

Adult Steelhead Trout and Salmonid Smolt Migration at the Keogh River, B.C. during Spring 2002.

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ABSTRACT

Adult steelhead migration into the Keogh river in 2002 totaled 115 wild fish and 13 hatchery strays, based on mark-recapture results, or 131 fish in total based on electronic counter and trapping results. This was lower than the run size in 2000 and 2001, and remains very low compared to historic records. This level is below that required for seeding of available habitat, at about 3 females per river kilometer (>250 fish). Steelhead smolt production declined marginally in 2002 to 1,892 fish; nonetheless, this was the fourth highest yield since 1993, but much lower than the average yield of 4,948 smolts (1977 to 2001) from this watershed. Coho smolt yield remained stable for the third consecutive year, at 60,213, or 96% of the historic mean (62,527; 1977 to 1999). Mean steelhead smolt length was slightly lower than in 2001, by 4%, and steelhead smolt length-at-age was also reduced slightly compared to 2001, by 2% for age 2 smolts, and 4% for age 3 smolts. These changes may be due to changes in the quantities of marine-derived nutrients from pink salmon carcasses, the amount of which varies annually, and particularly due to restoration treatments and nutrient addition over the entire watershed. One-year-old steelhead smolts were less abundant than in 2001 (4% of the total compared with 10%), two-yr smolts comprised >83% of the run, and the number of 3-year-old smolts decreased to 13%. The latter was a very significant decrease from age 3 abundance in pre-treatment years. Coho smolt length (all ages) and weight decreased marginally over 2001, on average, with values similar to those observed in 2000. Forty-four percent of coho smolts were coded-wire tagged to assess the by-catch of wild salmon during commercial and sports fishing openings, in subsequent and related studies. Dolly Varden adult and smolt enumeration also indicated that the population was stabilizing; >500 adults and 1,000 smolts were enumerated, a significant improvement over recent low numbers (1990's). There were no over-topping flood events in 2002. Numerous fence repairs, including horizontal screen replacement, beam replacement, main fence panel repairs, a bulkhead replacement, and riprap repairs were undertaken as part of 2002 contracts.

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1.0 Introduction

This is a data report on the 28th year of fisheries research and operation of the adult steelhead and salmonid smolt enumeration facilities at the Keogh River, B.C., on northern Vancouver Island. The primary objective of this study was to document this year's migration of adult steelhead for smolt-to-adult survival and monitoring of stock status. Also to enumerate and sample juvenile steelhead (*Oncorhynchus mykiss*), juvenile coho salmon (*O. kisutch*), and other migrant fish for subsequent comparison to the Waukwaas River's smolt migration, thus obtaining comparative data before, during, and after habitat rehabilitation work in the Keogh watershed. This data series has been important to the management and understanding of British Columbia's steelhead populations (Lill 2002; Johnston et al. 2002; Smith and Ward 2000). It provides an indication of stock status and recruitment (Ward 1996, 2000), serves to monitor the effects of environmental change (Tydemers and Ward 2001; Welch et al. 2000), and provides basic data on possible functional relationships in steelhead life history (e.g., Ward and Slaney; 1988, 1993a; Ward et al. 1989).

The Keogh River has been a key site for continuous studies of salmonid populations in British Columbia since 1975 (Irvine and Ward 1989, Ward and Slaney 1988, 1993b, Ward and Wightman 1989, Ward and McCubbing 1998, Ward 2000a, Ward et al. 2002, 2003), which has resulted in >100 scientific and technical papers, and is of key importance in ocean survival studies on steelhead trout and, more recently, coho salmon. Furthermore, the Waukwaas and Keogh watersheds have been chosen as a paired watershed study for Watershed Restoration Program (WRP) assessment of the effects of in-river restoration techniques on freshwater salmonid production and growth (McCubbing and Ward 1997, 1998, 2000a, b & c, 2001, 2002; Ward et al. 2002, 2003). The Waukwaas River was chosen as an environmental reference watershed in this study, i.e., no rehabilitation to habitat but subjected to environmental perturbations – results of those smolt investigations are published elsewhere (McCubbing 2002b in prep.). In addition, the Keogh River has been chosen as a site for electronic enumeration of migrating adult salmonids in B.C. coastal streams (McCubbing et al. 1999). Recently, the Keogh site is the experimental river for hatchery conservation research, and the living gene bank project (Ward 2000b). Keogh data has been instrumental in the determination of limit reference points for steelhead management (Johnston et al. 2002). The site, along with the Waukwaas River, is also part of international studies on the coastal migration pathways of salmonids and the Census of Marine Life, through the acoustic tagging of steelhead smolts, which began in 2001 and continued with “proof of concept” studies in 2002, via monitoring of arrays of acoustic receivers placed in coastal waters (Welch et al. 2002 a,b,c&d). Thus, the

biological data reported here serves many functions in fisheries research, and the value of the database grows annually.

2.0 Methods

2.1 Spring Trap Operations

The Keogh River and the site of the fish enumeration fence near the mouth (Fig. 1) were described elsewhere (Mottram 1977, Ward and Slaney 1988, Irvine and Ward 1989). Operations were as described in Ward et al. (1990) and Ward and McCubbing (1998). In 2002, fence installation began on April 1, following counting of steelhead by electronic methods, which continued throughout the run timing (see McCubbing et al. 1999). The upstream adult trap was fishing from April 4. The downstream smolt trap installation was completed on April 7th as was the downstream kelt trap. Inspections of the fence were made with a mask and snorkel weekly, particularly after a flood event, and potential escape routes were repaired if detected. The fence was inspected visually every day. No areas were found where fish might pass the fence unaccounted. After removal of the fence in June, all panels were inspected for damage, and repairs where required were instigated.

2.2 Biophysical Monitoring

Temperature was logged daily with a hand held thermometer to the nearest 0.5°C between 08:00 and 09:00 hrs. River depth was recorded at the “Pumphouse” gauging station, 1 km upstream, although assessment of river discharge from these data require production of a calibration curve from MWLAP, Water Resources staff. Environmental data (rainfall) for the Port Hardy airport was obtained from Environment Canada.

2.3 Adult Steelhead Population Estimates

2.3.1 Logie Resistivity Counter

In 2002, as from 1998 to 2001, the fence was not operated from December through March for partial enumeration and sampling of upstream migrants, as it was pre-1998. Instead, electronic counting was undertaken using the Logie 2100C resistivity fish counter, as described in McCubbing et al. (1999). Briefly, fish passing through the counter channels during this time were enumerated and sized, although some fish may have by-passed the channels under high spring tides (at least one incidence per month) and/or during flood conditions with a gauge reading of over 1.2m at the “Pumphouse” station. Such flood events on the Keogh River are varied and unpredictable year-to-year, but can account for several days during the migration period Dec 1st to April 30th. Total daily count upstream was considered as the number of fish passing in an upstream direction minus the number of fish passing in a downstream

direction from December 1st to March 1st. Downstream counts observed after March 1st were assessed to be early run fish, which, having spawned, were returning to the ocean as kelts. Thus, daily counts from March 1st to April 5th (when the fence was installed) were reported as the sum of daily upstream counts only.

2.3.2 Mark Recapture Estimates

Adult steelhead were marked by field staff who also supervised local anglers (volunteers) who in turn had marked fish on the Keogh in previous years, according to prescribed methods. Each fish was marked with a bus punch in the right operculum (Ward and Slaney 1988, 1990), sexed externally, measured for fork length and a scale sample was taken. Body colour ("brightness") was recorded as a relative number from 1 (low colouration) to 4 (high colouration). Ripeness was also assessed on a relative scale 1 (not ready to spawn) to 4 (ready to spawn) and 5 (spawned kelt). The general condition of each fish was also noted, including scars and wounds (data on file), as was the date and time of capture, location of capture, and angling conditions (excel file KeoghSHA2002). In addition, a redesigned upstream trap adjacent to a counter channel captured 18 fish, which were sampled and added to the counter total. In addition to the electronic counts, angling results provided a comparison of run size based on mark-recapture and that derived from a previous relationship established from catch/effort data and Keogh run sizes (Smith and Ward 2000).

Kelts were captured at the fence in a downstream trap and by seine netting the pool above the fence on a weekly basis, or when fish were observed holding upstream of the fence. Fish gender was assessed by external features and checked for an adipose fin clip, which indicated their origin (hatchery or wild). Fork lengths were measured (mm) and scale samples were removed by standard procedure for later analysis of age. As described in previous reports (e.g., Ward and Slaney 1988, 1990), the total numbers of adult males and females were estimated separately by mark and recapture using the adjusted Petersen estimate (Ricker 1975) by marking upstream migrant adults and capturing kelts during their downstream migration. Kelts, captured as they emigrated, were examined for bus punch marks on the operculum.

2.4 Adult Steelhead Aging and Marine Survival Estimates

Adult steelhead scales from upstream migrants and spawned kelts were analyzed for ages in marine and freshwater life stages using standard methods. The resulting age-class structure was tabulated as ocean one, two and three year maiden spawners and repeat spawners, as in Ward and Slaney (1988). The percent composition by age was then used to estimate the numbers of each age class in the 2002 adult population for both male and female wild adults. The number of returns were tabulated into year of smolt

yield to provide an estimate of the number of surviving adults from each smolt year class, or “marine survival”. As smolts may spend up to three years in the ocean prior to return as maiden spawners, marine survival estimates for smolt year classes were complete after 2002 returns up to and including the 1999 smolt year class, with ocean-age 2 returns available from the 2000 smolt year class.

