Pre-Dam Removal Monitoring of Goldsborough Creek, Washington:

2000 Smolt Trapping Study

Report to the

U.S. Army Corps of Engineers
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by

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ABSTRACT

Trapping of salmonid (*Oncorhynchus* spp.) smolts was conducted as part of the monitoring plan for the Goldsborough Creek, Washington, dam removal and stream restoration project headed by the U.S. Army Corps of Engineers. The aim of the current year's monitoring is to provide data on existing use of the watershed by salmonids prior to dam removal. These data will be assessed with data from other years to allow pre- and post-removal comparisons, and thus facilitate evaluation of the effect dam removal has on naturally reproducing salmonid populations. The 2000 smolt trapping study represents the first pre-removal collection of salmonid smolt data affiliated with the removal and restoration.

A primary goal of the dam removal project is to enhance access of spawning salmonids to habitat currently above the dam. This study used smolt trapping rather than spawner surveys to evaluate any improvement in access since spawner surveys can be unreliable, particularly with respect to coho salmon. If smolt trapping data show a post-removal increase in proportion of smolts originating from the upper watershed, it might be concluded that dam removal enhanced adult access to the upper watershed. As such, the 2000 study: 1) provides data on smolt production above the dam relative to production for the entire watershed; and, 2) offers preliminary conclusions on restrictions imposed by the dam on access to upper watershed habitat, which will be further evaluated with future pre- and post-removal studies. In addition, as part of estimating relative production from the upper watershed, potential mortality to smolts caused by passing over the dam spillway was assessed.

Two rotary-screw traps, one immediately above the dam and one near the mouth, were used to collect salmonid smolt data. Chinook and chum salmon were absent from the upper watershed, but were caught below the dam (103 chinook; 692 chum). Steelhead/rainbow trout were nearly absent from the upper watershed, but were found below (1 above; 53 below). Cutthroat trout were found above and below, but uncertainty regarding migratory patterns of this population precluded assessment of these data with respect to migrations across the dam. Observed relative production of coho salmon smolts from the upper watershed was 73-81% of all naturally produced coho smolts in the entire system, without considering spillway mortality. This dropped to 66-73% when spillway mortality was considered. Based on differences in habitat above and below the dam, estimates of upper watershed relative production were lower than would be expected if spawners had uninhibited access beyond the dam. Mean spillway mortality was estimated at 14.3%, or 1,283-1,435 smolts. Spillway mortality was not statistically significant (p=0.1151), but other indications suggested it was present.

Study results suggest that chinook salmon, chum salmon and steelhead trout were severely restricted from accessing the upper watershed. Coho salmon were moderately restricted, and may have been subjected to an additional limitation on population posed by spillway-induced mortality to emigrating smolts.

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INTRODUCTION

Background

Goldsborough dam, located at river kilometer (rkm) 3.4 is a badly deteriorating structure that is a partial barrier to migrating salmon in Goldsborough Creek (STC 1998). The dam was constructed in the 1920s to provided power to the City of Shelton. It was reconstructed in 1932 to furnish water for a mill operation and was later used as a water supply to provide fire protection for the mill. The structure was damaged during the winter of 1996 and no longer provides any useful purpose.

The structure consists of four steps that along with the degrading streambed at the downstream end of the dam results in a 35-foot vertical drop (STC 1998). A step-and-pool fish ladder on the north side of the dam was installed to provide fish passage. Although the ladder provides passage for some coho salmon, it is believed to be a complete barrier for chum salmon, chinook salmon, steelhead trout, and sea-run cutthroat trout (STC 1998).

The U.S. Army Corps of Engineers (Corps) approved the Goldsborough Creek Section 206 Ecosystem Restoration Report and Environmental Assessment in September of 1999 (Corps 1999). This report recommends the removal of Goldsborough dam. The primary objectives are to remove the dam and restore the stream to a more natural gradient that will allow fish passage for resident and migratory fish (TTI 1999). Although fish passage is the primary goal of the project, it is recognized that the project will also restore other important ecological and physical functions within the watershed. The dam is expected to be removed during the summer of 2001. A monitoring plan was developed by the Corps, the U.S. Fish and Wildlife Service (FWS), the Washington Department of Fish and Wildlife (WDFW), and Simpson Timber Company to evaluate the effectiveness of the project.

In accordance with the monitoring plan, the FWS conducted smolt trapping on Goldsborough Creek to obtain pre-dam removal data. Spawner surveys are also being conducted as part of a separate study. Together, these will allow future assessments of project success with respect to adult salmonid access to the upper watershed. Smolt trapping was selected in addition to spawner surveys to help compensate for uncertainties regarding the latter: spawner surveys are particularly unreliable and not well developed for coho salmon, one of the species of primary interest to this project.

