)
	Hozomeen	41	(2)	488	(15)	529	(16)
	Canada	200	(9)	1141	(49)	1341	(57)
	Total	379	(2)	2551	(15)	2931	(17)
Sep	Resort	107	(1)	686	(9)	793	(11)
	Hozomeen	105	(4)	613	(21)	718	(25)
	Canada	97	(6)	314	(20)	412	(27)
	Total	310	(3)	1613	(14)	1922	(16)
Oct	Resort	124	(3)	512	(13)	637	(16)
	Hozomeen	151	(7)	746	(35)	897	(42)
	Canada	0		0		0	
	Total	275	(4)	1259	(17)	1534	(21)
Ssn	Resort	1104	(4)	4959	(20)	6064	(25)
	Hozomeen	1250	(8)	5540	(36)	6790	(44)
	Canada	540	(8)	3157	(45)	3698	(53)
	Total	2895	(5)	13657	(26)	16552	(31)

[a]See *Figure 3* for location of access areas.

[b]Ninety-five percent confidence interval of estimated captures given in parentheses.

APPENDIX 14. Monthly and seasonal estimates of dolly varden/bull trout char captured by daytype in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

		Dolly Varden/Bull Trout Captured*					
Month	Daytype	Harvested		Released		Total	
Jul	Opener	0		10	(1)	10	(1)
	Weekday	0		0		0	
	Weekend	0		0		0	
	Total	0		10	(0)	10	(0)
Aug	Weekday	0		0		0	
	Weekend	0		5	(0)	5	(0)
	Total	0		5	(0)	5	(0)
Sep	Weekday	0		0		0	
	Weekend	0		0		0	
	Total	0		0		0	
Oct	Weekday	0		0		0	
	Weekend	0		8	(0)	8	(0)
	Total	0		8	(0)	8	(0)
Ssn	Opener	0		10	(1)	10	(1)
	Weekday	0		0		0	
	Weekend	0		13	(0)	13	(0)
	Total	0		24	(0)	24	(0)

*Ninety-five percent confidence interval of estimated captures given in parentheses.

APPENDIX 15. Monthly and seasonal estimates of trout and char captured by daytype in the Ross Reservoir sport fishery, July 1 to October 31, 1993.

Month	Daytype	Trout and Char Captured* Harvested		Released		Total	
Jul	Opener	190	(3)	720	(5)	911	(7)
	Weekday	540	(11)	2111	(43)	2651	(53)
	Weekend	601	(9)	2742	(42)	3343	(51)
	Total	1331	(10)	5574	(43)	6905	(54)
Aug	Weekday	193	(2)	1220	(9)	1413	(10)
	Weekend	134	(1)	968	(4)	1103	(5)
	Total	328	(1)	2188	(8)	2516	(9)
Sep	Weekday	148	(2)	880	(10)	1027	(11)
	Weekend	129	(1)	684	(6)	813	(7)
	Total	276	(1)	1564	(7)	1840	(8)
Oct	Weekday	82	(3)	447	(16)	530	(19)
	Weekend	190	(3)	642	(9)	832	(11)
	Total	273	(3)	1089	(12)	1362	(15)
Ssn	Opener	190	(3)	720	(5)	911	(7)
	Weekday	963	(5)	4658	(22)	5621	(27)
	Weekend	1054	(3)	5037	(17)	6091	(20)
	Total	2208	(4)	10415	(21)	12623	(25)

*Ninety-five percent confidence interval of estimated captures given in parentheses.

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