2.5 Biosampling of Smolts

Fish captured in the smolt trap were processed daily, after the sampling of adults and kelts. A single 1,500-l. tank supplied with fresh water and a submersible pump was used to hold downstream migrants. All fish were counted and a fraction (15% to 20% per day) of each species was randomly sampled for lengths daily, with the exception of coho smolts. Coho smolts were randomly sampled at a rate of 25 fish/day or the whole days catch, whichever was the least. Scale samples were taken from above the lateral line and behind the dorsal fin on coho and steelhead smolts in a sampling regime that was stratified according to fish size and migration time (Ward et al. 1989). Fork lengths (mm) were measured on all fish in the sub-sample. Weight (g) was recorded for a sub sample of fish once per week using an Acculab v400 electronic scale, by taring a bowl of water in which the fish were placed. Fish were anaesthetized with a dilute solution (1ml per liter) of clove oil, dissolved 1:10 in ethanol, during sampling for length and weights only. A mean condition factor for steelhead and coho smolts from each of the seven years of paired watershed study was calculated by the methods described by Ricker (1975).

2.6 Smolt Migration - additional monitoring

2.6.1 CWT Coho Smolt Tagging

Approximately 40% of coho smolts (>70mm in fork length) were coded-wire-tagged, under a separate Fisheries and Oceans Canada (FOC) project. Fish were anaesthetized in a dilute solution of clove oil dissolved in ethanol. The adipose fin was removed with a sharp pair of scissors and a coded-wire tag was placed in the nasal cartilage using a MK2 CWT tagging machine (Northwest Marine Technologies, Ltd.). Tag placement was checked each day by sacrificing one smolt/day and examining the tag site through an incision made laterally through the fish’s head. All fish were checked for immediate tag retention by passage through a quality control device (QCD) before release. Fish without tags present were re-tagged. Four separate groups of approximately 100 smolts were retained in a holding box for 24 hrs to assess tag retention.

2.6.2 Fence Efficiency Tests

Two tests were performed using coho smolts to assess the trap's gross efficiency at capturing fish. The first test began May 1st when 250 randomly selected coho smolts were fin-clipped (lower caudal) and

released 100m upstream of the trap. The second test was undertaken starting May 16th, when a further 250 fish were marked with both an upper and lower caudal fin clip. The caudal fin was cut dorso-ventrally at a point approximately one-fourth the distance from the tip of the lobe to the caudal peduncle. Caudal-clipped fish were not anaesthetized. Recoveries were recorded by mark as recaptures at the fence until June 15th.

2.6.3 O’Conner Lake Migration Study.

Coho smolts were captured in a box trap as they migrated from O’Conner Lake outlet towards the Keogh River fence. A small proportion of these fish, escapes from the Northern Vancouver Island Salmonid Enhancement Association (NVISEA) O’Conner Lake hatchery net-pen operations, were returned to NVISEA’s net pens for subsequent release elsewhere. The remainder, deemed to be of wild origin (i.e. adipose fin intact) were given an upper caudal clip and released downstream of the trap. All hatchery clipped steelhead smolts were retained for release back into the net pen operations. The number of marked smolts from O’Conner Lake that reached the Keogh River fence, were recorded daily to determine the proportion that survived the downstream migration.

2.6.4 Living Gene Bank, Smolt Captures and Smolt Release

The Living Gene Bank (LGB) experiment (Ward 2000b; Lill 2002) required the random collection of 110 wild Keogh River smolts stratified over the migration period April 1st to June 15th. These fish were not bio-sampled and were representative of the size range of smolts observed each sample week, by random collection of fish in a way as to represent a standard proportion of the abundance of wild smolts captured each week. Fish were held for a maximum of 5 days in a large secure holding box with good water circulation prior to transportation to the Vancouver Island Trout Hatchery (Duncan, B.C.). The second year of releases of adipose-clipped, first generation LGB smolts occurred in May and early June 2002. These fish transported from net pens in O’Conner Lake. All fish were released downstream of the fish fence in an area of good holding water during late afternoon.

2.6.5 Acoustic Tagging and Tracking of Steelhead Smolts.

A number of steelhead smolts were tagged with acoustic tags in the spring of 2002 in an attempt to monitor near ocean migration patterns with several lines of acoustic receivers (Welch et al 2002). Forty-nine wild steelhead smolts were internally tagged by surgery with Vemco V8SC-2L or –6L acoustic tags and immediately released on May 23rd, 25th and 26th below the fish fence. Twenty LGB smolts held in a large net pen at O’Connor Lake at the headwaters of the Keogh River were tagged on April 25th and returned to the same net pen. One smolt was subsequently

found floating dead at the surface of the net pen 2-3 days later by hatchery staff, leaving a tagged group of 19 smolts. The smolts in the net pen were then transported in two groups by tanker truck to the weir at the mouth of the Keogh River and then released at the peak of the wild steelhead emigration on May 22nd and 23rd. The exact date of release for each animal is uncertain because the animals from the net pen were transported over two days. An additional eighteen LGB smolts from the same net pen group were tagged and immediately released on May 23rd at the weir following tanker transport from the headwaters.

2.7 Smolt per Spawner Estimates

Smolt recruitment was calculated from the total number of smolts manually enumerated, their age based on scale analyses, and tabulation into brood year of origin. These data were used to estimate the smolts per spawner in comparison to the number of spawners, which contributed to their recruitment, as explained in Ward and Slaney (1993a), Ward (2000) and Ward et al. (2002, 2003).

3.0 Results

3.1 Spring Trap Operations and Biophysical Monitoring

Medium to high flows were dominant during the early periods of smolt and kelt migration in the 2002 field season, with one period when “gulper” trap operation was required from April 14th to 16th. After this date, precipitation was low and river discharge fell to medium summer levels (*approx. 1-2m³s⁻¹*). Daily water temperature ranged from an average daily low of 3.0°C on morning of April 16th to a high of 13.5°C on June 15th (Fig.2). Flow data was recorded but is not yet analyzed. Precipitation totals indicated April was dryer than normal with 87.2mm of rainfall (average from 1977 to 2002, 123mm), as was May with 52.9mm of rainfall (average, 1977 to 2002, 78mm).

3.2 Adult Steelhead

3.2.1 Logie Fish Counter - Adult Steelhead Estimates

The fish counter enumerated 102 steelhead trout entering the river between November 30th, 2001 and March 31st, 2002. A population estimate was based on larger fish (ocean age 2 and 3) only. Jacks, or ocean age 1 males, < 550mm in length, were not included during winter operation settings of the counter. The counter enumerated 113 adult steelhead, using a 90% counter efficiency correction factor. To this count were added 18 fish which were trapped and processed through the upstream adult trap adjacent to the counter pads. Thus, a total of 131 wild and

hatchery fish were assessed to have passed the counter and fence site, 300m upstream of the river mouth. A number (13) of downstream counts were recorded by the fish counter in March and early April, prior to full fence placement, indicating that some kelts exited unsampled. We assume marked and unmarked fish were equally represented in these few early emigrants.

3.2.2 Mark-recapture Steelhead Estimates

A total of 64 adult steelhead (including jacks) were tagged with operculum punches by angling and trapping during the migration period from December 2001 to April 2002. This represented 57% of the electronic counter estimate of upstream migrant adults. A total of 58 were of wild origin (91% of angled adults) whilst 4 were adipose-clipped hatchery strays, and two fish were returns from the living gene bank (LGB) experiment, as adipose-clipped jacks. During subsequent fence operations, after April 4th and until fence removal on June 15th, 18 kelts were recovered by seining and trapping. Of these fish, 8 were recaptures (44% of the sample), consisting of 7 wild fish and one hatchery stray. The population estimate was calculated at 125 adults based on the total wild male, wild female and hatchery (adipose-clipped) components of the run (Table 1). The number of wild male (50) and female fish (65) were estimated separately because a differential survival rate post-spawning occurs between sexes, for a total of 115 wild fish (Fig.3).

3.2.3 Migration Timing

In December, January, February and March the river was angled (453 hours) and adult steelhead were caught each month. Hatchery fish capture (small n) was mainly in January. Angling effort in March was low (40 hours) due to low water events, although only a few fish passed over the fish counter during this period. Run timing from electronic counts indicated a peak of migration in January and early February (Fig.4). Peak catch of wild fish occurred in January (22 fish), while highest CPUE (in fish per hour) was in February (0.15 fish per hour; Table 2).

3.2.4 Biological Data and Age Class Structure

Scale readings indicated that of the 60 wild fish sampled, one fish was an ocean-age 1 male, 28 were ocean-age 2 (13 males), 24 were ocean-age 3 (2 males), and there were 6 repeat spawners (Table 3). Length data was recorded for all adults and kelts of both hatchery and wild origin (Table 4). In general, females were larger (average, 739mm) than males (687mm), but not significantly ($p < 0.18$). The difference in size was due to a higher abundance of ocean-age 2 males (68%; n=19) than females, which

were predominantly ocean-age 3 or repeat spawners (63%; n=40). Length-at-age indicated no significant difference in size of ocean-age 2 male or female fish ($p=0.24$), but ocean-age 3 male fish were significantly larger (average, 842mm; $p=0.007$) than females (781mm).

3.2.5 Marine Survival Estimates

Marine survival estimates for adult steelhead were calculated from the stratified age data, population estimates, and smolt year-class strength. An estimated 4.5% of the 1999 smolt year-class returned as adult steelhead by 2002. Returns for the 2000 smolt year class, which yet require ocean-age 3 fish to return in 2003 to complete the estimate provided a preliminary estimate (of approx. 60% of the total result), of 2.5% survival from smolt-to-ocean-age-2.

3.2.6 Smolt Monitoring

Two assessments were performed using coho smolts to determine the efficiency of the fence at capturing fish. In both test periods, the fence was fully operational for the assessment period with no observed over topping or leakage. The recovery rate of tagged coho smolts was 82% and 64%, respectively, for fish released on May 1st and May 16th. A considerable delay in re-migration of tagged smolts was observed with both tag groups; recaptured fish were recorded up to 4 weeks after release, which may have resulted in loss of tagged fish through predation and residualization. Smolt production estimates were not increased to reflect these data as it was assessed that the missing tagged fish were unlikely to have bypassed the fence structure.