The overall smolt production monitoring plan relies on comparing the proportion of smolts produced in the upper watershed prior to dam removal with that obtained after dam removal. If smolt trapping data show a post-removal increase in smolts from the upper watershed, it might be concluded that the project was successful in improving spawner access. We plan to use proportions of smolts rather than actual smolt abundances since the latter is influenced by numerous other factors, including changes in ocean conditions and fisheries management.

Two smolt traps (screw traps) were used to assess smolt production in the system. One trap, located below the dam and just above the mouth, provided total smolt production for the watershed. A second trap was placed just above the dam and provided smolt production estimates for that portion of the watershed above the dam (termed "upper watershed). Three years of pre-dam removal smolt production estimates will be obtained (Brood Years 1998, 1999, 2000 - smolts in 2000, 2001, 2002) and compared to at least 3 years of post-dam removal smolt production estimates (e.g., Brood Years 2001, 2002, 2003).

The primary objectives of the current year's monitoring are as follow: 1) determine salmonid smolt production above the dam relative to smolt production throughout the entire watershed; 2) assess smolt mortality associated with passing over the dam spillway so that relative production estimates may be adjusted accordingly; and, 3) offer preliminary conclusions on the degree to which the dam restricts adult access to the upper watershed, which will be further evaluated with future pre- and post-removal studies.

Study Site

The Goldsborough Creek watershed lies in the southeast corner of Washington State's Olympic Peninsula (Figure 1), and drains the lower foothills of the southern Olympic Mountains (Williams et al. 1975). The creek flows east from the confluence of its two forks, through the City of Shelton, and into south Puget Sound's Oakland Bay at Hammersley Inlet. Total system length is approximately 45.5 kilometers (km) (Williams et al. 1975), of which 34.9 km are open to anadromy (Zillges 1977). The creek has 22.5 mainstem kilometers, divides into a north and south fork at rkm 14.3, and includes two major tributaries, Coffee Creek and Winter Creek. The dam is located at rkm 3.4, leaving 28.3 km of the available anadromous length above the dam, and 6.6 km below (Figure 1).

Williams et al. (1975) provide the following description of the Goldsborough Creek system:

> [Both forks of Goldsborough Creek are] spring fed streams that drain shallow upper watershed valleys. Gradient is shallow to moderate with intermittent marshy areas or small lakes. Watershed cover is predominantly second growth timber, with dense intermittent deciduous growth along the stream banks. Area bordering the stream is sparsely settled with rural homes and occasional small farms. At approximately [rkm 11.3] the valley begins to narrow and stream gradient steepens slightly, and eventually enters a rather confined section between [rkm 3.2] and [rkm 8.0]. This section is sparsely settled and is predominantly second growth timber, with excellent stream bank cover. Goldsborough Creek is in contrast with most Puget Sound streams, where upper watersheds have steep gradients and narrow valleys that broaden toward the stream mouths. Upper Goldsborough Creek lies in broad valleys and has shallow stream gradient and conditions reverse themselves downstream.

Land use in the watershed is dominated by timber extraction and regrowth, with farmland predominating in the Coffee Creek subwatershed. Urban and industrial uses are prevalent in the lower 3.4 km of Goldsborough Creek, including a gravel mining and washing operation near rkm 3.4, a timber processing facility at the mouth, and numerous homes and small businesses in between.

