BULL RUN LAKE CUTTHROAT TROUT

TRIBUTARY SPAWNING MONITORING REPORT 1999-2006

DAVID SAIGET

USDA FOREST SERVICE – MT. HOOD NATIONAL FOREST

ZIGZAG RANGER DISTRICT

2007

Caring for the Land and Serving People

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All Photographs:
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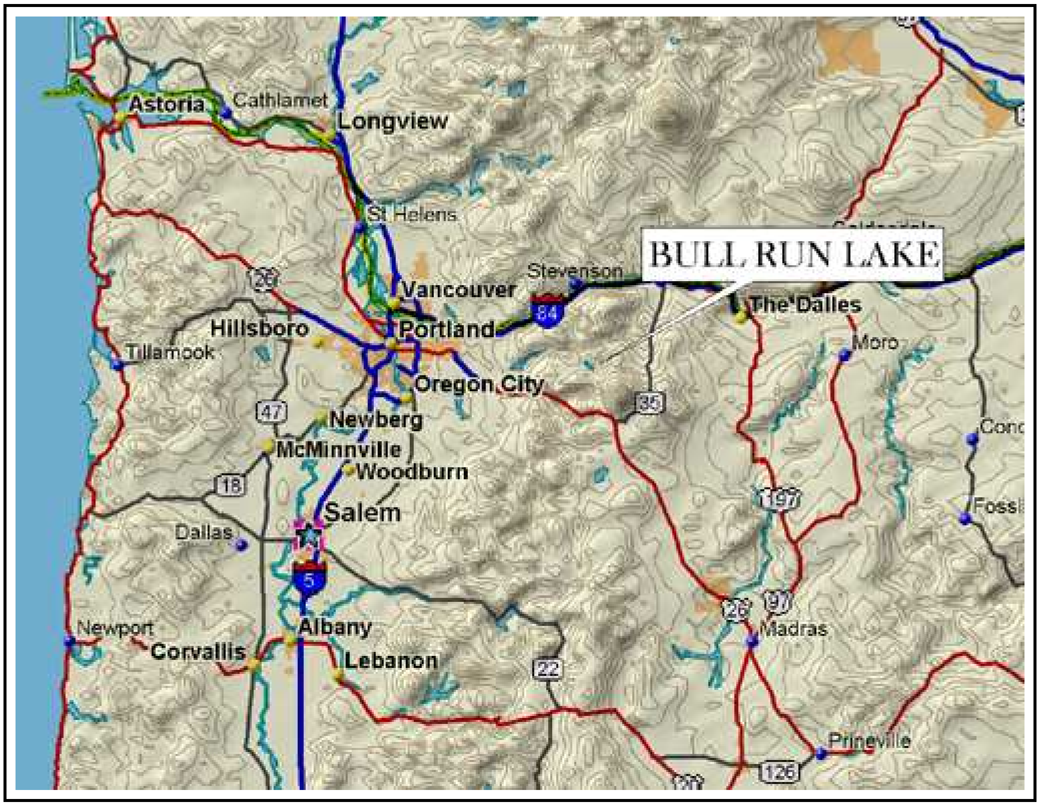

Figure 1.

Location of Bull Run Lake, Oregon

Figure 2. Bull Run Lake spawning tributaries (in red) and shoal spawning areas (in blue).

INTRODUCTION

Under a 20-year special use permit with the Mt. Hood National Forest (MHNF), the City of Portland Water Bureau (City) operates and maintains drinking-water supply facilities at Bull Run Lake. The special-use authorization that the City is currently operating under was signed on June 30, 1997.

The Bull Run Lake Mitigation and Monitoring Plan (*City of Portland 1998*), describes all monitoring activities necessary for evaluation of the effects of lake use on the aquatic ecosystem and the food base for the bald eagle, in addition to the mitigations. The goal of the plan is to describe measures needed to protect the fish, the lake ecosystem, and its capacity to provide a food base for the recovery of threatened bald eagles while carefully protecting water quality.

Bull Run Lake is a high elevation montane lake located on the western slopes of the Cascade mountain range 25 miles east of Portland, Oregon. The lake is situated within the 88,962 acre Bull Run Watershed within the Mt. Hood National Forest (*Figure 1*). The lake is the headwater source for the Bull Run River which flows 25 miles west into the Sandy River. In addition to the two reservoirs located on the mainstem of the Bull Run River, the City occasionally withdraws water from Bull Run Lake during drought years. Annual water level fluctuations during years when water is withdrawn from the lake average 18 ft. Refill rates during drawdown years average 3.3 feet per month.

Annual precipitation at the lake ranges from 110 to 130 inches per year. Surface water inflow comes mainly from many small steep tributaries around the lake basin (*Figure 2*). Bull Run Lake reaches maximum capacity ("full-pool") at 3,178 ft above sea level. At full pool, the lake depth averages 66 ft., with a maximum depth of 270 ft. The lake at full pool elevation has a circumference of 4.2 miles, a surface area of 486 acres and volume of 30,600 acre feet. Pristine watershed conditions have resulted in excellent water quality and clarity. Oligotrophic conditions prevail as indicated by low phosphorous and chlorophyll concentrations.

The water level in Bull Run Lake fluctuates naturally an average of ~12 feet per year. Natural fluctuations are likely due to the porous nature of underlying geology and variation in temporal precipitation regimes. The average refill rate for the lake is 2.6 feet per month. Weather conditions dictate when the lake will refill by precipitation and resulting run-off.

Native coastal cutthroat trout *(Oncorhynchus clarkii clarkii)* is believed to be the only fish species within the lake. The fish are a native, pure, unhybridized form of coastal cutthroat trout and are considered a unique stock by the Oregon Department of Fish & Wildlife. The only other species that have been reported are sculpin (*Cottus sp*.) and Whitefish (*Prosopium sp*.). However, no sculpin have been observed during spawning surveys since 1993. A twenty-inch whitefish carcass was observed on the lake shore by Beak Consultants, Inc. in September 1992 (*Beak 1993*) but no other sightings of whitefish have been reported. It is possible that raptors or other wildlife brought the carcass to the lake.

The main tributaries to Bull Run Lake provide important spawning and rearing habitat for the lake's cutthroat trout population. Spawning in the tributaries typically occurs from mid-May through mid-June.

Cutthroat trout pair spawning in shoals, Bull Run Lake. Female is at top. This female deposited about 100 eggs, some visible below the tails of the fish. After spawning, most of the eggs were predated on by the male and other fish. Fish lengths 14-16" (est.).

Spawning surveys are conducted in the tributaries and shoal areas of the lake each spring-summer by personnel from the US Forest Service, Zigzag Ranger District. Spawning surveys in the tributaries have been conducted since 1993 while shoal spawning surveys have been conducted beginning in 2006. The goal of the surveys is to assess potential effects of lake water withdrawals on the fish population and provide information for mitigation efforts.

Beginning in 1999, methods for data collection were modified and protocols were standardized (previous monitoring reports mistakenly refer to the first year of standardized protocols as beginning in 1998). This document reports results collected from the 2001-2006 surveys and provides an analysis of all data collected since 1999. Some data collected previous to 1999, such as water surface elevation and spawner counts are used in this analysis when consistent with the new protocols established in 1999.

Summary and analysis of spawning surveys from 1993-2000 is documented in *The Bull Run Lake Cutthroat Trout Spawning Monitoring Report for 1993-1999* (*Saiget 2000*) and *The Bull Run Lake Cutthroat Trout Spawning Monitoring Report for 2000* (*Saiget 2001*).

METHODS

Spawning surveys were carried out once per week during the spring-summer spawning season from May to July. When time and budget allowed, additional surveys were conducted into late summer to monitor stream conditions and fry emergence. Spawning surveys were comprised of redd counts and fish counts. Surveys were conducted by crews of at least 2 people with one person walking on each side of the creek. Survey crews were comprised of at least one person possessing a minimum of 3 years experience in identifying salmonid redds. Polarized glasses were used to aid viewing conditions.

Surveys were conducted on six tributaries to the lake. These six tributaries (labeled Tributaries 2, 4a, 4b, 4c, 5, 6) (*Figure 2*) have been monitored for cutthroat trout spawning since 1993. The length of each stream surveyed varies depending on location of potential passage barriers. Two tributaries have both an index reach and a non-index reach. Non-index reaches were surveyed as well as the index reaches. Tributary 2 has an index reach of 60 meters and a non-index reach of 150 m. Tributary 4a has an index reach of 110 m and a non-index reach of 87 m. The following tributaries have only an index reach (with distances): tributary 4b-70 m, tributary 4c-79m, tributary 5 branches after 28 m-left branch (looking upstream) is 44 m, right branch is 50m, and tributary 6 index reach is 83 m.

Following is a summary of data that was collected:

<u>Water and air temperatures.</u> Both were recorded in degrees Celsius. Water temperature was taken at the mouth of each tributary and the end of each index and non-index reach.

<u>Viewing conditions</u>. The ability of the surveyors to see clearly into the water was recorded as poor, fair, good, or excellent depending on water turbidity, lighting conditions, and degree of surface turbulence.

<u>Water surface elevation of the lake (WSE).</u> Water surface elevation (WSE) is the height in feet above sea level of the lake surface and recorded for each survey date. WSE is related to seasonal precipitation amounts, snow melt runoff, natural seepage, and waterwithdrawals (if any) for drinking water supply. WSE fluctuates daily; readings used are the mean readings taken at midnight each calendar day. This data was gathered from the United States Geological Survey Water Resources of Oregon home page on the World Wide Web which receives automatic uplinked data from remote sensors at the lake. Annual average WSE for each spawning season was derived from averaging all the midnight readings of each survey date for each year.

A WSE of 3174’ is believed to be the lowest elevation where tributary access for spawners is unhindered *(USFS 1995a).* The “full-pool zone”, designated as the area between 3174’-3178’, contains the most productive aquatic species habitat for juvenile fish and macroinvertebrates *(Bull Run Lake Special Use Authorization and Lake Level Management Plan Environmental Assessment 1995*. “Full-pool” elevation is the elevation where the lake is at “full” capacity in terms of water storage, currently designated at 3178’. “Lake drawdown”, “water release” or “water withdrawal” refer to the removal of lake water by the Portland Water Bureau to supplement drinking water supplies for their customers. The “drawdown zone” refers to the area of lake shore exposed at lake levels below 3174’. Water withdrawal occurs through gravity-fed and pumping of lake water through a submerged penstock located at the west end of the lake.

<u>Spawner Counts</u> Adult spawner counts are enumerations of all fish greater than 10 inches

estimated total length seen in the tributaries each year during the surveys. Fish of this size class assumed to be mature and in the tributaries to spawn but it is also accepted that not all mature fish may meet this size criterion. Spawner counts do not represent the total number of fish utilizing the tributaries for the spawning season but only a total count of all spawners observed in the tributaries during each year. Surveys occurred on average once per week.. Number of fish and estimated length were recorded. Length was visually estimated and categorized according to three size classes: < 6 inches total length, 6-10" total length, and > 10" total length. Fish > 10" were considered to be mature spawning fish.