3.3.1 Steelhead Smolt and Parr Migration

Steelhead smolt migrants were recorded upon trap initial operation, April 8th, and smolts were captured until June 13th. Peak migration was observed during the week starting May 25th, when 679 smolts were captured (Fig. 5). Total catch in 2002 was 1,874 smolts, the fourth highest recorded smolt migration since 1993 (Fig 6). Steelhead smolt length frequency indicated a normal distribution, as did steelhead parr (Fig. 7). Steelhead parr migration was similar to that of 1998, 1999 and 2001, i.e., there was a bimodal peak. There was a distinct peak of migration this year occurring in the weeks starting of May 10th, and then a second peak May 24th. The total catch for 2002 was 132 parr, comprising just 7.2% of the total juvenile steelhead migration. The mean length of steelhead smolts for 2002 was 171mm (n = 517), and mean weight was 41.0g (n=84; Table 5). Mean length of steelhead parr was 93.4 mm (n = 97) and mean weight was 12.5g (n=11; Table 5). A diversion in the trend of steelhead smolt condition factor was observed in 2002 (C.F. = 0.85), which indicated the lowest recorded value of recent sample years (Fig. 8). Condition factor was significantly different between years ($p<0.001$).

Scale sampling was stratified according to numbers migrating and fish size to provide trend data on proportional representation of age classes (Fig. 9). Two-year-old smolts now dominate the population, or 83% of all emigrants. Length-at-age of steelhead smolts was also calculated and while decreased from 2001 results (Fig. 10), was found to be higher than in years without nutrient addition, 1977 to 1981 and 1986 to 1996. A significant increase in length of two-year-old smolts ($p < 0.001$) by an average of 10.0mm, or 6.4%, and three year old smolts ($p < 0.001$) by 13.1mm or 7.3% was observed for years affected by nutrient addition.

A total of 108 steelhead smolts were collected for LGB brood stock, between April 26 and June 5. Releases of LGB adipose-clipped steelhead smolts of: 5,074 fish on May 22nd, 5,080 on May 23rd, and 1,439 on May 24th, all averaging 88.8g were undertaken. A further 3,489 fish, averaging 90.1g, 5,139 fish at 89.4g, 5,186 fish at 87.6g, and 1,197 fish at 87.6g were released on May 28th, 29th, 30th and 31st, respectively with a final group of 5,456 fish averaging 61.6g (downgrades) released on June 6th. Total releases in 2002 were 32,060 smolts.

3.3.2 Coho Smolt and Parr Migration

The coho smolt migration peaked May 11th to 17th when a total of 15,074 fish were captured at the trap (Fig. 11). The total coho yield for 2002 was 60,213 fish (Fig 12). A total of 85 coho parr were recorded at the fence during operations in 2002. The peak of this migration was during the first week of operations, April 7th to 12th. No evidence of smoltification was evident on any of these fish. Average coho smolt length was 97mm ($n=1,616$) and weight was 10.0g ($n=208$). Length frequency data indicated, one year class, which may be verified by archived scale samples (Fig. 13). Condition indicated a continuing trend of declining coho smolt condition in 2002 as seen in 2000 and 2001, with a significant difference between sample years (1996-2002, $p < 0.001$, Fig 14). Grouping years by full nutrient addition treatment (1999 through 2002) and partial or no nutrient addition (1996 through 1998) indicated that despite the recent decline in CF, on average coho smolts that originated from years with full river nutrient enhancement were larger ($p < 0.001$). A high proportion of the coho smolt run (44.7%) was coded wire tagged (and adipose clipped) for the FOC as part of a separate but parallel project. In total 26,794 coho smolts were tagged. Four 48 and 72 hour holding tests were undertaken on approximately 100 anaesthetized and tagged fish, which resulted in an average tag retention of 96% (Range 95-100%, data on file). Adjusting for tag retention, an estimated release of 25,556 CWT (no. 08-43-38) and adipose-clipped and tagged, and 1,238 adipose-clipped only, fish were released (Fig. 15).

Trapping of all out-migrants from O'Conner Lake was undertaken in 2002 as in previous years. Fifty percent of coho smolts captured were tagged (upper caudal clip) and released downstream of the trap in 2002, with the remainder returned to the hatchery operation. A total of 734 smolts were captured, tagged and released between April 14th and June 1st. Of these, only 75 or 10.22% were recovered at the main fence on the lower river.

Rainfall data for April and May indicated that drier than normal conditions persisted for much of the spring migration period. Thus, coho smolt yield, which appears linked to spring discharge (Fig 16), was expected to be reduced.

3.3.3 Dolly Varden, Adult, Smolt and Parr Migration

The total catch of Dolly Varden adults for 2002 was 520 fish, similar in quantity to recent years 1999 and 2001. The peak migration was the week of May 4th to 10th when 154 fish were captured at the fence (Fig. 17). Mean length and weight were 251mm and 149.0g, respectively (Table 5). The total number of Dolly Varden smolts and parr which migrated downstream in 2002 was 1167 fish, the second highest recorded yield since 1996. Mean length and weight was 148 mm and 28.0g respectively (Table 5). Peak migration occurred in the week of May 18th to 24th, slightly later than recent historic peaks (1998-2001) have occurred (Fig.17).

3.3.4 Cutthroat Trout Migration

Small numbers of cutthroat trout were enumerated at the Keogh River in 2002, as in past years. The number of adults captured was low at 7 individuals; these were classified as adults by their lack of silver colouration (characteristic of smolts) and their size, >200 mm. Mean adult length was 226 mm (Table 5). The smolt escapement was 38. Peak migration occurred in the week starting April 15th to 19th when 10 smolts were recorded. A mean length of 158mm was recorded for these fish and a mean weight of 32.0g (Table 5, Fig.18). A total of 6 cutthroat parr were also enumerated with a mean length of 109mm and a weight of 11.5g.

3.3.5 Cottus spp. & Lamprey Migration

Cottus asper and *Cottus aleuticus* were pooled during enumeration this year. The peak of cottid migration was bi-modal in 2001 and occurred the weeks starting April 27th and May 18th. The total catch was 131. The total catch of Lamprey on the Keogh River in 2002 was one individual, Pacific Lamprey, (*Lampetra tridentatus*).

4.0 Discussion

4.1 Steelhead Adults and Kelts

Based on the mark-recapture data, a total wild population of 115 adult steelhead, was recorded returning to the Keogh River in 2002. This is a slightly lower than in 2000 and 2001, and does not indicate a return to the previously high numbers observed in the 1980's (Ward 2000). The estimate of 65 wild females (lower than in 2001 by 5 fish and in 2000 by 23 fish) is below two wild females per km of river length. This level of seeding is unlikely to be enough to boost production of smolts from the system to historic means, despite watershed restoration efforts (1975 to 2000 mean, 5,070). Counter data suggested a similar steelhead escapement of 131 fish in total, hatchery strays and wild fish combined. Confidence limits (95%) on the mark-recapture data are high at 47 to 313, due to low recapture rates, but both counter data and the very high incidence of recapturing tagged fish while marking by angling (n=19 or 30% of marked group), indicate the low estimate is reasonably accurate.

Marine survival estimates based on these data indicate a reversal of the recent upward trend in marine survival for the 1999 smolt year class, with 4.5% marine survival. This is lower than 1997 and 1998 smolt year classes (8.1% and 14.6% respectively), but comparable with the average of 3.1% survival for the previous six years (1991 to 1996). Recent increases in smolt production to ca. 2,000 individuals (1999 through 2002 smolt year class, McCubbing 1999, 2000, 2001) indicates the potential for further increases in adult escapement, but only if marine survival rates remain high. Data from steelhead returns in 2001 and 2002 (and coho returns from both years) indicate poor marine survival conditions prevail once more, resulting in escapements, which at best remain stable but poor. A continued conservative approach to steelhead management is suggested until this situation improves.

4.2 Smolt Production

4.2.1 Steelhead smolts and parr

A slight reduction in steelhead smolt production over the past three years data was observed in 2002, with 1,859 smolts enumerated. Reason for this decline could be associated with brood year strength, over-winter survival of fry and parr and spring migration conditions. As the majority of smolts (>80%) were two years in age the 2000 brood year is responsible for much of the smolt production. This brood year had indicated the potential for increased smolt production with the highest female escapement observed in some years (estimated at 88 females, McCubbing 2000), thus spawning escapement is unlikely the cause of such a decline. Increases in steelhead fry densities were also recorded for this brood year, although not at a significant level (McCubbing and Ward 2001). However, relatively poor parr densities observed in

the summer of 2001 (McCubbing and Ward 2002) suggest that over-winter fry survival in 2000/2001 was lower than previously observed, despite fry entering the winter months large for their age and in good condition (McCubbing and Ward 2001). Despite this marginal decline in smolt production in 2002, a significant increase ($p=0.001$) in average yearly production of 56%, to 2112 steelhead smolts has been observed from 1999 through 2002, when compared to production in 1994 through 1997, a period of poor ocean survival, low adult escapement and un-restored freshwater conditions. Further significant increases in production are yet required to bring production up to historic levels (mean production 1977 to 1993 was 6502 smolts) before declines in ocean survival occurred. To affect such a level of change will probably require significant increases in adult spawners, a problem being addressed with the supplementation of Living Gene Bank smolts from 2001 through 2004. Smolt per spawner yield has increased dramatically from 2 to 8 smolts per spawner in the brood years of 1986 to 1995, to 13 to 52 smolts per spawner for the 1996 through 1999 brood year (Ward et al. 2002, 2003). With observed reductions in marine survival from the 1999 and 2000, this increase in smolt per spawner yield may be essential to the maintenance of a steelhead population in the absence of alternate enhancement (LGB)

Age class data indicated a further shift towards 2 year-old smolts, now representing >80% of the total smolt run. This compares to an average of 50 to 60% in previous years when the river had undergone complete nutrient treatment or partial treatment (McCubbing and Ward 1997, 2000). A noticeable reduction in 1-year smolts, from over 10% to less than 3%, may be attributed to the ability of fry of the 2001 brood year to forage on Pink salmon eggs and carcasses. Evidence that variation in weight, length and condition of coho and steelhead smolts is related to pink salmon exists (Sheng et al 1990), and it has been hypothesized that age structure of smolts through variance in growth may also be affected on a yearly basis (Ward and Slaney 1988). Similar, although less pronounced changes in year class strengths were documented in inorganic nutrient addition trials in the early 1980's (Johnston et al.1990; Slaney and Ward 1993). Along with a change in smolt age class structure, positive changes in length at age of steelhead smolts can be observed. Smolts produced from nutrient enhanced conditions were significantly larger than those of the same age but resulting from un-restored conditions. Condition factor had also showed an improving trend over the period of recent nutrient enhancement, although 2002 data is contrary to this trend.