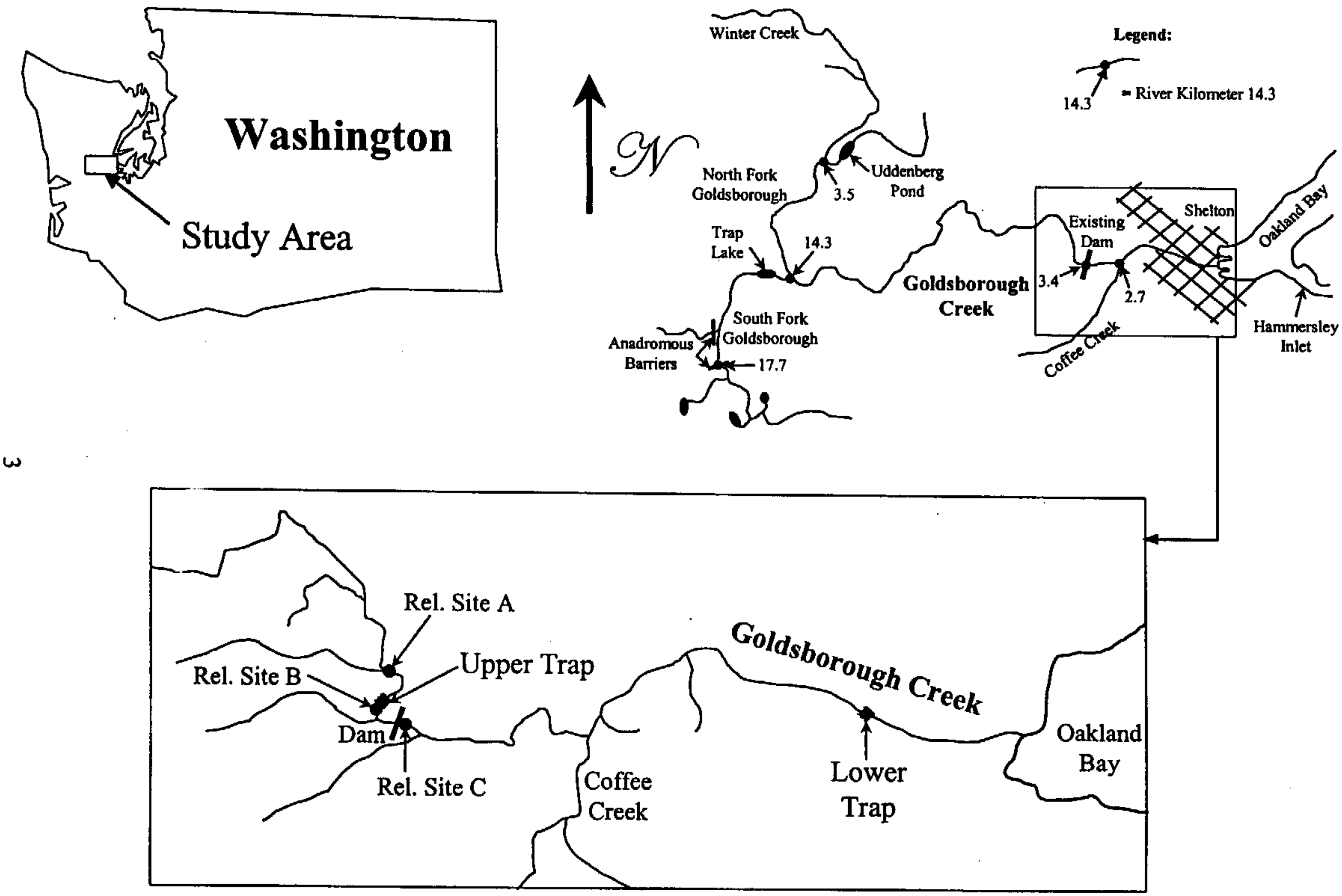

Figure 1. Study area of Goldsborough Creek, including locations of rotary screw traps and marked smolt release sites.

Previous Smolt Trapping Results

During 1975 and 1976, the Washington Department of Fisheries conducted smolt trapping operations on Goldsborough Creek (Blankenship and Tivel 1980). Despite occasional loss of traps from freshets during the trapping period, coho smolt outmigration was estimated at 14,465 in 1975, and 8,164 in 1976. These figures represent the last 2 years before artificial supplementation efforts were initiated.

The Squaxin Island Tribe sampled the smolt migration using a rotary-screw trap in 1999 (Bernard 1999). They reported total coho outmigration at 12,895 smolts, with a 95% confidence interval ($CI_{95\%}$) of 8,102-17,688 smolts (adjusted for unsampled portion of migration). Artificial supplementation efforts that may have contributed to the 1999 migration included the following: off-station release of 97,492 coho fry on March 24, 1998; remote site incubation of 30,000 coho eggs on South Fork Goldsborough; remote site incubation of 15,000 coho eggs on Coffee Creek; release of 25,000 coho fry in 1998 by Choice High School (CHS), Shelton, Washington; and, 20,000 coho eggs planted in egg tubes in 1997, also by CHS (Bernard 1999; K. Garrison, CHS, personal communication, August 2000).

Artificial Supplementation Expected to Contribute to the 2000 Smolt Migration

Goldsborough Creek has been the site of numerous artificial supplementation efforts since 1977 (Bernard 1999). These have included off-station fry releases, remote site incubation, egg tube incubation, and school hatchery releases. Prior to initiation of this study, FWS requested that all such artificial supplementation efforts be terminated to eliminate these as a source of bias in natural production assessments. Two efforts were not identified, however, allowing these to contribute to the 2000 smolt migration.

One source of artificial supplementation was a remote site incubator (RSI) located on the south fork of Goldsborough Creek. This produced 26,306 fry which were released above the dam in the spring of 1999. At the request of FWS, WDFW, in cooperation with the RSI operator, captured fry emerging from the RSI. Captured fry were anesthetized with tricaine methanesulphonate (MS-222) and adipose fin clipped prior to release. This was done to allow identification of these fish during the 2000 smolt trapping study.