Redd counts and location. Number of redds and location were recorded. The number of redds from each survey date were added at the end of the season to derive an annual total redd count Criteria used to identify redds were: 1) disturbed substrate, usually as an excavated bowl-shaped depression with an associated mound covering the eggs 2) substrates consisting of fine to very course gravel (where gravel sizes, as defined by Platts et al. (1983) are: fine gravel: 4-8 mm, medium gravel: 8-16 mm, coarse gravel: 16-32 mm, and very coarse gravel: 32-64 mm). 3) excavated gravels are "sorted" from largest to smallest size as distance increases from depression or mound, in the direction of the predominant water flow at the redd site (*Photo 2).*

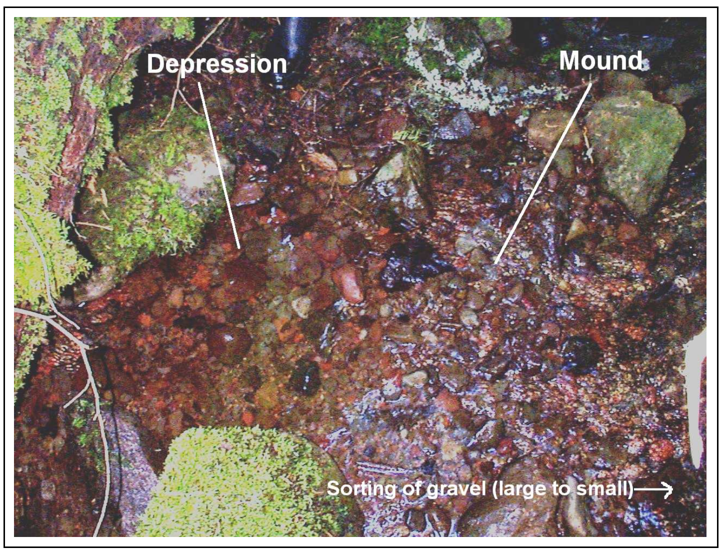

Photo 2. Features of typical cutthroat trout redd, Bull Run Lake. Note depression, mound, and associated sorting of gravels. Approximate scale: 0.75 inches =1 foot

Depressions or mounds not associated with sorting of gravels were not considered redds. All redd locations were identified and recorded so that they could be relocated in future surveys. This was done to prevent a redd from being counted more than once and as an aid for monitoring the condition of the redd during future surveys. Each redd was marked using two flags placed in the bank a minimum of 3 feet apart. Distances from the flags to the center of the redd depression were recorded. Redds could then be relocated by triangulating back to the center of the redd depression (*Photo 3*).

Photo 3. Recording distances to redds for relocating in future surveys.

On subsequent surveys, previously identified redds were first relocated before new redds were identified and marked (*Photo 4*).

Photo 4. Spawning area in tributary 4a, showing relocated redds (orange flagging).

Redd condition ratings were assigned as follows: poor - most or all of the redd (mound and depression) not underwater and exposed to air; fair - part of the redd exposed to air but the majority of the redd underwater; good - entire redd underwater.

Passage conditions. This is an assessment of the ability of fish to access the tributaries from the lake. Assessment of these conditions were made using the following categories: 1) no passage: access completely blocked or hindered, or questionable access from the lake for adult fish; 2) difficult-access possible with difficulty; and 3) good: unhindered access.

Wildlife observations. This included observations of all wildlife with special attention given to birds of prey such as osprey and Bald Eagles.

RESULTS

Surveys occurred once per week through the spawning season. Surveys usually took one day. In 2002, surveys did not begin until early June due to a deep snowpack. See *Appendix table 1* for survey dates for each year.

Surveys were conducted until no new redds were counted. A minimum of two surveys were conducted after the last redds were identified to ensure that the spawning was complete. *Appendix Table 1* summarizes survey results for 1999-2006.

Water Surface Elevation

Table 1 shows the average WSE for each spawning season (May-July) from 1998-2006, computed by averaging the midnight WSE for each survey date for each season. *Figure 3* shows WSE in graph form.

Table 1. Annual mean water surface elevations during spawning season for each survey year, 1998-2006.

Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Mean WSE	3,177.2	3,180.3	3,179.4	3,166.8	3,175.9	3,174.5	3,173	3,168.7	3,174.46

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Average WSE for the period 1998-2006 was 3174.48 feet above sealevel. The three-year period from 1998-2000 had the highest WSE's but the "full-pool" elevation of 3178' was only reached in the 1999 and 2000 seasons. In six of the nine years (1998, 1999, 2000, 2002, 2003, 2006), mean spring WSE reached the "full-pool zone" of 3174'-3178'.

The 2001 WSE was the lowest for all years, 7.68 feet below average. This occurred after a winter drought in 2000-2001 and a 6' lake drawdown in September of 2000. The 2005 season had the second lowest WSE during the 8-year period and was 5.78' below average. This occurred after a drought during the winter of 2004-05. Range of WSE for 1998-2006 was 13.5 feet.

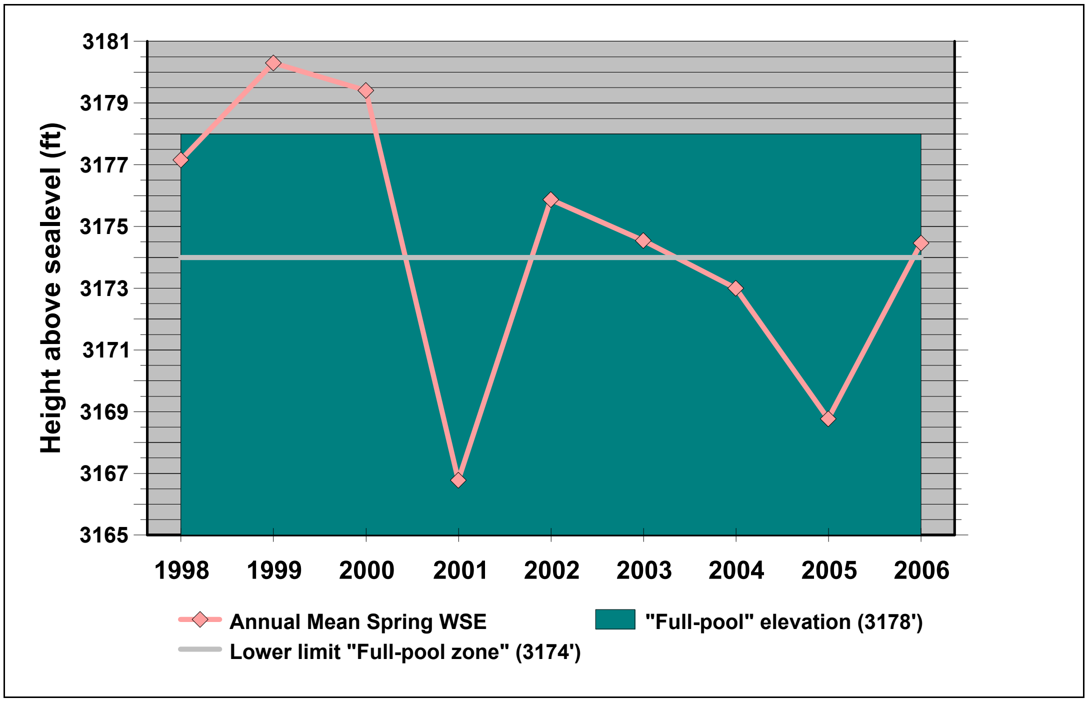

Figure 3. 1998-2006 mean spring midnight WSE (pink line), lower elevation (3174') of "full-pool zone" (gray line), and "full-pool" elevation of 3178' above sealevel (solid background).

Historical Lake Elevations pre-1915 to present

Figure 4 shows the years when the spring high lake-level reached "full-pool zone" of 3174', years when levels did not reach "full-pool zone", and years when summer/fall water releases occurred. No data exists for the years 1961-1969. No data of water releases is available for the years prior to 1970.

The "full-pool" elevation prior to the 1915 dike construction was estimated at 3168'. Subsequent dike modifications varied the "full-pool" elevation from 3163' to the present day 3178' above sealevel *(USFS 1995b).*

Years in which lake levels did not reach the "full-pool zone" were the period prior to 1915, from 1920-58, 1970-77, 1987-89, 1992-94, 2001, and 2004-2005. Water releases occurred 10 times since 1970, in 1976, each year from 1985-1992, and in 2000. Highest annual lake elevations usually occur during April and May, after the winter/spring rainy season. Past water releases occurred during the months of July to October. Earliest waterwithdrawal on record occurred on July 11 in 1990 and latest waterwithdrawal occurred on October 26 in 1991. Refill, when it occurs, takes place during winter and spring.

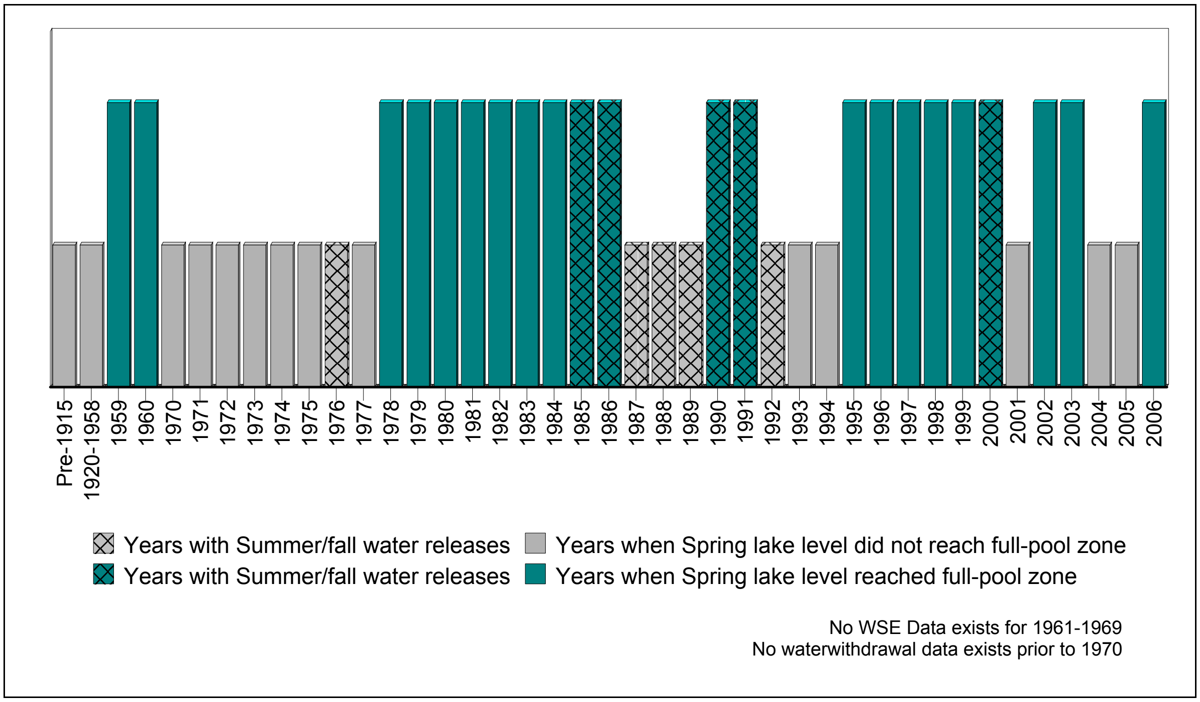

Figure 4. Years when the spring high lake elevation reached the "full-pool zone" of 3174' above sealevel (blue bars), years where it did not reach the "full-pool zone" (grey bars), and years when summer/fall water withdrawals occurred (cross hatching). Waterwithdrawals occurred in 1976, 1985-1992, and 2000. No WSE data exists for the years 1961-1969. No waterwithdrawal data exists prior to 1970. Sources: Bull Run Lake Special Use Authorization and Lake Level Management Plan Environmental Assessment 1995; Beak 1993.

In the years prior to 1915 and from 1920-1958, lake levels did not reach 3174'. From 1970-2006, lake levels reached the "full-pool zone" in 21 of the 36 years, or 59% of the time. "Full-pool" was reached in 9 of the 36 years, or 25% of the time. In the 10 years when water withdrawals did occur, lake levels returned to the "full-pool zone" by the following spring 30% of the time (3 years out of 10).

Adult Spawner Counts

Table 2 shows total numbers of spawners counted during the survey years for 1999-2006. Average number of spawners seen per year was 70. Range was 11-157 fish. Highest counts occurred in 1999 and 2004. Lowest counts occurred in 2001 and 2002.