4.2.2 Coho smolts and parr

The observed coho smolt production of just over 60,213 smolts was a slight increase over production observed in 2001. Recent production has averaged 61,651 smolts annually, an increase of 43% compared to 1994 through 1997 data, a period of poor ocean conditions for salmonid smolts (Ward 2000), but still

lower than pre 1994 production (mean of 68,379 smolts). The 2000 brood year responsible for at least 80% of the 2002 smolt production numbered only 1,170 fish, a 65% reduction in escapement over 1999, due to poor, ocean survival, (2.3%, McCubbing 2000 data on file). The observed increase in smolt production is thus attributed to increased egg to smolt survival with smolt per spawner (SPS) production increasing to 46 from 21 for the 1999 brood and only 9 for the 1998 brood year. The resilience of smolt yield to large reductions in adult escapement may in part be an encouraging response to watershed restoration treatments, although coho salmon are acknowledged to have such regulatory density compensating relationships (Simpson, FOC, Naniamo, pers com.).

The smaller smolts observed in 2002, also with reduced condition factor may have resulted from the observed cool spring conditions and the “off” year for pink salmon escapement in 2001. Coho salmon have been observed feeding heavily on chum salmon eggs, carcasses and fry in some watersheds (Sheng 1990) and are likely to behave in a similar manner when large numbers of pink salmon are present in the river. The absence of such a food source may have affects on growth to smolt size in the year prior to smoltification. Coho smolts in 2002 remained, on average, over 40% heavier per unit length than those captured in the pre-nutrient addition conditions of 1996. These observations are likely to have occurred due to the nutrient enhancement program and are concurrent with observations of increased growth rate in coho fry during the preceding summer months (McCubbing and Ward 2001).

The apparent very high mortality of coho smolts originating from O’Conner Lake, at 88%, during their downstream migration was attributed to predation and/or delayed migration due to low flows from O’Conner Lake and in the Keogh River. Smolts were in good visual condition at their site of initial capture but in poor condition on there subsequent sampling at the lower river fence. As water levels remained very low throughout the majority of the smolt migration period, predation in the form of otters, mergansers and resident cutthroat trout are thought to be responsible for the larger part of the observed mortality. Trap redesign is required at the O’Conner creek site, to alleviate delayed migration at low flows, and to replace the degenerating structure.

4.2.3 Other Species

Dolly Varden numbers were marginally lower for smolts than in 2001, remaining significantly depressed (less than 50%) compared to historic levels. The strong smolt year class of 2000 appeared to result in maintaining increases in adult counts in 2001 but not resulting in the predicted further increases in the adult counts expected in 2002 (McCubbing 2001). Increased Pink salmon escapement linked to improved foraging for adults may be required to increase Dolly Varden production further.

Numbers of migratory cottids remain severely depressed as in 2000, although in river data might suggest otherwise with increasingly larger numbers of individuals detected throughout the lower and Middle River to West Main (data on file). Concerns over upstream access for adults over the existing fence sill was addressed with new rip rap placement in 1999, but with little appreciable detected difference in production.

Slight reductions in smolt production of Cutthroat trout were observed in 2001, over 2000 data, with numbers remaining numerically low compared to historic data. These consistently low numbers of adults and smolts observed at the fish fence indicate that a sea-run stock probably subordinate to the resident stock in the watershed, whose numbers are increasing (L. Burroughs, pers.com., Port Hardy, B.C.).

5.0 Tables

Table 1. Steelhead population estimates for the Keogh River, 2002.

| | No. Marked | No. Captured | No. Recaptured | Population Estimate | Confidence Limits (95%) |
|-----------------|------------|--------------|----------------|---------------------|-------------------------|
| All steelhead | | | | 125 | 70 to 222 |
| Hatchery strays | 4 | 3 | 1 | 10 | 3 to 18 |
| Wild Males | 24 | 3 | 1 | 50 | 15 to 91 |
| Wild Females | 34 | 12 | 6 | 65 | 32 to 142 |
| Total Wild | | | | 115 | 67 to 202 |

Table 2. Migration timing of hatchery and wild steelhead adults into the Keogh River 2002, based on angler catch data.

| | No. of hatchery fish captured | | No. of wild fish captured | | Effort (hrs.) | CPUE Hatchery (fish/hr.) | CPUE Wild (fish/hr.) |
|-------|-------------------------------|------------|---------------------------|------------|---------------|--------------------------|----------------------|
| | | % of Catch | | % of Catch | | | |
| Dec. | 1 | 12.5% | 15 | 27.5% | 122 | 0.01 | 0.12 |
| Jan. | 5 | 18.5% | 22 | 46.7% | 198.5 | 0.03 | 0.11 |
| Feb. | 2 | 14.3% | 12 | 24.1% | 92.5 | 0.02 | 0.13 |
| March | 0 | 0.00% | 1 | 1.7% | 40.0 | 0.00 | 0.02 |

Table 3. Age classification of adult steelhead from the Keogh River based on scale analysis, 2002 (s indicates spawn mark observed).

| Smolt Year | ocean age | | Smolt Age 1 | Smolt Age 2 | Smolt Age 3 | Regenerated Scale |
|------------|-----------|------|-------------|-------------|-------------|-------------------|
| 2000 | 1 | 1 | 0 | 1 | 0 | 0 |
| 1999 | 2 | 2 | 1 | 19 | 0 | 8 |
| 1999 | 2 | s1 | 0 | 1 | 0 | 0 |
| 1998 | 3 | 1s1 | 0 | 3 | 1 | 1 |
| 1998 | 3 | 3 | 2 | 6 | 4 | 13 |
| 1998 | 3 | ss1 | 0 | 0 | 0 | 0 |
| 1997 | 4 | 1ss1 | 0 | 0 | 0 | 0 |
| 1997 | 4 | 2s1 | 0 | 0 | 0 | 0 |
| 1997 | 4 | sss1 | 0 | 0 | 0 | 0 |

Table 4. Mean length (mm) of steelhead adults and kelts in the Keogh River in 2002.

| Type Adults | Sex | Length (mm) | | | S.D. | N |
|----------------|--------|-------------|-----|-----|------|----|
| | | Mean | Min | Max | | |
| Wild | Male | 687 | 385 | 930 | 113 | 32 |
| | Female | 739 | 600 | 860 | 74 | 45 |
| Adipose | Male | 615 | 400 | 675 | 98 | 6 |
| | Female | 703 | 635 | 760 | 66 | 4 |

Table 5. Mean length (mm) and weight (g) of salmonid out-migrants from the Keogh river during the spring of 2002 (nd = no data recorded).

| Species | Type | Mean Length | S.D. | Range | n | Mean Weight | S.D. | Range | N |
|--------------|-------|-------------|------|---------|------|-------------|------|----------|-----|
| | | (mm) | | | | (g) | | | |
| Steelhead | Smolt | 171 | 18.6 | 130-319 | 517 | 41 | 13 | 20.4-94 | 84 |
| | Parr | 93.4 | 11.9 | 61-129 | 97 | 10 | 7 | 2.6-21.4 | 11 |
| Coho | Smolt | 97 | 16.9 | 70-186 | 1616 | 10 | 5 | 3.5-31.6 | 208 |
| | Parr | 66 | 4.3 | 49-66 | 82 | 3 | 1 | 1.9-4.7 | 9 |
| Dolly Varden | Adult | 251 | 33.1 | 200-403 | 149 | 149 | 54 | 74-400 | 28 |
| | Smolt | 148 | 16.4 | 73-199 | 28 | 28 | 9 | 11.3-60 | 63 |
| Cutthroat | Adult | 203 | 27.3 | 139-245 | 7 | nd | nd | nd | nd |
| | Smolt | 154 | 15.4 | 121-196 | 29 | 32 | 3 | 12.4-58 | 4 |
| | Parr | 104 | 10.7 | 74-124 | 6 | nd | nd | nd | nd |

6.0 Figures



Figure 1. The Keogh River fish fence showing smolt and adult salmon and steelhead trapping facilities, 2002.

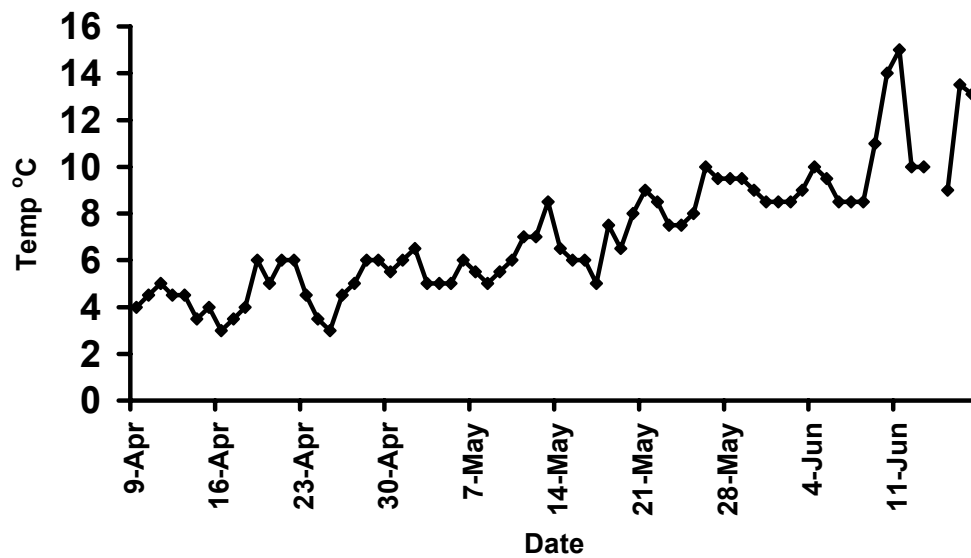


Figure 2. Daily temperature (08:00 to 09:00hrs) at the Keogh River, April to June 2002.