The second source of artificial supplementation consisted of in-stream egg tube incubation. Egg tubes were located approximately 100 meters (m) upstream from the dam, and incubated 20,000 eyed coho eggs and 20,000 eyed chinook eggs. Coho tubes were installed in December 1998, and chinook tubes in January 1999. Five tubes, each containing 4,000 eggs, were installed for each species. Egg tube incubation was conducted as part of an annual biology project by CHS (K. Garrison, CHS, personal communication, August 2000). Guidance in constructing, filling, planting and monitoring the tubes was provided by WDFW via an instructional pamphlet entitled "Salmon Egg Tube Incubation." During incubation, one tube of each species was excavated and its contents emptied, examined, repacked and replanted. Survival was estimated after emergence by excavating several tubes, emptying the contents, and enumerating the dead eggs and alevins. The 1998 plants were believed to be relatively successful, with an estimated 70% survival to emergence (K. Garrison, CHS, personal communication, August 2000).

Eggs for both RSI and egg tubes came from the Washington State hatchery at Minter Creek, an independent tributary to south Puget Sound's Carr Inlet (C. Baranski, WDFW, personal communication, October 2000).

METHODS

Fish Capture

Two rotary-screw traps were used to catch outmigrating smolts from April 10 to June 23 at two sites. One trap fished the area upstream of the dam, and was termed the "upstream," or "upper" trap (Figure 1). The other trap, located just above the mouth, fished the entire stream system, and was termed the "downstream," or "lower" trap. The upper trap was installed at rkm 3.5, 100 m upstream from the dam. The trap was located in the stream's main stem, approximately 20 m downstream of where a side channel diverted a small proportion of flow. The lower trap was installed 2.9 km downstream of the dam at rkm 0.5. This site was used by the Squaxin Island Tribe in 1999, and was selected because it was low enough to sample the entire system, yet upstream of tidal influence (Bernard 1999). The traps were positioned in the thalweg at each site and secured with cables to nearby trees.

Each trap consisted of a stainless-steel mesh barrel-and-cone construction positioned on aluminum covered foam pontoons (Figure 2). The barrel was 1.52 m (5 feet) in diameter, one-half of which was submerged during operation. Attached to the inside of the barrel-and-cone were screw-type vanes that caused the entire assembly to rotate when struck by stream flow. Fish entering the barrel were transported through the rotating structure and into an 0.80 square meter live box. The partitions created by the rotating screw vanes prevented any fish from escaping. The live box was equipped with a continuously operating debris removal system.

The lower trap was configured with a weir to enhance efficiency. The weir angled upstream from the trap entrance to the opposite bank (Figure 3). The weir consisted of several abutting sections of ½-inch Aquamesh screen stapled to a wood frame. Each section of the weir was equipped with a "blowout" panel, which ran the length of the upper portion of each section. Blowout panels were designed to dislodge and thus relieve stress on the main structure in the event that high flows and debris accumulations exerted excessive force on the weir.

Both traps were generally checked every day of operation from April 10 to June 14, then every other day until June 23 (see Appendix A for exact dates of trap visits). During each visit, all fish were removed from the live box and enumerated. Non-salmonids were identified to family and released. All salmonids (*Oncorhynchus* species) were anesthetized with MS-222, identified to species, and examined for marks. When numbers allowed, at least 20 fish were randomly