Table 2. Total number of spawners (fish >10" estimated total length) observed annually in tributaries during survey years from 1999-2006.

Year	1999	2000	2001	2002	2003	2004	2005	2006
# spawners	157	42	11	17	62	127	66	76

Because annual total spawner counts are derived from once-per-week surveys, it is assumed that these annual spawners counts are underestimating actual adult population size. Annual total counts have generally never exceeded any of the one-day survey counts except for the 1999 count Lowest total annual spawner counts occurred in 2001 and 2002 with 9 and 11 fish counted, respectively. Lake gillnet and hydroacoustic surveys may provide more reliable estimates of adult abundance as these methods involve greater sampling areas and greater sampling time (gillnet sampling occurs overnight and hydroacoustic sampling comprise multiple transects of the lake).

Historical Fish Counts

One-day fish counts from past stream, snorkel, boat, gill-netting, and hydroacoustic surveys are shown in *Figure 5*. Numbers counted are not total annual counts as in *Table 2* above but are one-time counts of fish observed during surveys lasting one day or less. Stream, lake snorkel, and boat counts all occurred during spring spawning season. The 1973 gillnet survey occurred during spawning season and the remaining gillnet surveys occurred during summer or fall. Lake hydroacoustic surveys occurred in summer or fall.

The largest single-method, one-day fish count was 208 fish, observed in a 1994 hydroacoustic survey. Past one-day fish counts have ranged from 9-208 fish. A May 30-31, 1973 combined stream/gillnet survey resulted in 206 adults caught by gill net and 130 spawners estimated in two tributaries, indicating a one-day count of at least 336 adults. A 2003 boat survey estimated 115 adults.

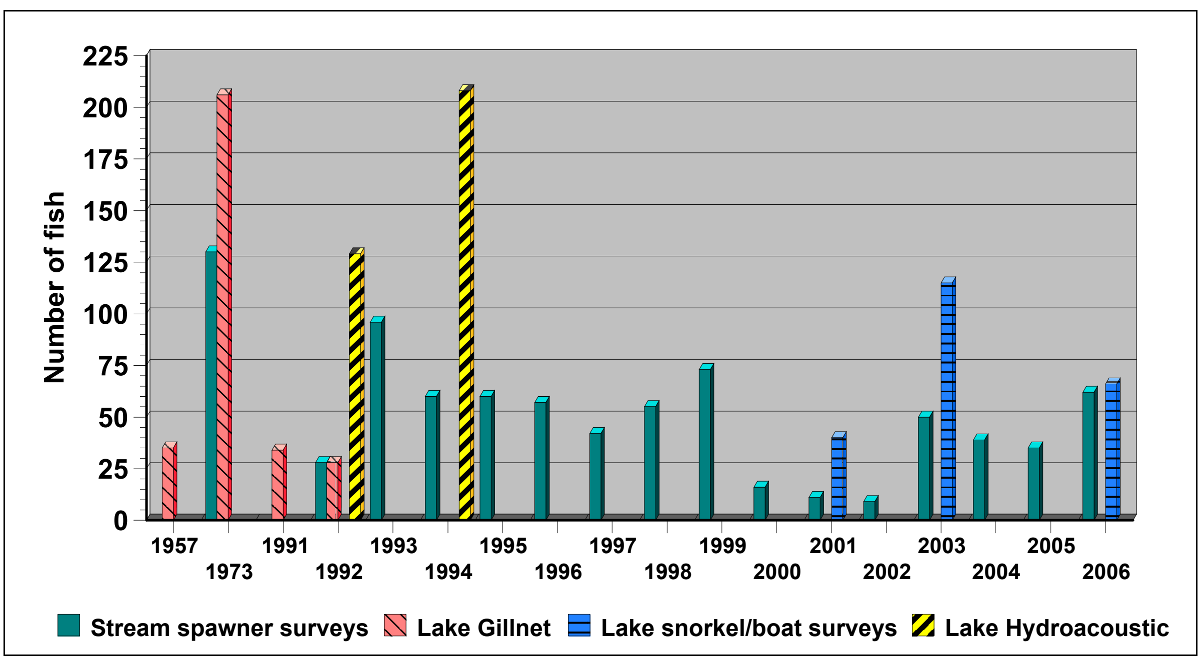

Figure 5. Historical one-day fish counts at Bull Run Lake. Numbers are not total annual fish counts but counts from one-day surveys. Sources: 1992-2006 U.S. Forest Service stream, snorkel, and boat surveys data; Gillnet and 1973 stream survey data from Hewkin 1992; 1992 Hydroacoustic data from Thorne and McClain 1993; 1994 Hydroacoustic data from Nealson and Ransom 1994.

Male (top) and female over redd. Boat ramp shoal area, Bull Run Lake.

Annual tributary redd counts and water surface elevation

Annual total tributary redd counts are enumerated by totaling all new redds counted for all the tributaries for each survey date, for each year. *Table 3* and *Figure 6* show redd counts for 1999-2006. .

Table 3. Total tributary redd counts by year, 1999-2006.

Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Redds	86	48	*13*	17	78	73	30	53

The 1999, 2003, and 2004 seasons had the highest redd counts with 86, 78 and 73, respectively. Lowest counts occurred in 2001, 2002, and 2005 with 13, 17, and 30 redds, respectively. Average for the period was 50 redds.

Highest WSE's occurred in 1999 and 2000 with lake levels exceeding the "full-pool" elevation of 3178' (*Figure 6*). In both these years, the spring WSE exceeded 3179'. The lower threshold "full-pool zone" elevation of 3174' was exceeded in 5 of the 8 years: 1999, 2000, 2002, 2003, and 2006. Lowest WSE's occurred in 2001 and 2005 when the spring WSE was ~3165' in 2001 and ~3169' in 2005.

The lowest redd count occurred in 2001 when the spring WSE was over 8' below the "full-pool zone". This resulted in hindered tributary access with 4 of the 6 tributaries recorded as "no passage" with no redds observed. Only tributaries 2 and 4a had redds but passage conditions in these tributaries became "difficult" to "no passage" by July, 2001.

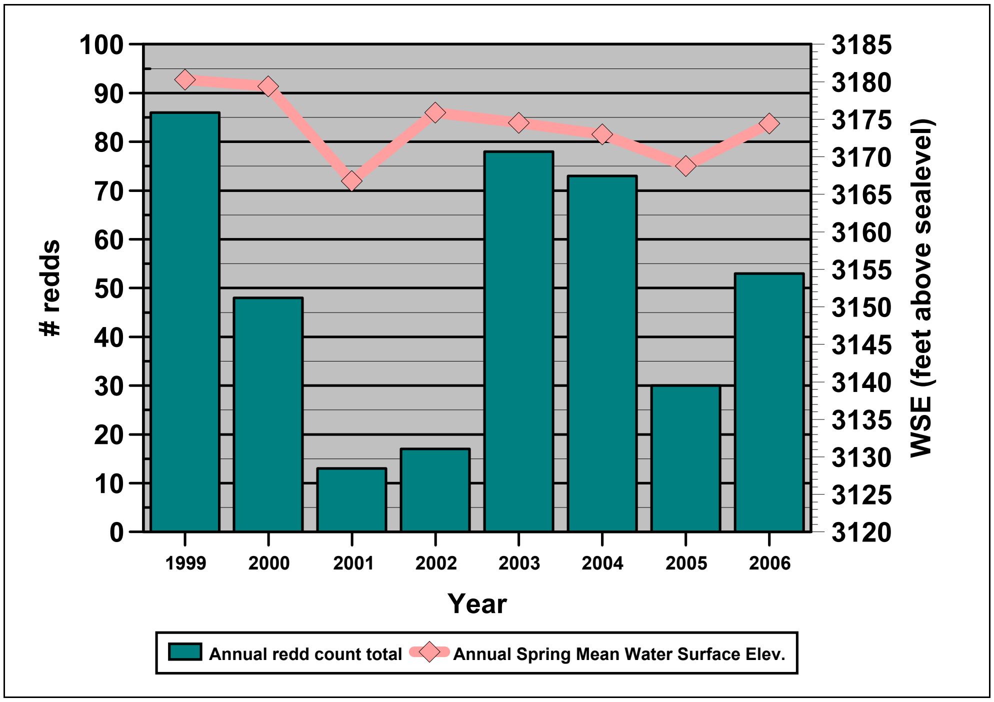

Figure 6. Redd counts (bars) and water surface elevation (line) for 1999-2006.

The second lowest redd counts occurred in 2002. At that time, however, there were no access problems for fish as the lake elevation exceeded 3174'. The 2002 year had the third highest WSE for the period from 1999-2006 and was one of the 15 highest lake levels attained in the 36 years since 1970.

A regression analysis of WSE and redd counts from 1999-2006 did not produce a significant correlation coefficient indicating no relationship between height of lake levels and magnitude of redd counts. A regression analysis of lake levels above the "full-pool zone" against redd counts during those years also did not produce a significant relation.

Redd counts by tributary

Figure 7 shows total redd counts for each tributary from 1999-2006. Tributary 4a had the highest counts (173) followed by tributaries 6 (86) and 5 (63). Lowest redd counts were seen in tributary 4b with 12 redds and 4c with 18 redds. Tributary 2 had 59 redds.

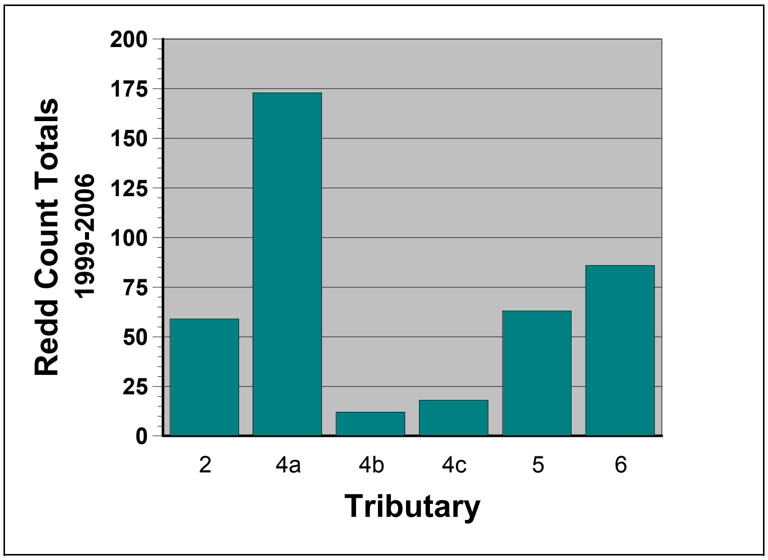

Figure 7. Total redd counts by tributary, 1999-2006.

Figure 8 shows redd counts by tributary by year. Only the 2003 and 2004 seasons had redds constructed in all of the tributaries. Five of the 6 tributaries had redds in 1999 and 2006. The 2001 and 2002 seasons had the lowest production with only 2 and 3 tributaries, respectively, having redds.

Tributaries 4a, 5, and 6 have the highest redd counts while tributaries 4b and 4c are the least productive. Tributary 4a has had redds constructed in all years. During 2001, redds were seen in only 2 of 6 tributaries (2 and 4a) and 62% of those (8 out of 13) were in tributary 4a. In 2002, redds were only seen in 3 of the 6 tributaries (2, 4a, and 4b) with 60% of the redds (10) in tributary 4a.