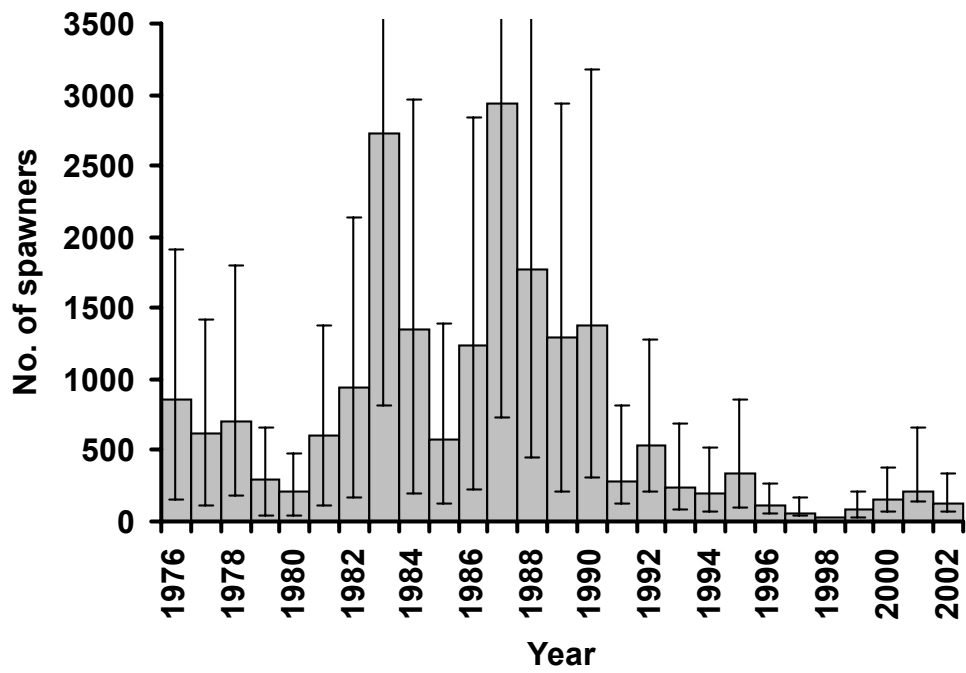


Figure 3. The number of adult steelhead at the Keogh River from 1976 to 2002 +/- 95% CL.

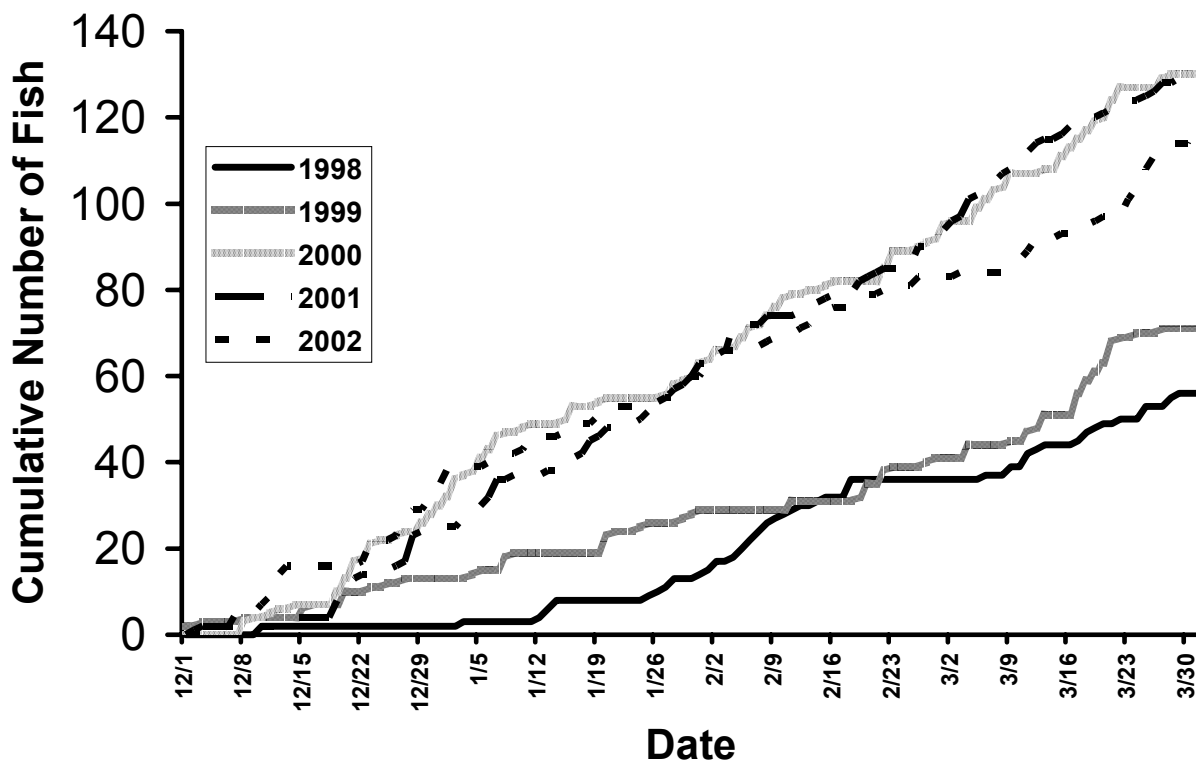


Figure 4. Electronic counts (cumulative number) of steelhead migrants into the Keogh River from December to April, 1998 (solid black line), 1999 (dark gray line), 2000 (light gray), 2001 (long and short dashed dark line), and 2002 (dotted dark line).

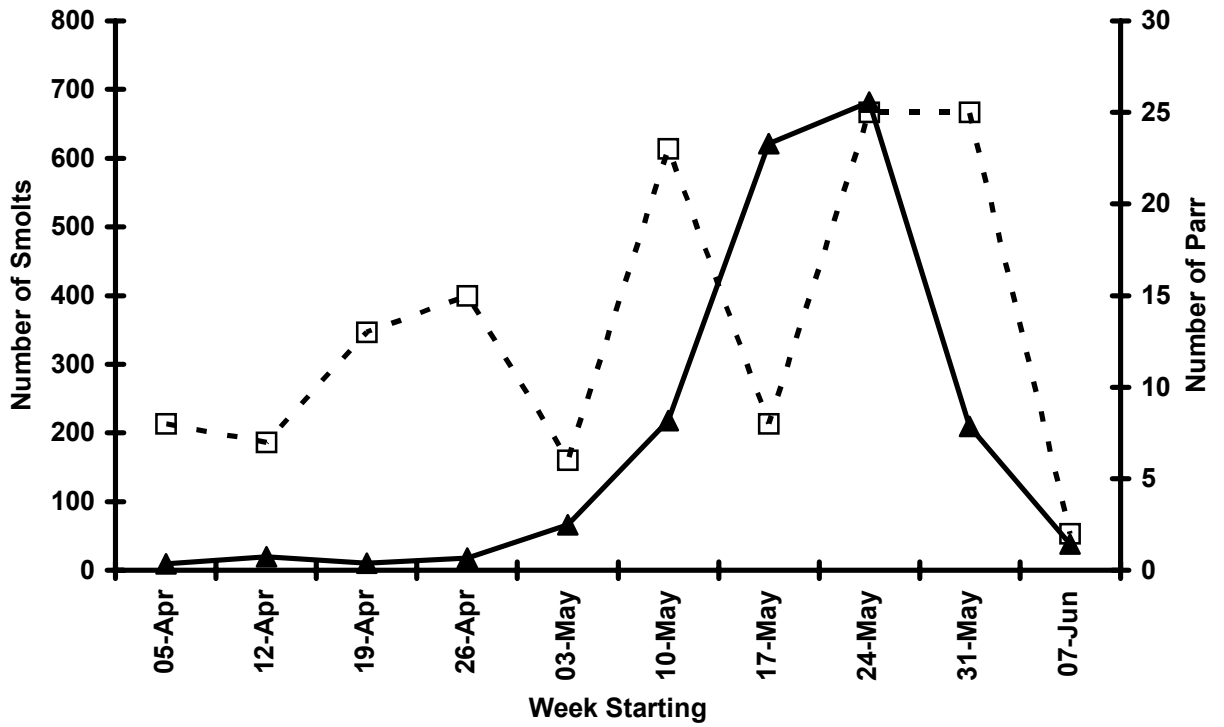


Figure 5. Weekly totals of the number of steelhead smolts (solid line) and parr (broken line) migrating from the Keogh River, 2002.