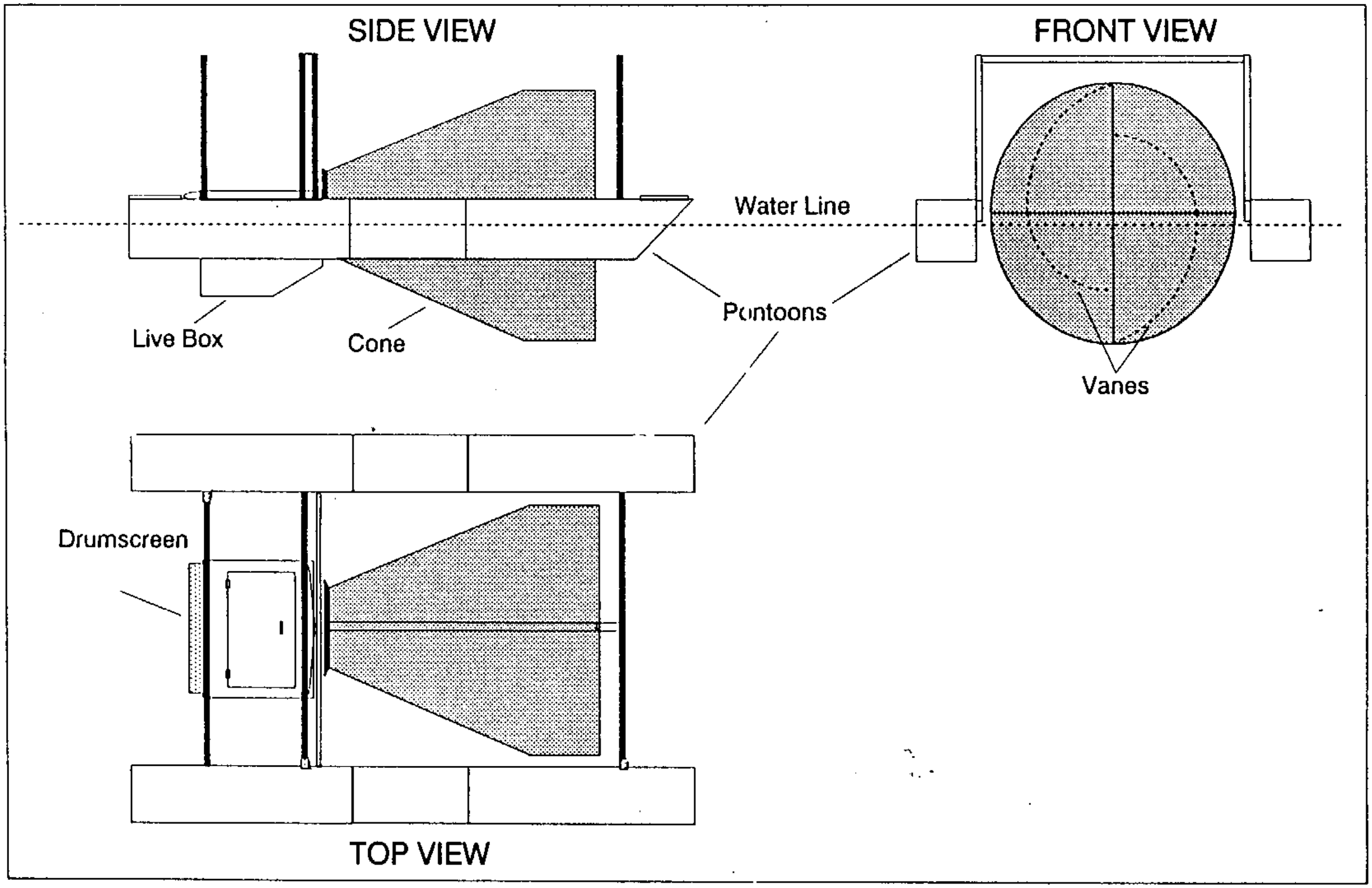

Figure 2. Diagram of rotary screw trap used on Goldsborough Creek.
Source: Polos 1997