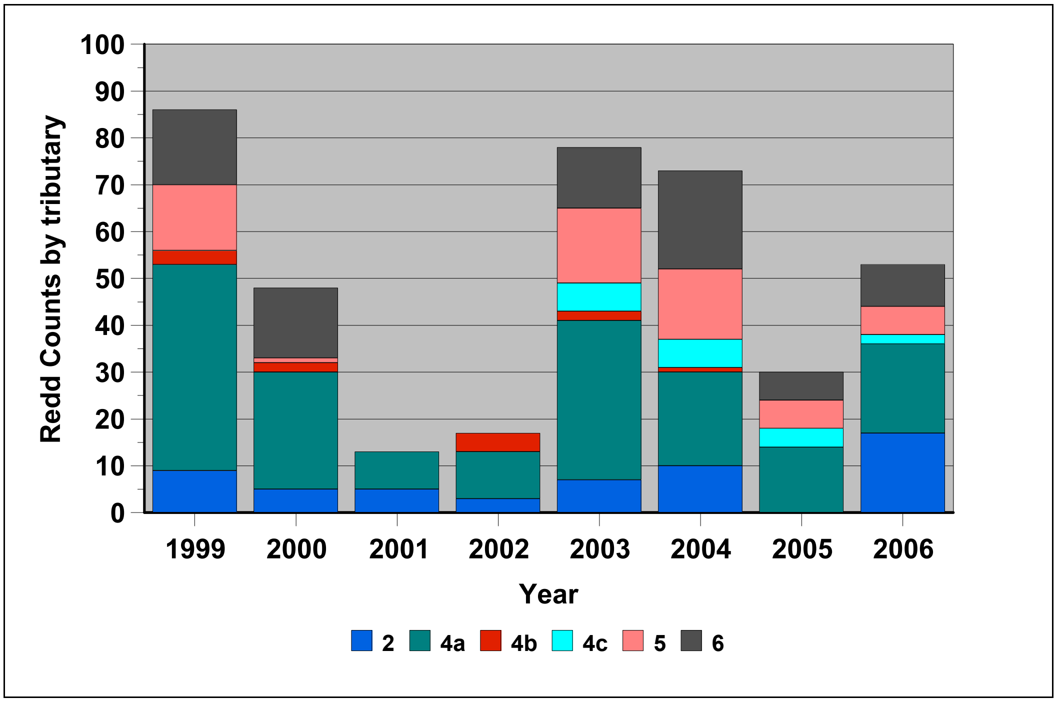

Figure 8. Tributary Redd counts by year, 1999-2006.

Tributary Habitat Conditons/Productivity

The following section summarizes tributary habitat conditions data gathered from spawning, stream habitat, and longitudinal profile surveys

Stream habitat surveys of all the spawning tributaries of the lake were conducted in the summer of 2005. Tributaries were surveyed using U.S. Forest Service Region 6 Level II Inventory Methodology. Complete results of the survey are reported in *The 2005 Stream Survey Report Bull Run Lake Tributaries (Mt. Hood 2005a*).

Longitudinal profile surveys of the drawdown zones from 3174' to ~3166' in each of the tributaries was also conducted in the summer of 2005. The longitudinal profiles were conducted to identify potential fish passage barriers that emerge as lake levels decrease below the "full-pool zone" elevation of 3174'. Complete results are reported in *The Bull Run Lake Tributary Longitudinal Profile Survey 2005 (Mt. Hood 2005b).*

Tributary 2: Tributary 2 had the third lowest redd counts (59), has the second lowest amounts of spawning gravels (~50 sq. ft.), and the second highest gradient (16%). Tributary 2 is generally more productive than 4b and 4c but has variable redd counts from year to year. Bankfull widths average ~7' with substrates dominated by large angular gravels to 6". This tributary has a steep gradient beginning near the mouth. Redds are usually confined to isolated pockets of gravel. A barrier to most flows exists near the end of the index reach (200' upstream), limiting the amount of available spawning habitat. Above the barrier, resident cutthroat trout redds have been observed every year; small cutthroat trout with dense spotting characteristic of resident forms

have been observed here.

Tributary 4A: Tributary 4a has the highest redd counts of all the tributaries (173), the highest amounts of spawning gravels (~225 sq. ft.), and the lowest average gradient of 9%. Tributary 4a has a low gradient outflow into the lake and a relatively large spawning bed ~120' upstream from the lake. This spawning area is the largest of all the spawning areas identified in all of the tributaries, approximately 90' in length, with bankfull widths to 12'. Substrates consist primarily of gravels. The combination of low gradient and smaller substrates in a relatively large area is suspected to be the reason for this tributary having the highest redd counts. During 2001 when lake levels were below the "full-pool zone", tributary 4a appeared to be the least affected in terms of tributary access due to the lower gradient in the drawdown zone. The other tributaries had areas in the drawdown zone with vertical or near vertical hydraulic jumps or shallow incision and shallow water depths that prevented fish passage.

Tributary 4b: Tributary 4b has the lowest redd counts (12), the lowest amounts of spawning gravels, the smallest bankfull width (6.3'), with an overall gradient of 10%. Tributary 4b also has the shallowest water depths, and lowest flows of all the tributaries with a steep gradient beginning a short distance from the mouth. When spawning does occur here, the steep gradient, step-pool habitat, and narrow widths can result in stranding of fry during summer low flows.

Tributary 4c: Tributary 4c has the second lowest redd counts (18) but the 2nd highest amounts of spawning gravels (~170 sq. ft., estimated from dry channel conditions). The gradient is 10%. This tributary has large substrates composed of small cobble. A barrier falls that precludes passage at all but the highest flows exists 120'-150' upstream from the mouth. Tributary 4c has relatively wide bankful widths and sees spawner utilization each year. However, this tributary drains a small basin area and the stream usually goes subsurface by early summer. Desiccated redds are seen here every year.

Tributary 5: Tributary 5 has the third highest redd counts (63), 3rd highest amount of spawning gravels (~130 sq. ft.), and an overall gradient of 9%. Tributary 5 has the widest overall bankfull widths (to 8') and highest flows of all the tributaries. Fish utilization, as evidenced by adult counts, can be very high but redd counts are usually less than tributaries 4a, and 6. This tributary has low amounts of suitable spawning gravels, usually found in small, isolated pockets $<0.5yd^2$. This tributary also has the largest substrates of all the surveyed tributaries, comprised of large gravels and small cobbles. These large substrates may affect redd counts either by making it harder for fish to construct redds or by making it difficult for surveyors to identify redds in the larger substrates.

Tributary 5 had no redds in 2001 or 2002. It is believed that the low redd count in 2001 was due to the low WSE that prevented tributary access. A near vertical hydraulic jump emerges at a lake level of ~3169'. In 2003, 16 redds were counted in tributary 5.

Tributary 6: Tributary 6 has the second highest redd counts (86), 3rd lowest amounts of spawning substrates, and the highest gradient (18%) of all the tributaries. The drawdown zone for this tributary is the 2nd steepest gradient of all the streams, after tributary 2. There is very little incision in the drawdown zone resulting in dispersal of stream flows and shallowing of water depth. This tributary usually is one of the first tributaries to become impassable as water levels recede. However, within the stream itself, a series of steppools with suitable spawning gravels exist. This stream can high redd counts when passage is unhindered.

Individual tributary trends in redd counts

Figure 9 shows variations in redd counts by tributary. With a few exceptions, individual tributary fluctuations tend to reflect total lake fluctuations. From 1999-2001, redd counts declined in all tributaries. All tributary counts declined in 2005. In 2006, redd counts in tributaries 2 , 4a, and 6 increased while the rest of the tributaries either stayed the same or decreased.

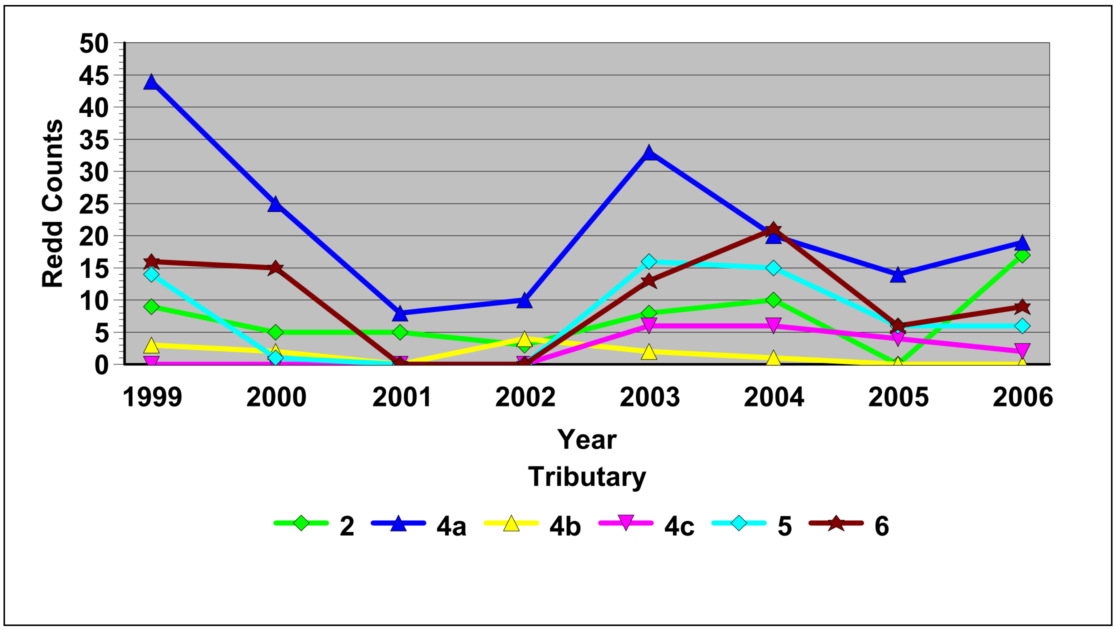

Figure 9. Trends in redd counts by tributary, 1999-2006.

Tributary run timing

Figure 10 shows dates of peak redd counts for 1999-2006. Timing of spawner entry into tributaries is variable and can differ by as much as a month. Date of peak redd counts ranged from late May (2004) to late June (1999, 2000). No run timing data was established for the 2001 season because of a low WSE early in the season which prevented access to the tributaries during the bulk of the spawning season. Run timing is believed to be driven by both lake and tributary water temperatures and tributary access.

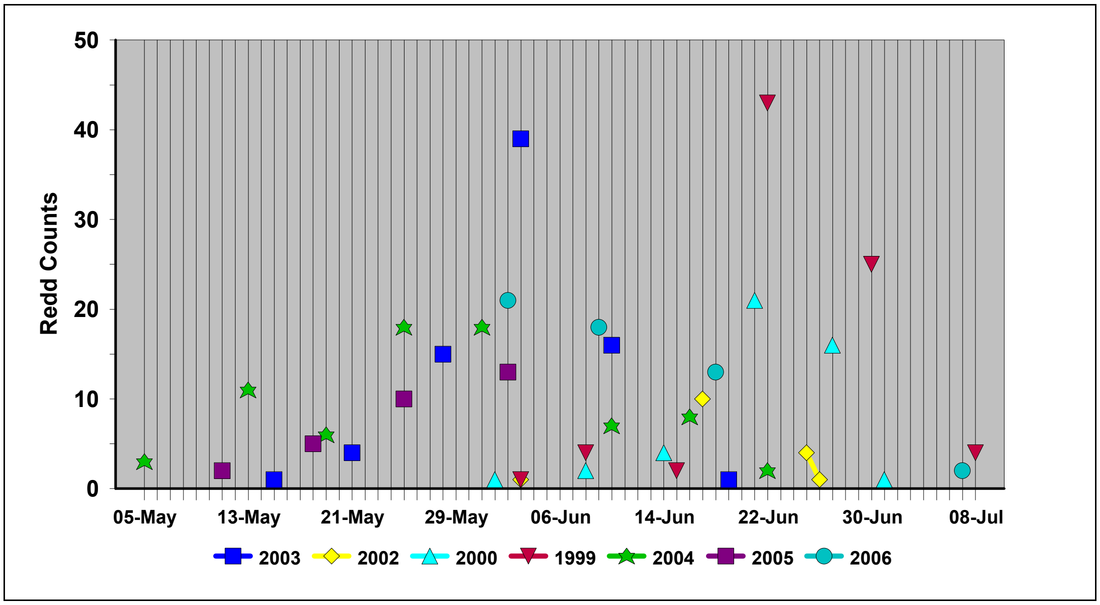

Figure 10. Tributary run timing from peak counts, 1999-2006.