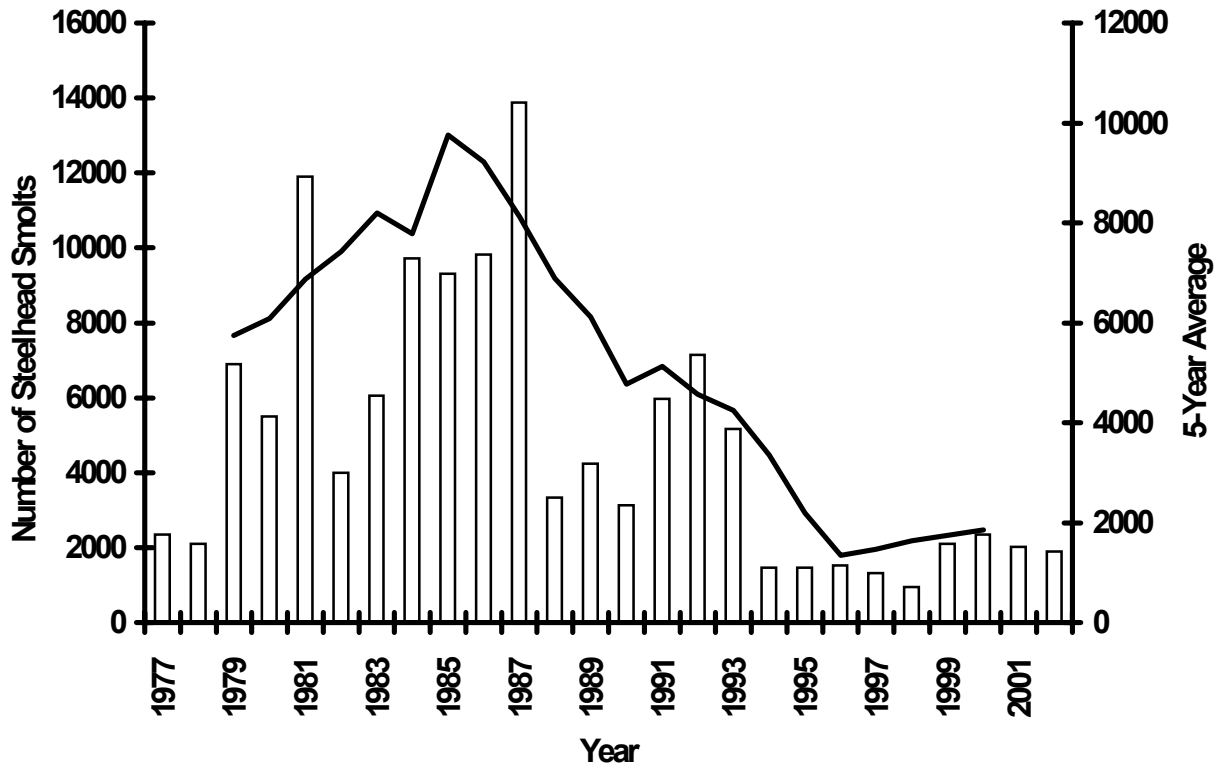


Figure 6. Steelhead smolt yield from the Keogh River 1977 to 2002 (open bars), and the 5-year trend (running average; solid line) .

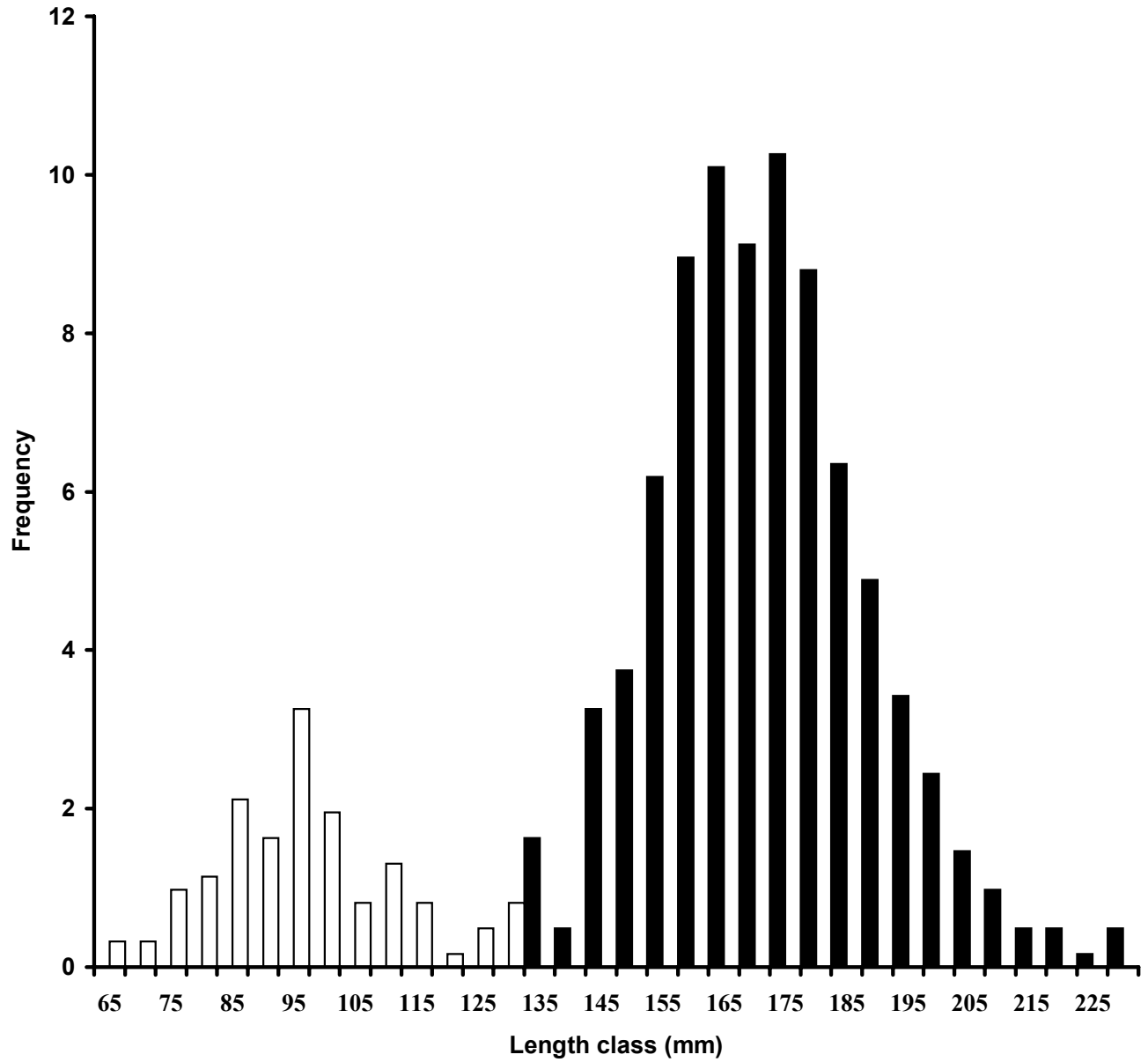


Figure 7. Length frequency distributions of steelhead parr (open bars) and smolts (solid bars) from the Keogh River in 2002.

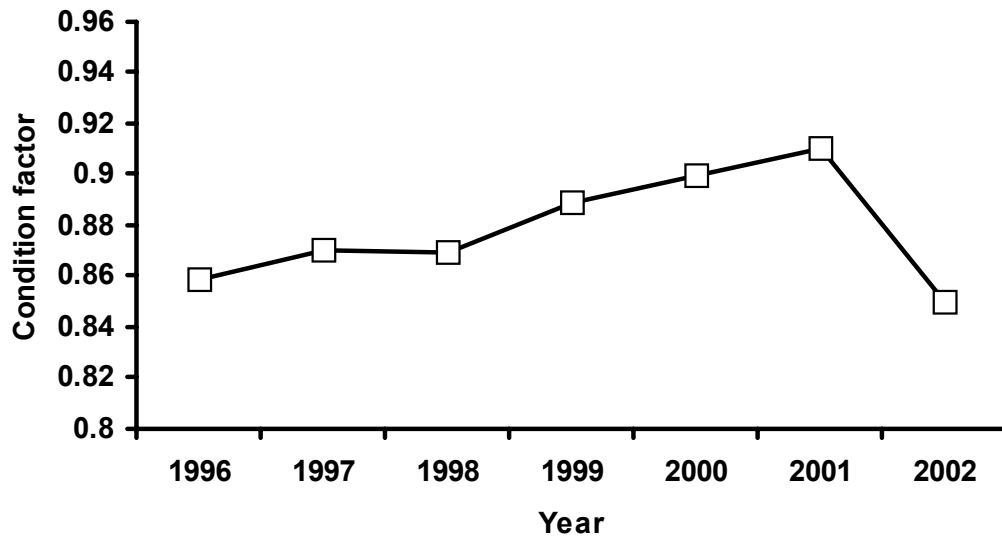


Figure 8. Condition factor (annual mean) of steelhead smolts in the Keogh River from 1996 to 2002.

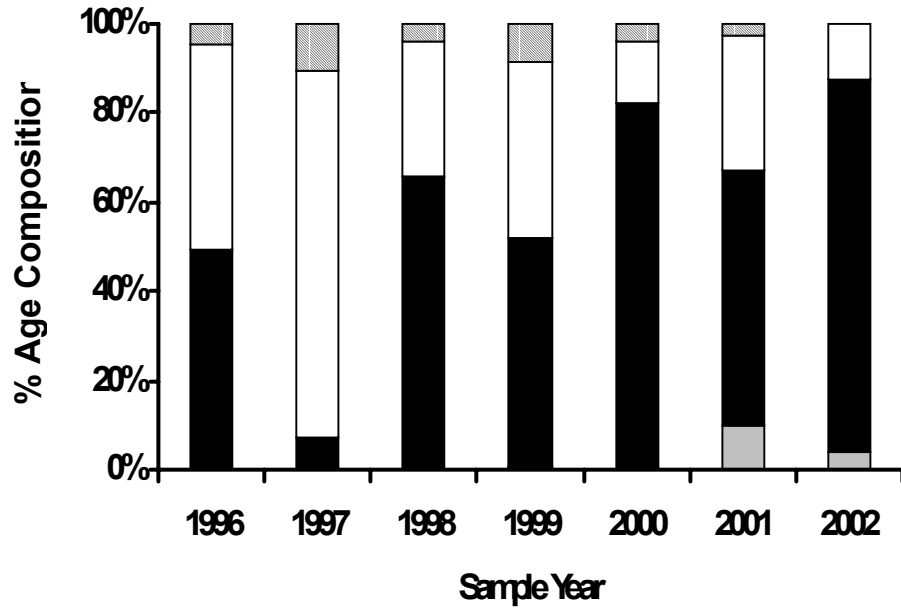


Figure 9. Percent composition of age 1 (grey bar), age 2 (black bar), age 3 (white bar), and age 4 (hatch bar) steelhead smolts in the Keogh River in 1996 and 1997 (no nutrient addition), and from 1998 to 2002 (nutrients added).