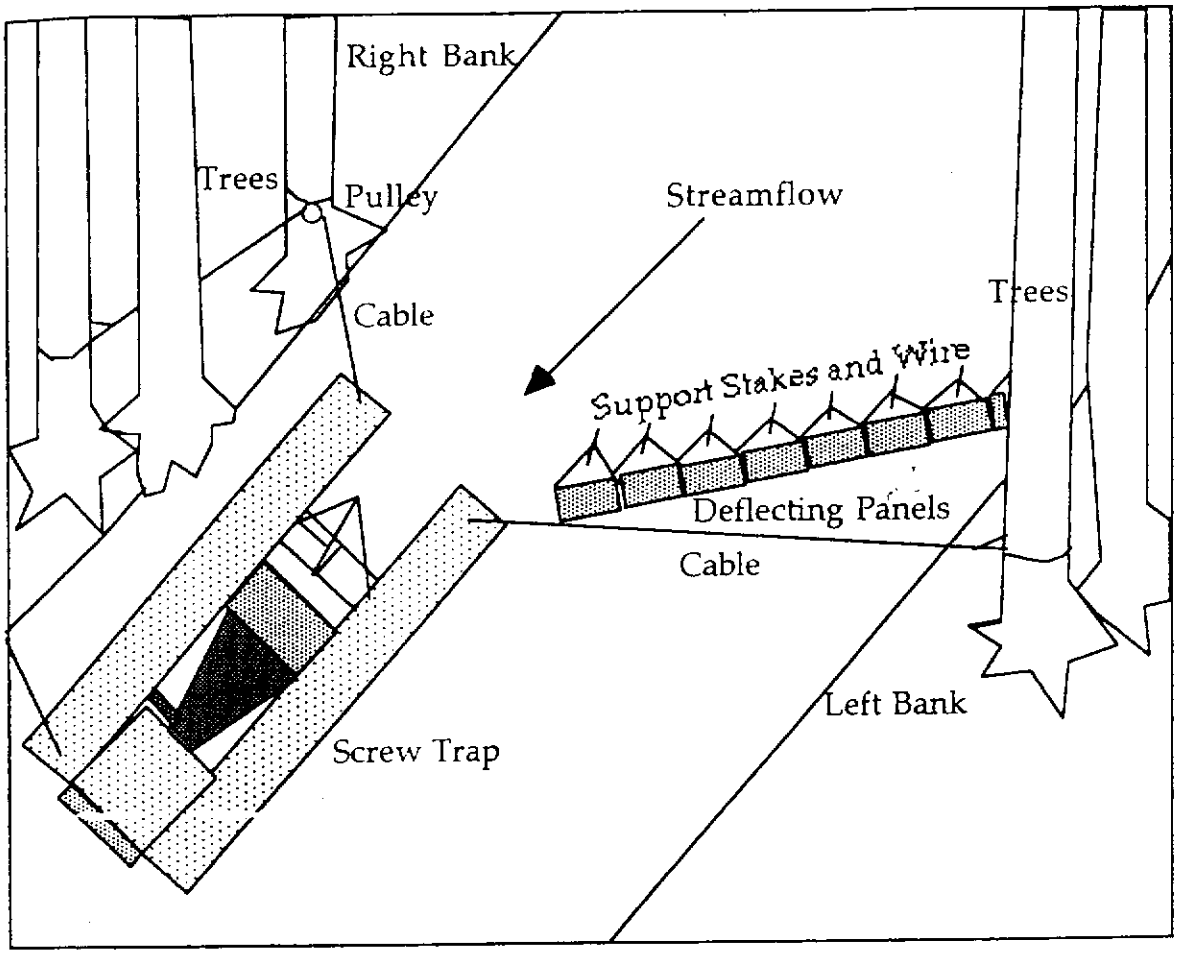

Figure 3. Screw trap and guidance panel configuration used at lower trapping site.
Source: Bernard 1999.

selected and measured for fork-length. When less than 20 were present, all individuals were measured. Fish were allowed to recover for approximately 10-30 minutes, then released in calm water adjacent to cover. Fish were typically released between 1000 and 1400 hours.

Stream Discharge

A staff gage was driven into the substrate at each trap location to provide relative measurements of water level. Water level was recorded during most site visits. Stream discharge was estimated at each site three times during the study. Discharge estimates were log-transformed and simple linear regression was used to establish an equation correlating staff gage height with discharge (Appendix B). Stream discharge (Q) was then estimated for each site visit that water level was recorded (Appendix A).

Mark-Recapture

Throughout the study period, coho smolts were marked and released to estimate upper and lower trap efficiency, and to assess mortality to smolts migrating over the dam spillway (Table 1). Fish were marked and released approximately once per week for each purpose during the study period. Although more releases were desirable to enhance statistical validity of results, constraints imposed by budget, available marking techniques and staffing limited the number of releases that could be performed.

Fish caught in the upper trap were used for all but two releases: both releases on May 25 included fish from both upper and lower traps. Marked fish were released at three sites (Figure 1). Site A was located 100 m upstream from the upper trap and was used for upper trap efficiency estimates. Site B was immediately adjacent to the upper trap on the downstream side and was used for mortality assessments. Site C was immediately below the dam spillway and was used for both lower trap efficiency estimates and mortality assessments.

Marking techniques included partial fin-clipping of one or both caudal fin lobes, and injecting non-toxic acrylic paint into caudal fin rays with a hypodermic needle. Six colors were used for marking, and the same colors were reused no less than 10 days after their previous use to allow all members of the preceding release group to exit the study site. After marking, fish were allowed to recover for approximately 10-30 minutes, then released in calm water adjacent to cover.

Staffing

The project fieldwork was staffed by a FWS technician, and volunteers coordinated by WDFW. The FWS technician was accompanied by one volunteer 5 days each week to check the traps. The traps were checked on the remaining 2 days by all-volunteer crews.

Table 1. Releases of marked coho smolts used to estimate trap efficiencies and assess smolt mortality associated with dam spillway.

Date of release	Release site[1]	Mark[2]	Number released	Use
4/14/00	A	lcc/ucc	28	Upper trap efficiency
4/17/00	A	lcc	75	Upper trap efficiency
4/26/00	B	purple	50	Mortality
4/26/00	C	yellow	50	Lower trap efficiency; Mortality
4/27/00	A	orange	50	Upper trap efficiency
4/28/00	C	lcc	165	Lower trap efficiency
5/01/00	C	lcc	362	Lower trap efficiency
5/03/00	B	blue	45	Mortality
5/03/00	C	red	45	Lower trap efficiency; Mortality
5/05/00	A	ucc	100	Upper trap efficiency
5/10/00	B	purple	50	Mortality
5/10/00	C	yellow	50	Lower trap efficiency; Mortality
5/11/00	A	orange	50	Upper trap efficiency
5/11/00	C	lcc	60	Lower trap efficiency
5/18/00	B	blue	35	Mortality
5/18/00	C	red	35	Lower trap efficiency; Mortality
5/20/00	A	green	71	Upper trap efficiency
5/25/00	C	yellow	19	Lower trap efficiency; Mortality
5/25/00	B	purple	27	Mortality
5/28/00	A	orange	25	Upper trap efficiency

1 A = above upper trap; B = above dam, below upper trap; C = below dam.
2 lcc = caudal clip, lower lobe; ucc = caudal clip, upper lobe; lcc/ucc = caudal clip, both lobes.