Water temperature and spawning

Figure 11 shows stream temperatures taken during redd count surveys for 1998-2006. No data was available for 2004. Temperatures were taken at the mouth at the beginning of each survey; redd counts are new redds counted since the previous survey.

The majority of redds where counted when stream temperatures were between 5-8 degrees C with highest redd counts occurring around 6 degrees C. Temperatures given are not temperatures during redd construction but at the time of redd count surveys. Surveys were conducted every 3-7 days.

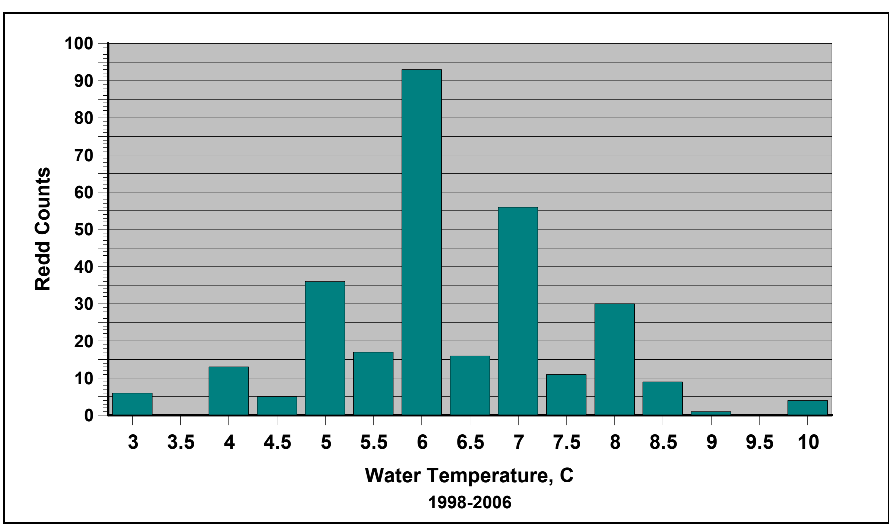

Figure 11. Tributary water temperature and redd counts, 1998-2006.

Broodyear summer rainfall amounts and redd counts at first-return

Figure 12 shows a regression of 1999-2006 annual redd count totals and June-July precipitation during the broodyears. Precipitation amount was the sum of June and July rainfall totals, 4 & 5 years previous to the annual redd counts. Precipitation amounts from 4 and 5 years earlier were used because age-at-maturity for these fish is assumed to be 4 or 5 years. Rainfall amounts were tabulated from the Blazed Alder Snotel site, located approximately 3 miles southwest of the Lake.

A coefficient of correlation (R^2) of 0.643 was produced from the analysis indicating a significant relationship between rainfall amounts during egg incubation/ fry emergence in the broodyear and number of adults returning to spawn 4 & 5 years later (the 2001 redd count was omitted from the analysis because of hindered access to tributaries during that year).

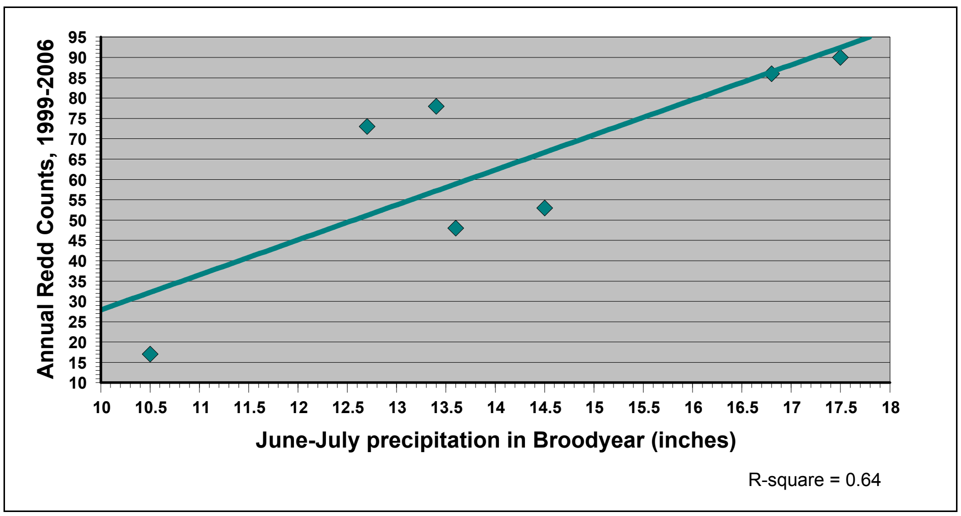

Figure 12 Regression of redd counts from 1999-2006 and June-July precipitation amounts 4 and 5 years earlier (1994-2002). Redd count data from 2001 was not included in regression

Other analyses of rainfall amounts and redd counts were conducted in 2003, 2004, and 2005 (*Table 4*). Incorporating fewer data points, these other analyses showed higher coefficients of correlation between summer rainfall amounts in the broodyear and numbers of redd counts occurring later at first spawning.

*Table 4. All regression analyses conducted to date of annual redd counts and summer precipitation amounts in the broodyear. Precipitation amount incorporating two years of data was the sum of the amounts from June 1-July 31 for each year. The 2003 analysis used one year of precipitation data, from June 1-August 31. *Analysis excludes 2001 redd counts.*

Year of Analysis	Conducted by	Redd Counts Analyzed	Precipitation Years Analyzed	Precipitation Location	Regression result
2003	FS	1999-2003*	4 yrs prev.	Blazed Alder	0.988
2004	Clearwater Assoc.	1998-2004	4 & 5 yrs prev.	Headworks	0.794
2005	FS	1998-2004*	4 & 5 yrs prev.	Blazed Alder	0.682
2006	FS	1998-2006*	4 & 5 yrs prev.	Blazed Alder	0.643

The high correlation coefficient of 0.988 in the 1995-1999 relationship suggests that low summer precipitation amounts in the broodyear can have severe adverse effects on adult returns in later years.

Tributary fry emergence and lakeward migration

Young-of-the-year were observed in large numbers by late July/early August. Most of the fry were seen lower down in the tributaries near the mouth, or in the drawdown zone. No fry were seen in upper stream reaches. Densities of fry increased towards the lake. Surveys of tributaries through summer and fall did not observe young-of-the year within the tributaries, implying that rearing takes place in the lake and not in the tributaries.

Cutthroat trout juvenile (1+) foraging in lake margins during summer, Bull Run Lake .

In 2002, surveyors placed 50 eggs found lying on top of the streambed in tributary 4a into a Tupperware container placed in the stream. Nineteen of the 50 embryos hatched after 5 weeks (July 19-July 25). Total length of alevins averaged about 10 mm.

Each year, surveyors have recorded embryos developing on the surface of the streambed. The embryos were documented in various stages of development: fertilized egg, eyed-stage, alevin, and fry (*Photo 7*). Very little spawning substrate is available in these tributaries with much of it present only as isolated pockets. Lack of spawning habitat may be causing displacement of embryos by the digging and superimposition of redds by other spawning fish.

Photo 7. Alevin and embryos developing on top of streambed in tributary 4a, 2004.

Fecundity

From 2002-2006, surveyors were able to excavate 8 desiccated redds from Tributary 4c. Flow in this tributary regularly goes subsurface by early summer leaving some redds dry. The number of eggs counted in the desiccated redds ranged from 85-353 with an average of 191 egg (*Figure 13*).

A literature review was conducted to establish an estimate of fecundity among adult cutthroat trout. The literature review suggested that fecundity rates increased with size of the female, ranging from 400-1500 eggs. Previous efforts to describe the population of Bull Run Lake have estimated the average (of all age classes) of female fecundity at 700 eggs per female (Wall, 1993).

Whether these egg totals represent total numbers of eggs per female or if multiple redds are dug is not known. However, given the fecundity estimates suggested in other studies, the low numbers of eggs found in these redds may indicate that more than one redd is being constructed in some instances.

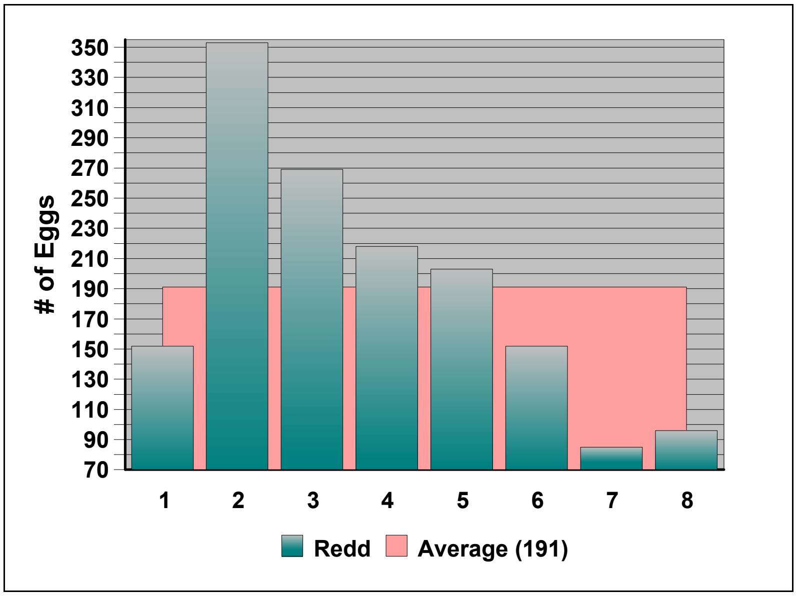

Figure 13. Numbers of eggs counted in 8 desiccated tributary redds (bars) from 2002-2006 and average (191) (background).

Seasonal Habitat Utilization

Figure 14 shows seasonal habitat usage and migration times based on surveys and observations. Periods of lake usage for the fry-to-juvenile and adult life stages are implied from general life history patterns for this species. Age-at-maturity is assumed to be 4-5 years. Actual time spent in spawning migration and spawning may be as little as a few days to one week or more. Incubation time in the tributaries implied from surveys is 6-7 weeks. Fry migration is estimated from observations of fry migrating to the lake after emergence. Once fry enter the lake, the lake is used for rearing, trophic, and refuge habitat until maturity and tributary spawning in the spring. Spawning of fish in the lake shoals has also been observed indicating the use of the lake by some fish for spawning habitat as well.

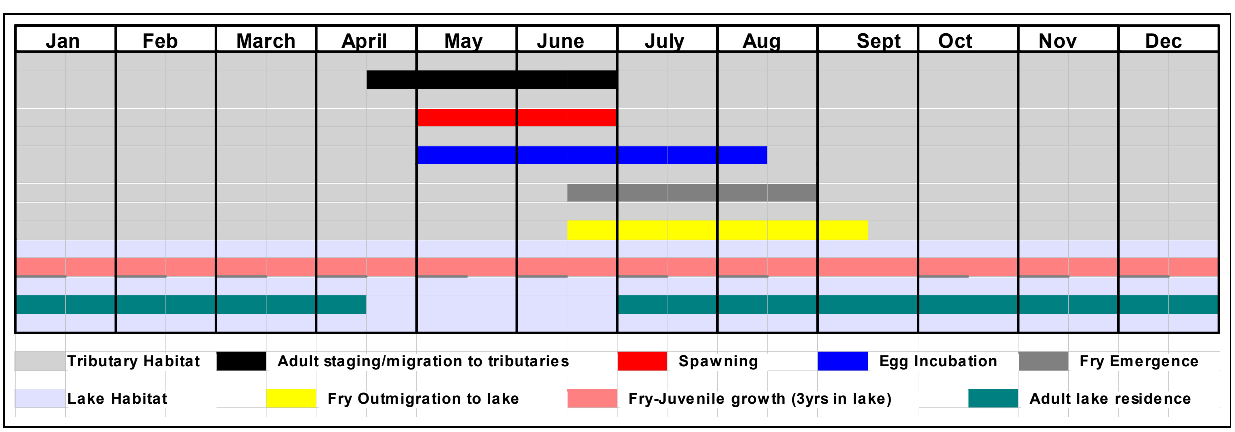

Figure 14. Habitat utilization by month implied from surveys and observations.