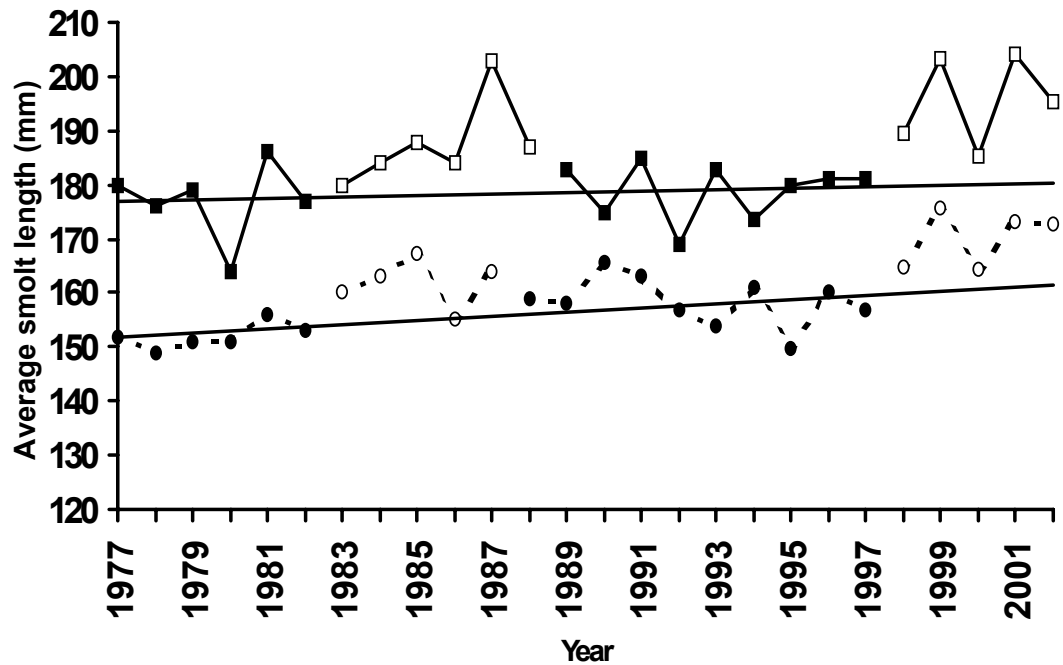


Figure 10. Mean length of 2-year-old (broken line, circles) and 3-year-old (solid line, squares) steelhead smolts in the Keogh River from 1977 to 2002. Open markers indicate years affected by nutrient addition treatments.

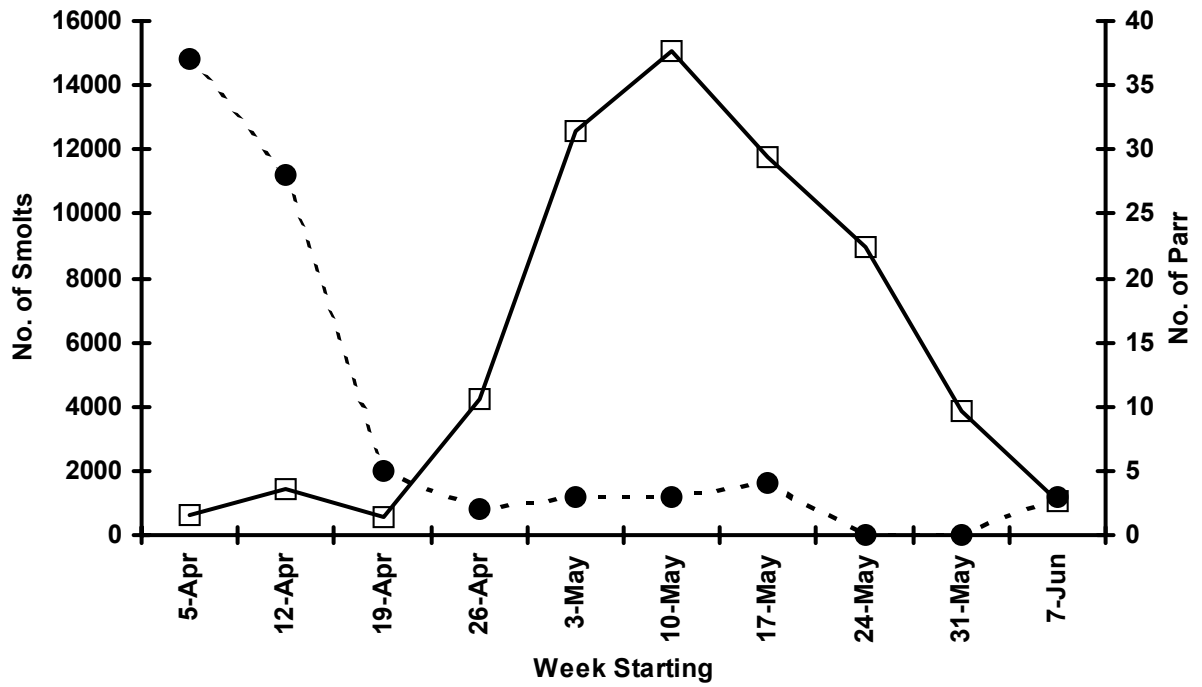


Figure 11. The timing and number of coho smolts (solid line) and parr (broken line) migrating from the Keogh River, 2002.

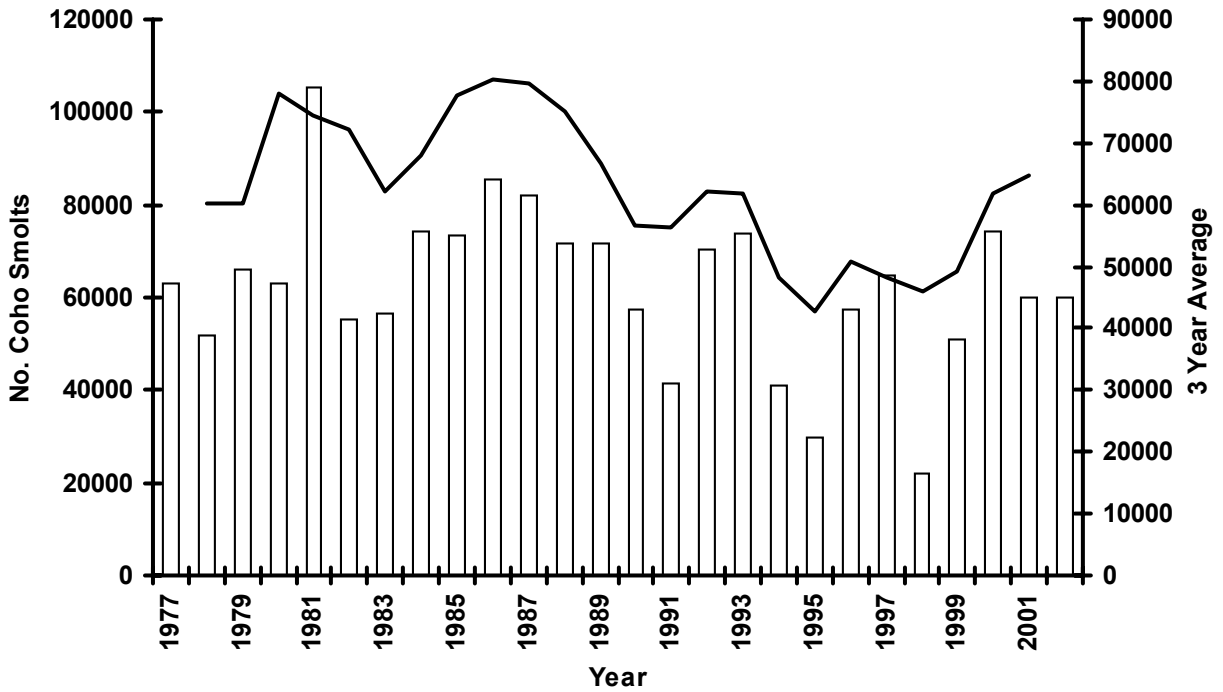


Figure 12. Coho smolt yield from the Keogh River from 1977 to 2002 (open bars), and the 3-year trend (running average; solid line).

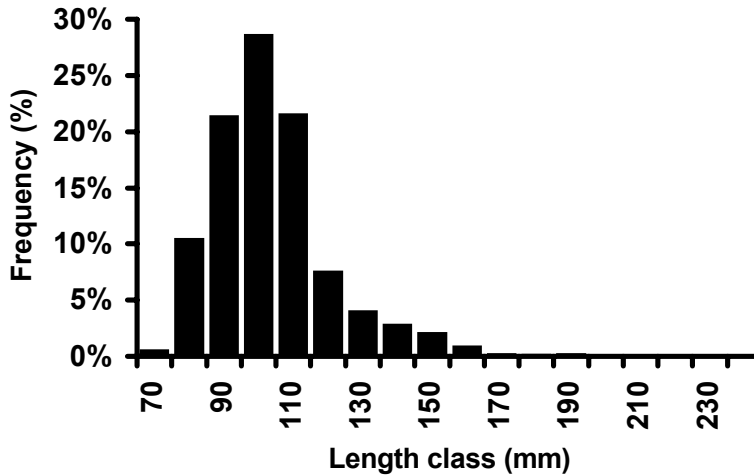


Figure 13. Length frequency distribution of coho salmon smolts at the Keogh River, 2002.