Trap Efficiency

Trap efficiency was estimated using the results of mark-recapture described above. For each sample (i.e., each release), the trap efficiency point estimate was calculated as the proportion of marked fish recaptured:

$$[\hat{E} = R/m]_i; \tag{1}$$

for sample i, $\hat{E}$ is the point estimate of trap efficiency, R is number of marked fish recaptured, and m is the number of marked fish released. Each release was considered one sampling of trap efficiency. Trap efficiency estimates were specific to coho since only coho were used for mark-recapture. Efficiencies specific to other species could not be estimated due to the low number of outmigrants, among other factors. Assumptions associated with the application of mark-recapture techniques to trap efficiency estimates include the following:

1. no mortality of marked fish after release;
2. all marked fish migrated downstream through the trapping sites within 10 days of release;
3. equal capture probability of marked and unmarked fish (homogeneous distribution of marked and unmarked fish as they migrated through the trapping sites); and,
4. all marks were observed and recorded.

A single seasonal trap efficiency estimate was calculated for each trap rather than a discharge-based estimate since discharge did not appear to affect efficiency during the study (Appendix C). Seasonal trap efficiency for each trap was calculated as the mean of all samples of efficiency (Table 2). In order to obtain the most accurate estimate, proportional data from each sample were normalized using angular transformation (Zar 1984). While data were angular transformed, 95% confidence intervals were calculated, then transformed back to proportions. The retransformed mean was adjusted using the correction factor suggested by Quenouille in Zar (1984). Results of mark-recapture efficiency samples, including mean discharge during sampling are presented in Table 2. Though variable, sample estimates for the lower trap were similar (chi-square: p=0.8736). Upper trap sample estimates were not similar (chi-square: p=0.0294). One sample (the April 27 release) was significantly different from four of the other six releases (Tukey-type multiple comparisons for proportions, with angular transformation: p<0.05). This sample was retained, however, primarily because smolt trap efficiency can be highly variable, even at similar flows (Seiler et al. 1984; Kennen et al. 1994; Polos 1997), rendering small sample sizes such as that used here (N=7) less likely to exhibit similarity.

During a high water include event between trap visits on May 9 and 10, two adjacent weir blowout panels were completely dislodged, while a third was partially disconnected. The panels remained in this manner until they were reaffixed on May 17. Trap efficiency was sampled twice while the panels were dislodged (releases on May 10 and May 11) to determine impact of weir breach on trap efficiency. These samples yielded efficiencies of 0.3200 and 0.4167, compared to the intact-panel mean of 0.3463 (0.2930-0.4003 $CI_{95\%}$). Intact-panel estimates were

Table 2. Mark-recapture results and stream discharge for trap efficiency estimates. Symbols refer to equation (1).

Upper trap					Lower trap				
Release date	Number marked (m)	Recaptures (R)	Efficiency ($\hat{E}$)	Discharge[1] (cfs)	Release date	Number marked (m)	Recaptures (R)	Efficiency ($\hat{E}$)	Discharge[1] (cfs)
4/14	28	11	0.3929	114	4/26	50	17	0.3400	113
4/17	76	23	0.3026	90	4/28;5/1[2]	527	200	0.3795	115
4/27	50	8	0.1600	90	5/3	45	16	0.3556	113
5/5	100	43	0.4300	90	5/10[3]	50	16	0.3200	127
5/11	50	13	0.2600	95	5/11[3]	60	25	0.4167	106
5/20	71	27	0.3803	72	5/18	35	13	0.3714	91
5/28	25	7	0.2800	79	5/25	19	5	0.2632	94
Mean efficiency ($CI_{95\%}$): 0.3194 (0.2324-0.4053)					Mean efficiency ($CI_{95\%}$): 0.3533 (0.3105-0.3959)				

[1] Average discharge for time period between release and 80% cumulative recapture.
[2] This sample combined two releases from same mark and location that occurred 3 days apart.
[3] Estimates obtained during guidance panel breach.

also independent of discharge (linear regression: r=0.4129, p=0.4896), and were similar (chi-square: p=0.8509). The similarity in breached and unbreached efficiency estimates indicated that the weir breach had no affect on efficiency.

Smolt Production

Number of outmigrating coho smolts passing each trap was estimated by:

$$(n = C/\hat{E})_j; \qquad (2)$$

n is estimated number of outmigrating smolts, and C is total catch for trap j. In order to avoid double counting, upper trap catch (C_u) consisted of unmarked fish only since marked fish were included in the catch when they were first caught and marked. Adipose-clipped smolts were considered unmarked for these purposes. Lower trap catch (C_l) included all unmarked and marked fish since marked fish had not yet been sampled by the lower trap.

Total yield of other salmonid species could not be estimated due to the inability to obtain other species-specific trap efficiencies.