DISCUSSION

Fry Emergence

Peak of spawning in the tributaries generally ranges from early to late June. Incubation time implied from surveys is 6-7 weeks and is dependent on water temperatures. By August, fry are emerging and migrating from the tributaries down into the lake. Surveys in the late summer and fall did not observe young-of-the-year residing in the spawning streams indicating that fry do not rear in the tributaries after emergence.

The tributaries appear to all have similar temperature trends and similar timing for height of spawn and fry emergence, except for tributary 6, where in 2003 the height of fry emergence was two weeks later than the other tributaries. The reason for delayed fry emergence in tributary 6 may be related to water temperatures. In 2003, tributary 6 water temperatures remained lower for a longer period of time than was seen in the other tributaries. Late fry emergence could also be related to later arrival of spawners into the stream. Tributary 6 has the one of the steepest gradient at the mouth of any of the tributaries (only tributary 2 is steeper) and has little incision with flows dispersed over a large area, resulting in shallow water depths.

Fry mortality has been observed in spawning streams. During summer, some fry have been seen stranded in pools with no access to the lake. Most often, trapped fry have been seen in tributaries 4b and 4c which are the first tributaries to experience low flows.

A low lake level occurring during fry outmigration will increase the distance fry must travel to reach the lake. This could result in higher mortality due to predation, stress, or stranding, especially if low stream flows and/or high temperatures exist in the drawdown zone.

WSE trends

WSE data for 1998-2006 show that under natural conditions with no water withdrawals, lake water surface elevations may not always reach the "full-pool" elevation of 3178' or even the "full-pool zone" (3174'-3178') every year.

In the absence of water withdrawals, winter droughts preventing refill of the lake appear to be the primary reason for low spring lake elevations. Low lake levels preceding the coming winter, either due to natural conditions, waterwithdrawals, or both, may exacerbate spring low lake levels if a drought occurs during the winter.

The two years with the lowest spring WSE (2001, 2005) were both preceded by droughts the previous winter. In addition, a water withdrawal drawdown of 6' occurred in September 2000, prior to the winter drought of 2000-2001, and contributed to the low 2005 spring WSE that occurred in the spring of 2001. A 2004-2005 winter drought resulted in a spring water level nearly 5 feet below the designated "full-pool zone" but there was no lake drawdown the preceding fall. Available data of WSE from 1970-2006 show that lake levels fluctuate markedly even during periods of no waterwithdrawals due to annual cycles of natural seepage during the dry season and recharge during the winter season. For the period 1970-2006, lake elevations reached the “full pool zone” 59% of the time (21 out of the 36 years) while “full-pool” was reached 25% of the time (9 of the 36 years). Waterwithdrawals occurred in ten of those years with releases occurring every year from 1985-1992. Lake levels returned to “full-pool” in the spring after water withdrawals 30% of the time (3 years out of 10).

Thus, under naturally occurring conditions, lake levels do not always return to the “full-pool zone” elevation. Effects of this trend on the tributary spawning population over the long term is unquantified however the continued existence of this population suggests that annual recruitment in spite of periodic low lake levels has been sufficient to maintain a viable population.

From a management perspective, naturally occurring low WSE’s that could hinder tributary access should be regarded as being a potential possibility every year. Lake levels significantly below the “full-pool zone” may result in a loss of, or reduction in yearclass production in the tributaries if stream flows are not sufficient to allow passage through the drawdown zone.

The ability of a particular yearclass to adapt and survive through environmental constraints may depend on the degree to which other life stages of the yearclass have previously been impacted. Poor passage, incubation or emergent fry stream conditions in the broodyear added with lake-residence mortality in the 1 to 3 year old prespawners age-classes will all affect the numbers of 1st time spawners returning to the tributaries.

Potential effects of water withdrawals on the tributary spawning population would depend on the WSE at time of water withdrawal, the amount withdrawn, and natural lake recharge ensuing after drawdown and before spring spawning.

Consecutive years of hindered tributary access could have adverse effects to multiple yearclasses. Multiple years of low WSE occurring within one generation of fish (4-5 years) could result in threats to the viability of the lake tributary spawning population.

From a fish population viability perspective, the potential for the lake to return to sufficient levels for spawning should be carefully considered before any water withdrawal, especially if it occurs during, or immediately after, a period of low lake levels where tributary access or passage has already been hindered and or shoal areas exposed.

Factors affecting spawning

Due to the absence of development activity (roads, dams, timber harvest, angler harvest, development, etc.) in the lake, tributary habitat quantity and quality is assumed to remain constant Similarly, in the absence of waterwithdrawals, lake conditions of water quality, food resources, and refuge habitat are assumed to be fairly consistent throughout the year. Principle causes of mortality of fry that survive to the juvenile prespawners stage is assumed to be predation by other fish, birds, and mammals.

Environmental variables that could affect spawning success include lake levels and rainfall amounts. Low lake levels or poor instream flows resulting from reduced precipitation or lake drawdown may prevent access to the tributaries. This occurred in 2001 when low lake levels resulted in hindered access. However, the variation in tributary redd counts is not entirely explained by variations in WSE. Regression analysis of WSE and redd counts did not produce a significant correlation. A regression using only years where lake levels exceeded "full-pool" zone with redd counts also did not show any relation. This indicates that other variables are acting on spawners and that trends in redd counts cannot be explained by lake levels alone.

Except in years when WSE is low enough that spawners cannot access the tributaries, results suggest that trends in redd counts may be related to egg-fry survival in the broodyear. Reduced precipitation after spawning can affect survival in the egg-to-fry and stream resident fry-to-juvenile life stages by desiccating redds, stranding emergent fry, or increasing water temperatures. Analysis of instream flow conditions during summer incubation of eggs was found to be related to redd counts 4 and 5 years later. Thus, in years where tributary access is not hindered, summer precipitation may be the limiting factor in annual recruitment. High instream flows during spawning and incubation may also reduce recruitment by washing out redds and eggs.

In years where run timing is later, especially in late June (as occurred in 1999 and 2000), there may be more than one environmental constraint acting on the yearclass. Low lake levels that restrict spawner access and reduced instream flows due to the summer dry season could both result in reducing recruitment for the yearclass.

Other environmental constraints may occur during lake residence that would affect survival in life stages other than spawning and the young-of-the-year stage may be exist. Adverse overwintering conditions resulting in poor overwintering survival or poor summer feeding conditions could both contribute to lowered numbers of adults reaching maturity. As mentioned earlier, effects to the macroinvertebrate population resulting from low lake levels could also affect food availability for fish.

Yearclass trends

Preliminary analysis of the 8-year period of redd counts from 1999-2006 suggest the presence of two generations of fish, with first spawning occurring at age 4. This is implied by evaluation of reddcount strength in the broodyear and relative strength of reddcounts at the first year of spawning for the broodyear, also referred to as "first return".

The redd count trend in the 4 years from 1999-2002 appears to be repeated in the 4 years from 2003-2006 where the first year of each of those periods had the highest redd counts, followed by a decreasing trend in the second and third years, and an increasing trend in the fourth year.

The 1999 and 2000 broodyears, both with relatively strong reddcounts, produced the 2nd and 3rd highest redd counts 4 years later in 2003 and 2004. In 2001, the lowest redd count for the period occurred and 4 years later, in 2005, this broodclass produced the 3rd lowest redd count.

The 2002 brood year was the one yearclass where redd counts did not appear to follow a trend based on 4 years. This yearclass had the second lowest redd counts but produced the 4th highest redd counts 4 years later. Factors such as lake rearing or lake overwintering conditions may be acting on the yearclass, resulting in increased survival in the fry-to-juvenile, or juvenile-to-adult stages.

Broodyear stream incubation conditions

Other studies of coastal cutthroat trout suggest that first spawning in these fish can occur from age 3 to 5 (*NOAA 1999*). Number of adults reaching maturity in a given year may be related to stream conditions during egg incubation and trends in redd counts may be related to variable egg-to-fry survival in the tributaries during the brood year 3 to 5 years earlier.

Available data of summer waterflows over redds show a proportion of redds become de-watered during the post-spawning, incubation period, generally lasting from June through August. Eggs begin to hatch within 6-7 weeks of spawning, depending on temperature (*NOAA 1999*). In 2000, 27% of the redds had portions, or all of the redd dewatered within 7 weeks of redd construction. In 2002, 35% of redds were dewatered within 7 weeks of redd construction, 20% were dewatered in 2003, 10% in 2005, and 26% were dewatered in 2006 (no data available for 2004).

Summer flows in the tributaries of Bull Run Lake are primarily dependent on surface runoff from rainfall. Snowmelt contributes to flows early in the spring but by early summer, the snowpack has melted. Low rainfall amounts during egg incubation of the 1998 brood year may have affected the strength of the 4 year-old, 2002 yearclass. Rainfall total from June to August 31 in 1998 was the lowest for the period 1995-2000.

A correlation between summer rainfall amounts and redd counts was first established in 2003 when 1995-1999 rainfall amounts were regressed against adult redd counts 4 years later. The high coefficient of correlation that resulted also implied that age-at-maturity for these fish is 4 years.

Analyses conducted before 1999 suggested that annual total redd counts in the tributaries were directly correlated with height of WSE during spring spawning. However, analysis of data since that time has shown that fluctuations in WSE do not completely explain fluctuations in redd counts. Low lake levels can result in reduced redd counts through hindering of tributary access but higher WSE's do not automatically mean higher redd counts. Additionally, the specific lake levels in which tributaries become inaccessible are different for each tributary and depend on stream channel conditions present in the drawdown zone at each tributary. Tributary habitat surveys conducted in the drawdown zone in 2005 identified locations of potential barriers.

Additional regression analyses of summer rainfall amounts and redd counts were conducted for the 2004-2006 years. Results of these analyses suggest that age-at-maturity is 4 or 5 years. Although the later analyses did not produce as high a correlation as the 2003 analysis, they still showed a high degree of correlation between broodyear stream conditions and magnitude or redd counts in the first adult return.

The high correlation coefficients suggest that post-spawning tributary conditions may be a limiting factor in annual recruitment. Low numbers of fish spawning in the tributaries, or low lake levels resulting in hindered access, coupled with poor stream conditions during incubation and emergence may result in weak future yearclasses.

Individual tributary trends

Trends in individual tributary redd counts mirror overall total lake redd count trends suggesting that factors affecting annual recruitment are manifested at a lake-wide scale, and affect all tributaries similarly. This would be true for factors such as rainfall amounts, lake overwintering conditions, and lake summer growing conditions.

Factors that may not evenly influence tributary production include low lake levels that disproportionately affect each tributary due to gradients and stream conditions in the drawdown zone. In 2001, only two tributaries had redds due to a low lake level.

Some tributaries exhibit greater utilization by spawners than others. Tributary 4a historically has the highest redd counts of all the tributaries and thus if access to this tributary was hindered, a significant reduction in total lake production would result. Longitudinal profiles of the tributaries conducted in 2005 showed differences in stream habitat conditions and presence of barriers in the drawdown zone at different lake levels.