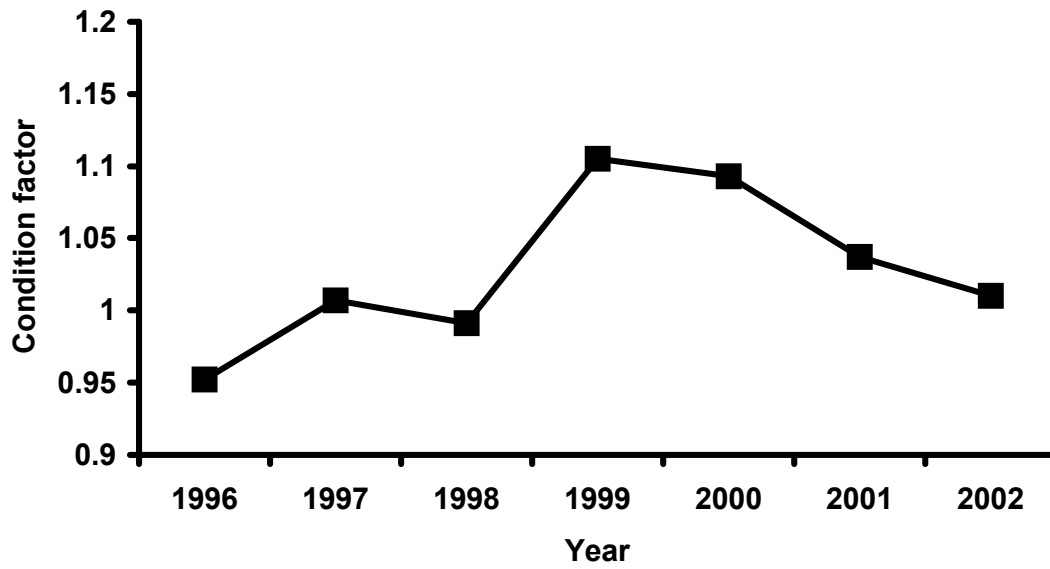


Figure 14. Condition factor (annual mean) of coho smolts from the Keogh River from 1996 to 2002.

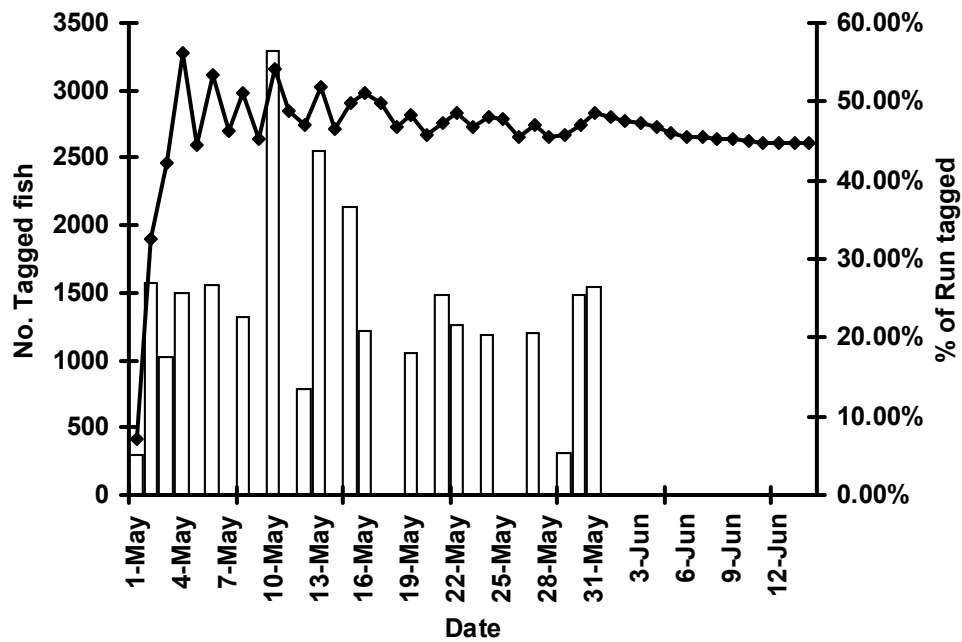


Figure 15. Daily coho smolt count (open bars) and the cumulative percent of the total count implanted with coded-wire tags (solid line) at the Keogh River in 2002.

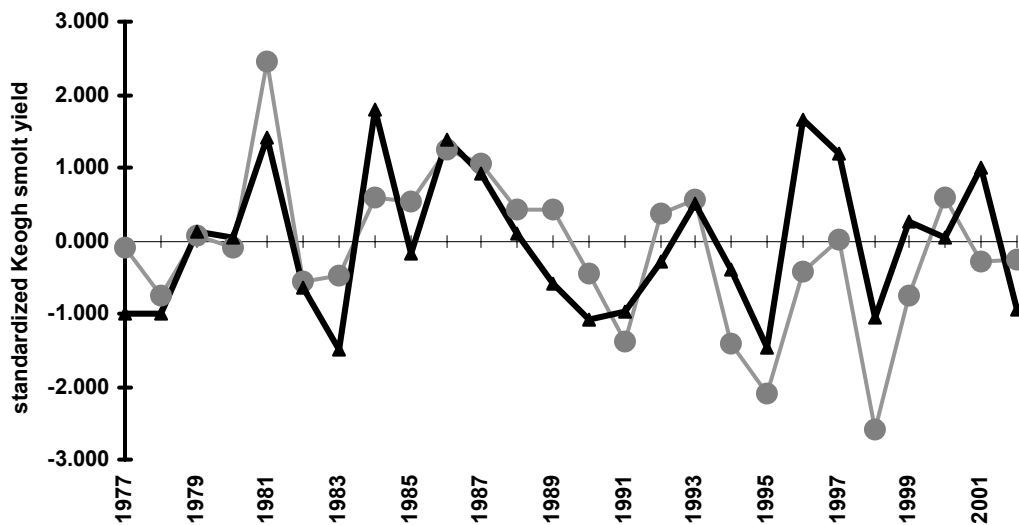


Figure 16. Standardized coho smolt yield (gray line, circles) and total precipitation from April to May (Environment Canada, Port Hardy Weather Station; black line, triangles) on the Keogh River, 1977 to 2002.

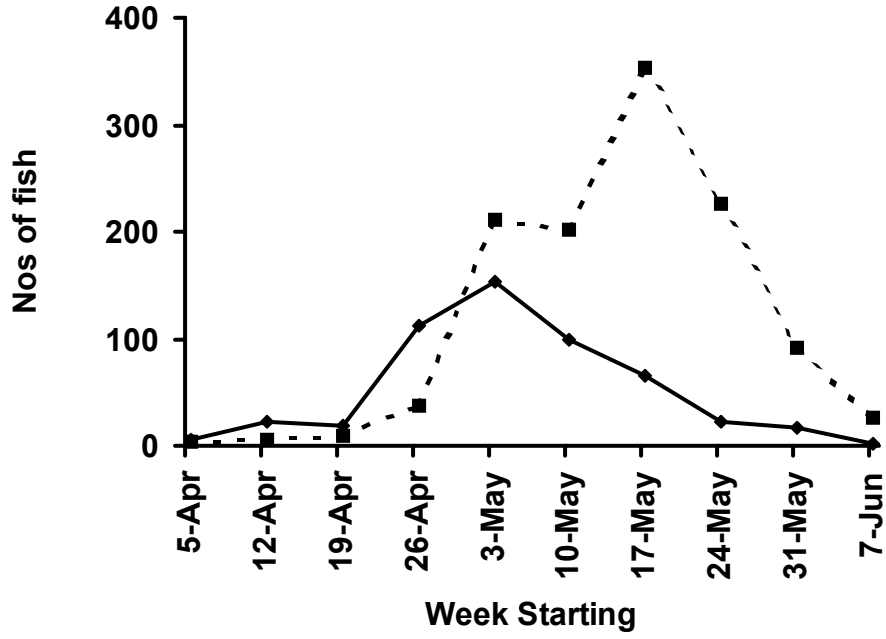


Figure 17. Migration timing and number of Dolly Varden smolts (broken line) and adults (solid line) from the Keogh River in 2002.

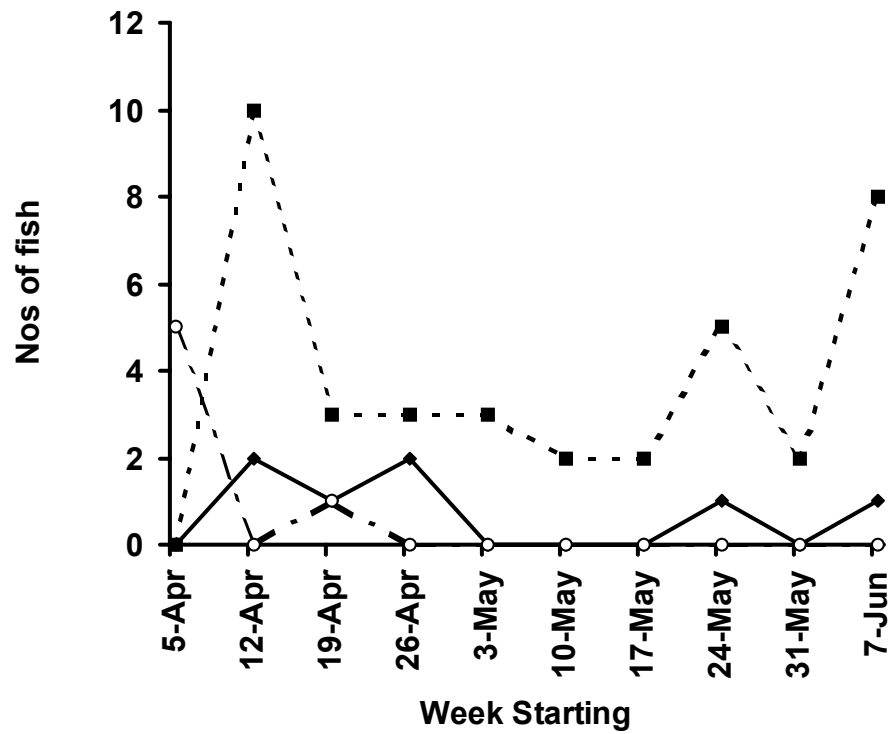


Figure 18. Migration timing and number of Cutthroat trout adults (solid line), smolts (dotted line) and parr (dashed line) migrating from the Keogh River in 2002.

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