Shallow water, lack of stream channel incision, and exposed barriers in the drawdown zone are believed to be the primary causes of fish being unable to reach the spawning tributaries. Throughout the 2001 spawning season, fish were seen staging at the mouths of the tributaries. At low lake levels, the water depths in the drawdown zone of tributaries 2, 4a, 4c, and 6 are shallow with no channel incision and/or steep gradients, providing few resting pools and adequate depth for fish passage.

In 2001, conditions in the drawdown zone of tributaries 4b and 5 appeared to be of sufficient incision, water depth, and gradient with adequate sized substrates to be suitable for spawning. However, no redds were observed in these drawdown zones. Spawners may prefer to use the upland forested reaches of the tributaries. Deeper pools and more abundant cover habitat are present in these forested stream reaches.

Population size and trend

With the presence of both shoal and tributary spawning occurring in the lake, estimates of annual recruitment or adult abundance in the lake population needs to include both tributary counts and shoal counts. In 2006, surveys conducted in the shoals counted 58 redds in the shoal areas of the lake (*Bull Run Lake Shoal Report 2006*). When added to the 2006 tributary redd count total of 53 redds, a total of 111 redds is totaled for the lake in 2006. Assuming that fish only spawn once, the number of spawners implied from this redd count total would be 222.

A length frequency distribution derived from hydroacoustic surveys conducted in the lake by the Portland Water Bureau in 1992, 1994, 1995, and 2006 show the presence of an age-class of fish in the 40-129mm range (*PWB 2006*). Since 0+ fish are not detected in these surveys, it is implied that this first age-class seen in the distribution would represent the age 1+ fish.

The 2006 hydroacoustic survey estimated 2,185 fish (+/- 1,141, 95% CI)(*PWB 2006*). The proportion of fish detected of lengths 40-129mm from all hydroacoustic surveys conducted was approximately 0.56 (56%), implying that approximately 1224 of the 2,185 fish estimated in the

2006 survey were in the 40-129 mm length class (1+ fish) and 961 fish were larger than the 40-129 mm length class (age 2+ and older).

A fisheries model to estimate population response to lake level management assumed that only 4-6 year old fish would spawn, that they would spawn annually, and that these age classes would make up 54% of the population ages of 2-6+ (USFS 1995a). Using the 2006 hydroacoustic estimate of 961 fish of age 2-6+ and the model assumption that 54% of these are spawners aged 4-6+ results in a calculation of 519 spawners in 2006.

This 2006 modeled estimate of 519 spawners is ~57% higher than the 222 spawners implied from the 58 shoal redds plus 53 tributary redds counted in 2006. Similarly, if fish spawn only once and the proportion of males to females is 50%, then 519 spawners would imply a total of ~259 redds. The 111 redds seen in 2006 represents only 43% of the redds predicted by modeling.

It is difficult to explain the difference in adult abundance predicted through modeling and the spawner and redd count data observed. Given the difficulty of positively identifying every redd constructed with the infrequency of spawner surveys, it is possible that spawner and redd counts are being undercounted. In addition, fish may not spawn every year. If this is the case, it would help explain the difference in adults implied from redd counts and adult estimates derived from hydroacoustic surveys and modeling.

Given the relatively high adult abundance estimates implied from modeling and the relatively low numbers supported by historic spawner and redd counts seen (especially in recent years), it is difficult to predict with any degree of confidence current population size, status, and trend from the existing data collected so far.

A census of spawners returning to the tributaries would help verify redd count surveys in the tributaries, and together with adult counts in the shoals, would provide better estimates of lake adult abundance. A more reliable estimate of adult abundance in the lake is needed to make effective management decisions regarding population persistence in light of waterwithdrawal activities.

Historical periods of low lake levels

Based on records of historical lake levels, the longest periods when lake levels remained below the "full-pool zone" of 3174' were the 38 years from 1920-1958 and the 7 year period from 1970-1977 (*USFS 1995b*). More recently, periods of low lake levels occurred during 1992-1994, 1987-1988, and 2005.

Low lake levels may also affect the macroinvertebrate population which the fish prey on. Macroinvertebrates provide the major food source to the cutthroat trout population (*Liknes 1988 and Wisseman 1992*). Exposure of the rocky littoral zone from water withdrawal may have short-term catastrophic impacts on many of the invertebrate taxa present in the lake littoral including higher predation rates by fish as invertebrates are forced out onto finer grain substrates found in deeper parts of the lake, loss of hard surfaces for perches or for scraping (feeding), and loss of egg laying sites for some taxa (*Wisseman 2000*). Drawdowns may also affect lake shoal spawning by exposing substrates. Eggs and fry may be isolated during drawdowns and allochthonous leaf-litter inputs may change if vegetation growth is altered. Survival of age-0 fish may also be reduced because of reduced cover along the lake margin.

Given the historic periods of low lake levels before 1970, and during 1970-77, the continued presence of a tributary spawning population today may indicate that the fish population is adapted to lake levels below 3174' and that it is capable of withstanding periods of lower lake levels. The presence of a fish population today may also indicate that the aquatic biotic community that the fish population coexists with and depends on has also adapted to periods of low lake levels.

Spawning in the shoals may be one of these adaptations to periods when low lake levels hinder tributary access. However, consecutive years of low lake elevations that both prevent tributary access and expose shoal spawning beds could have adverse effects on lake annual recruitment.

During spawning seasons when tributary access is hindered, it is possible that ripe spawners may choose to spawn in the shoals. Although there have been no surveys to document that this occurs, it is clear that shoal spawning is an adaptation of fish in this lake and that, under naturally occurring conditions, lake WSE may not always reach elevations to allow unhindered tributary access.

The biological relationship between tributary and shoal spawners is not clear. It is possible that the lake shoal spawners and tributary spawners represent two divergent life histories with mutually exclusive spawning times and habitats. Limited spawning habitat within the tributaries may be creating a need for spawning elsewhere.

During spring, water in the lake becomes warmer earlier than water in the tributaries. Data suggest that the difference in spawn timing within the lake and the tributaries is water temperature related. Shoal fry emerge earlier and have a longer growing season than fry in the tributaries. Whether this earlier emergence makes them more fit (better condition) than the tributary fry is unknown.

It is still unclear whether the fish population is in decline, increasing, or stable. Low numbers of redds have been counted in recent years and should be cause for concern. Once-per-week spawner counts have not provided reliable information on population size. Annual total spawner counts have ranged from a high of 157 in 1999 to a low of 11 in 2001. Historical one-day spawner counts from 1957-2006 have been also been variable, ranging from 9-336. Redd counts of 13 and 17 in 2001 and 2002 would suggest a much smaller spawning population than hydroacoustic estimates or the past one-day high spawner counts would indicate.

As stated earlier, validation of redd counts through daily spawner counts would give a better index of adult abundance. Resource managers would then be better able to assess magnitude of effects to the fish population due to water withdrawals and naturally-occurring low lake levels.

Until more reliable estimates of lake adult abundance can be determined, the population should be managed conservatively. Adverse effects to the fish population and the aquatic biota they depend on should be avoided.

Drawdowns, if they occur, should take place as late in the season as possible to avoid impacts to emergent fry and should be of the smallest amount possible. Consecutive years of low lake levels should be avoided to reduce potential impacts to multiple yearclasses.

CONCLUSIONS

Given the historic natural periods of spring-low lake levels below the “full-pool zone”, and the associated naturally occurring periods of hindered tributary access, the continued presence of a tributary spawning population today may indicate that the fish population is adapted to lake levels below 3174’ and that it is capable of withstanding periods of low WSE.

Low lake levels, either as a result of natural conditions, or due to water withdrawals, may not result in catastrophic impacts to the lake population. However given that population status and trend is still largely unknown, and that surveys have shown both a wide range of spawner counts and extremely low redd counts in recent years, conservative management of the population is warranted.

Lake level management should take into consideration potential impacts to the population from past and future water withdrawals if they occur during or after periods of naturally-occurring low lake levels. Multiple spawning impacts to a yearclass should be avoided. For example, poor tributary access conditions that occurred during the broodyear of a yearclass should be avoided for the adults of that yearclass returning for first-time spawning.

Similarly, lake level management should also take into consideration the incubation and fry outmigration life stages. If weak recruitment in the broodyear occurred as a result of poor summer flows, measures should be taken to avoid impacts to the spawning cohort during the first return of adults from the weak yearclass.

Multiple yearclasses affected by low levels and/or poor summer flows may result in threats to the population viability of tributary spawners, especially in years with low redd counts. As yearclasses fail to recruit, and as the existing tributary adults die off, there will be no replacement of the tributary spawning population. Tributary redd counts need to be verified to assess actual numbers of spawners in tributary population: better estimates of numbers of adults in the spawning population is crucial for determining population status and trend.

Poor tributary access coupled with poor summer flows may result in cumulative impacts to a yearclass. Low lake levels that both hinder tributary access and expose shoal spawning areas may result in no lake recruitment for that year.

Current data does not show a relationship between height of lake level and magnitude of redd counts.

Data suggests that age-at-maturity for this population is between 4 and 5 years. Regression analysis shows a significant correlation between rainfall amounts in the broodyear and number of adults returning to spawn 4 & 5 years later.

Tributary 4a is the highest producing tributary and should be considered the most important tributary for maintaining access and passage for spawners and fry. Tributaries 5 and 6 are also significant spawning streams.

Limiting Factors

- Low lake levels resulting in hinder access to spawning tributaries
- Low lake levels resulting in exposure of shoal spawning areas
- Low lake levels resulting in exposure of macroinvertebrate habitat
- Low summer flows during egg incubation.
- Low summer flows during fry outmigration.
- Low availability of spawning gravels.

Key Habitats/Processes

- Spawning in the tributaries
- Spawning in the shoals
- Streamflow in tributary spawning areas
- Lake/stream passage for spawners and young-of-the-year (fry)

Factors Affecting Annual Recruitment

- Impacts to fish macroinvertebrate-food resources resulting from exposure of macroinvertebrate habitats in lake margins
- Increased lakeward fry-migration distance
- Increased spawner-migration distance from lake to tributaries
- Low lake-level/low stream flow passage barriers for spawners and young-of-the-year *(fry)*
- Low lake-levels that expose shoal spawning areas

- Multiple and/or consecutive years of impacts to spawning, emergence, or fry outmigration life stages
- Multiple impacts to individual cohorts
- Drawdowns of lake that occur beyond the magnitude, frequency, and duration of naturally occurring fluctuation levels
- Drawdowns occurring before, or during fry migration to lake
- Exposure of fish habitat in lake margins

Critical Information gaps

- Adult abundance in lake and in tributaries
- Survival of fry during lake rearing
- Juvenile-adult survival in lake
- Validation of tributary redd count indices with adult spawner counts
- Total annual lake production estimate incorporating annual production estimates from shoal spawning and tributary spawning

Potential Mitigation Opportunities

- Decrease potential predation of spawners transiting through the exposed drawdown zone at low lake levels through use of net enclosures or other methods
- Consider use of spawning gravel enhancement in lake drawdown zones to encourage shoal spawning during low lake levels, primarily when low lake levels expose traditional shoal areas
- Decrease potential predation of fry during lakeward migration during low lake levels through use of net enclosures or other methods
- Where opportunities exist, improve tributary fish passage conditions in the drawdown zone during low lake levels and in the streamchannel during low flow conditions

- Where opportunities exist, improve egg-to-fry survival in streams during summer low-flows through use of instream egg-box incubators, channel modification to redirect or augment flow to ensure sufficient inundation of redds, or other methods

- Where opportunities exist, improve streamflows/passage conditions during fry lakeward migration

- Monitor stream conditions after spawning to assess impacts to individual yearclasses/cohorts and incorporate results into lake level management plans and/or conservation measures.
- Decrease disturbance of redds on boat ramp from trailering and boat launching and discourage fish from spawning in the boat ramp.

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APPENDICES

APPENDIX TABLE 1: Tributary spawning survey data: dates of surveys, water surface elevations (WSE), spawner counts, redd counts, 1999-2006.

2006

Date	WSE	TRIB 2 Sp Rd	TRIB 4a Sp Rd	TRIB 4b Sp Rd	TRIB 4c Sp Rd	TRIB 5 Sp Rd	TRIB 6 Sp Rd
6/2	3175.06	Good 26 1	Good 8 16	No Survey	Good 4 0	Good 4 0	Good 20 3
6/9	3175.06	Good 10 15	No Survey	Good 0 0	Good 0 1	Good 2 2	No Survey
6/15	3174.94	Good 0 0	Good 0 0	Good 0 0	Good 1 0	Good 0 0	No Survey
6/21	3174.62	Good 0 0	Good 0 2	Good 0 0	Good 0 1	Good 0 4	Diffclt 1 6
6/30	3173.76	Diffclt 0 0	Diffclt 0 0	NP 0 0	No Survey	Diffclt 0 0	Diffclt 0 0
7/7	3172.99	Diffclt 0 1	Diffclt 0 1	NP 0 0	No Water	Diffclt 0 0	Diffclt 0 0
7/13	3172.38	Diffclt 0 0	NP 0 0	NP 0 0	No Survey	Diffclt 0 0	NP 0 0
7/18	3171.82	Diffclt 0 0	NP 0 0	No Survey	No Survey	Diffclt 0 0	NP 0 0
7/25	3171.04	NP 0 0	NP 0 0	NP 0 0	No Survey	NP 0 0	NP 0 0
Total		**36 17**	**8 19**	**0 0**	**5 2**	**6 6**	**21 9**

2005

Date	WSE	TRIB 2 Sp Rd	TRIB 4a Sp Rd	TRIB 4b Sp Rd	TRIB 4c Sp Rd	TRIB 5 Sp Rd	TRIB 6 Sp Rd
5/11	3168.96	NP 0 0	Good 4 0	Good 0 0	Good 4 2	Good 26 0	Good 1 0
5/18	3169.25	Good 0 0	Good 0 4	Good 0 0	Good 0 1	Good 17 0	Good 2 0
5/25	3169.25	Diffclt 1 0	Diffclt 1 6	Diffclt 0 0	Diffclt 0 0	Diffclt 3 2	Diffclt 3 2
6/2	3169.03	Diffclt 0 0	Diffclt 4 4	Diffclt 0 0	Diffclt 0 1	Diffclt 0 4	Diffclt 0 4
6/8	3168.83	Diffclt 0 0	Diffclt 0 0	Diffclt 0 0	Diffclt 0 0	Diffclt 0 0	Diffclt 0 0
6/15	3168.54	No survey	No survey	No survey	No survey	No survey	No survey
6/22	3168.37	No survey	Diffclt 0 0	Diffclt 0 0	NP 0 0	Diffclt 0 0	NP 0 0
6/29	3167.93	NP 0 0	Diffclt 0 0	NP 0 0	NP 0 0	Diffclt 0 0	NP 0 0
Total		**1 0**	**9 14**	**0 0**	**4 4**	**46 6**	**6 6**

2004

Date	WSE	TRIB 2 Sp Rd	TRIB 4a Sp Rd	TRIB 4b Sp Rd	TRIB 4c Sp Rd	TRIB 5 Sp Rd	TRIB 6 Sp Rd
5/5	3,171.89	Good 0 0	Good 2 3	Diffclt 0 0	Good 0 0	Good 0 0	No survey
5/13	3,172.07	Good 3 0	Good 0 3	Good 1 0	Good 0 1	Good 2 3	Good 21 4
5/19	3,172.02	Good 1 0	Good 4 3	Diffclt 0 0	Good 0 1	Good 4 1	Good 30 1
5/25	3,172.49	Good 0 1	Good 5 1	Diffclt 0 1	Good 0 4	Good 4 3	Good 25 8
5/31	3,173.78	Good 5 6	Good 0 3	Good 0 0	Good 0 0	Good 1 2	Good 18 7
6/10	3,174.22	Good 0 2	Good 0 4	Good 0 0	Good 0 0	Good 0 0	Good 1 1
6/16	3174.32	Good 0 1	Good 0 3	Good 0 0	Good 0 0	Good 0 4	Good 0 0
6/22	3,173.9	Good 0 0	Good 0 0	Good 0 0	Good 0 0	Good 0 2	Good 0 0
6/30	3173.15	NP 0 0	Diffclt 0 0	NP 0 0	NP 0 0	Good 0 0	Poor 0 0
7/13	3171.79	NP 0 0	Diffclt 0 0	NP 0 0	NP 0 0	Good 0 0	Poor 0 0
Total		**9 10**	**11 20**	**1 1**	**0 6**	**11 15**	**95 21**

2003

Date	WSE	TRIB 2 Sp Rd	TRIB 4a Sp Rd	TRIB 4b Sp Rd	TRIB 4c Sp Rd	TRIB 5 Sp Rd	TRIB 6 Sp Rd
5/21/03	3,175.49	Good 0 0	Good 0 3	Good 0 0	Good 0 1	Good 0 0	Good 0 1
5/27-29	3,175.64	Good 0 1	Good 2 4	Good 1 1	Good 1 0	Good 2 5	Good 0 4
6/2-3	3,175.56	Diffclt 0 5	Good 11 18	Good 0 1	Good 2 4	Good 12 7	Good 25 4
6/10/03	3,174.97	NP 0 1	Good 0 7	Good 0 0	Good 2 1	Good 2 3	Good 1 4
6/19/03	3,174.1	NP 0 1	Good 0 1	NP 0 0	NP 1(m)0	Good 0 1	Good 0 0
6/25-27	3,173.48	NP 0 0	Diffclt 0 0	NP 0 0	NP 0 0	Good 0 0	Good 0 0
7/2/03	3,172.87	NP 0 0	Diffclt 0 0	No survey	NP 0 0	Good 0 0	Good 0 0
Total		**0 8**	**13 33**	**1 2**	**6 6**	**16 16**	**26 13**

2002

Date	WSE	TRIB 2 Sp Rd	TRIB 4a Sp Rd	TRIB 4b Sp Rd	TRIB 4c Sp Rd	TRIB 5 Sp Rd	TRIB 6 Sp Rd
6/3	3,174.3	Good 0 1					
6/17-19	3,175.78	Diffclt 5 2	Good 3 8	Good 0 0	Good 0 0	Good 0 0	Good 0 0
6/25	3,176.29	Good 1 0	Good 3 1	Good 0 4	Good 1 0	Good 0 0	Good 4 0
6/2	3,176.57	Good 0 0	Good 0 1	Good 0 0	Good 0 0	Good 0 0	Good 0 0
7/9	3,176.09	Good 0 0	Good 0 0	Diffclt 0 0	Good 0 0	Good 0 0	Good 0 0
7/16	3,175.25	NP 0 0	Diffclt 0 0	Diffclt 0 0	NP 0 0	Good 0 0	Diffclt 0 0
Total		**6 3**	**6 10**	**0 4**	**1 0**	**0 0**	**4 0**

A2

2001

Date	WSE	TRIB 2 Sp Rd	TRIB 4a Sp Rd	TRIB 4b Sp Rd	TRIB 4c Sp Rd	TRIB 5 Sp Rd	TRIB 6 Sp Rd
May 7	3,165.6	Diffclt 0 0	Diffclt 0 0	Diffclt 0 0	Good 0 0	Good 0 0	NP 0 0
May 14	3,166.88	NP 0 1	NP 0 0	NP 0 0	Good 0 0	Good 0 0	NP 0 0
May 17	3,167.07	NP 0 0	No survey	NP 0 0	No survey	Good 0 0	
May 22	3,167.16	NP 0 2	Diffclt 9 2	NP 0 0	Good 1 0	Good 0 0	NP 0 0
May 29	3,166.96	Diffclt 0 0	No survey	NP 0 0	No survey	No survey	No survey
Jun 5	3,167.09	Diffclt 0 1	Diffclt 0 4	NP 0 0	Good 1 0	Good 0 0	NP 0 0
Jun 12	3,167.18	Diffclt 0 1	Diffclt 0 1	NP 0 0	Good 0 0	Good 0 0	NP 0 0
Jun 21	3,166.65	NP 0 0	Good 0 1	NP 0 0	NP 0 0	Diffclt 0 0	NP 0 0
Jun 27	3,166.54	NP 0 0	Poor 0 0	Diffclt 0 0	Diffclt 0 0	Good 0 0	NP 0 0
Jul 2	3,167.08	NP 0 0	Diffclt 0 0	NP 0 0	NP 0 0	Diffclt 0 0	NP 0 0
Total		**0 5**	**9 8**	**0 0**	**2 0**	**0 0**	**0 0**

2000

Date	WSE	TRIB 2 Sp Rd	TRIB 4a Sp Rd	TRIB 4b Sp Rd	TRIB 4c Sp Rd	TRIB 5 Sp Rd	TRIB 6 Sp Rd
May 24	3,180.31	good 0 0	good 0 0	good 0 0	good 0 0	good 1 0	good 3 0
June 1	3,180.41	good 0 0	good 2 2	good 0 0	good 1 0	good 0 0	good 7 1
June 8	3,180.27	good 1 1	good 4 1	good 1 0	good 1 0	good 3 0	good 6 0
June 14	3,180.66	good 2 0	good 5 3	good 0 0	good 1 0	good 0 1	good 0 0
June 21	3,180.19	good 1 0	good 0 9	good 0 1	good 0 0	good 3 0	good 0 11
June 27	3,179.55	good 0 4	good 0 8	good 0 1	good 0 0	good 0 0	good 0 3
July 6	3,178.57	good 0 0	good 0 1	good 0 0	good 0 0	good 0 0	good 0 0
July 12	3,177.88	good 0 0	good 0 0	good 0 0	good 0 0	good 0 0	good 0 0
July 21	3,176.8	poor 0 0	poor 0 1	poor 0 0	poor 0 0	poor 0 0	poor 0 0
Aug 1	NA	NA	NA	NA	NA	NA	NA
Aug 8	NA	NA	NA	NA	NA	NA	NA
Total		**4 5**	**11 25**	**1 2**	**3 0**	**7 1**	**16 15**

1999

Date	**WSE**	**TRIB 2 Sp Rd**	**TRIB 4a Sp Rd**	**TRIB 4b Sp Rd**	**TRIB 4c Sp Rd**	**TRIB 5 Sp Rd**	**TRIB 6 Sp Rd**
5/26/99	3,179.85	good 4 0	good 0 0	good 0 0	no survey	no survey	no survey
6/3/99	3,180.44	good 0 0	good 3 0	good 0 0	good 4 0	good 2 1	good 2 0
6/8/99	3,180.51	good 0 0	good 0 3	good 0 0	good 1 0	good 0 0	good 2 1
6/15/99	3,180.56	good 8 2	good 2 3	good 2 0	good 0 0	good 26 0	good 35 0
6/22/99	3,180.39	good 0 5	good 40 23	good 1 0	good 1 0	good 2 8	good 5 11
6/30/99	3,180.32	good 0 2	good 12 14	good 0 3	good 3 0	good 0 3	good 1 3
7/8/99	3,180.06	good 0 0	good 1 1	good 0 0	good 0 0	good 0 2	good 0 1
Total		**12 9**	**58 44**	**3 3**	**9 0**	**30 14**	**45 16**

NP: no passage
Diffclt: with difficulty
M: Mort