Mortality of Smolts Migrating Over Dam Spillway

Mortality to smolts caused by migrating over the dam spillway was assessed by comparing recapture rates of marked smolts released above and below the dam. Each simultaneous above and below dam release provided a sample of mortality:

$$M = \frac{(P_C - P_B)}{P_C} \; ; \qquad (3)$$

M is a point estimate of the proportion of smolts killed by passing over the dam spillway; P_C is proportion of marked fish recaptured from Site C (below dam) release; and, P_B is proportion of marked fish recaptured from Site B (above dam) release. Seasonal mortality was estimated as the mean of the sample mortalities.

Statistical significance (α=0.05) was tested for each sample mortality estimate and for overall seasonal mortality. Sample mortalities were tested by comparing P_C and P_B using a one-tailed Fisher exact test for comparing two proportions (Zar 1984). Significance of seasonal mortality was tested by combining probabilities (i.e., p-values) of these sample mortality tests using the method "combining probabilities from tests of significance" offered by Sokal and Rohlf (1981).

Contribution of Naturally Produced Smolts to the Total Smolt Migration

Total production of naturally produced smolts (n_n) and the proportion of naturally produced smolts migrating from above the dam (P_n) were estimated. High and low estimates of each were necessary to encompass the range of uncertainty introduced by the egg tubes.

Estimates of natural production were obtained by first subtracting the mean number of smolts originating from the RSI (n_{RSI}) from mean total production (n). The n_{RSI} was found simply by enumerating adipose fin-clipped smolts captured in each trap, and expanding this catch by trap efficiency. Fry-to-smolt survival of RSI supplemented fish ($S_{FS\text{-}RSI}$) was then calculated by dividing expanded catch of RSI smolts in the lower trap ($n_{RSI\text{-}lower}$) by the total number of fry released from the RSI.

The number of smolts contributed from egg tubes (n_{ET}) was estimated considering different possible survival rates to encompass the range of uncertainty introduced with this method. High and low estimates of egg-to-smolt survival were calculated using different potential egg-to-fry and fry-to-smolt survival rates (Table 3). In addition, emergent fry may have migrated past the trapping site before the study period due to the close proximity with which egg tubes were located to the upper trap. Therefore, high and low estimates of upper watershed relative production were calculated to include both of the following possibilities:

1. smolts from egg tubes were not represented in upper trap catch (i.e., all egg tube fry migrated past the study site before the study period); and,
2. all smolts from egg tubes were represented in upper trap catch (i.e., egg tube fry did not migrate past the study site before the study period).

Statistical Calculations

Linear regressions and associated analysis of variance were performed using the computer software application program *SYSTAT® 9* (SPSS Inc. 1999). Results of other statistical procedures, including chi-square, Fisher exact test, angular transformation, Tukey-type multiple comparisons of proportions, and combining independent tests of significance, were obtained using standard mathematical functions available in typical computer spreadsheet programs. Pre-programmed statistical functions available in some spreadsheet programs were not used.

Table 3. Survival rates considered for estimates of smolt production from egg tubes.

Use of given survival rate	Survival rate	Source
		Egg-to-fry
high estimate	0.70	actual estimated survival
low estimate	0.50	approximate average observed for egg tubes and similar incubation devices (Maret et al. 1993; J. Fraser, WDFW personal communication, August 2000)
		Fry-to-smolt
high estimate	0.0758	general mean survival for coho (Bradford 1995)
low estimate	0.0263	survival observed with RSI, unadjusted for spillway mortality
		Egg-to-smolt
high estimate	0.0531	combined high estimates of egg-to-fry and fry-to-smolt survival given above
low estimate	0.0132	combined low estimates of egg-to-fry and fry-to-smolt survival given above

RESULTS

Coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), chum salmon (*O. keta*), cutthroat trout (*O. clarki*), and steelhead/rainbow trout (*O. mykiss*), were all caught in one or both traps (Table 4). Chinook and chum salmon were caught only in the lower trap. Coho salmon and cutthroat trout were caught in relatively large numbers in both traps. One steelhead/rainbow trout was caught above the dam, while 53 were caught below. Total catch of both traps, including salmonids, non-salmonids and adipose-clipped (RSI) coho, are shown in Table 4. Appendix A provides daily catch of both traps.

Each trap attained mean seasonal efficiencies greater than 30% (Table 2). Seasonal trap efficiencies were 31.94% (0.2324-0.4053 $CI_{95\%}$) and 35.33% (0.3105-0.3959 $CI_{95\%}$) for the upper and lower traps, respectively.

Total coho salmon smolt migration from Goldsborough Creek was estimated at 14,048 (12,537-15,982 $CI_{95\%}$) smolts, with 10,618 (8,366-14,594 $CI_{95\%}$) of these produced above the dam. Natural production accounted for 12,294-13,092 smolts from the entire watershed, unadjusted for spillway mortality. Correcting for spillway mortality, 13,464-14,414 naturally produced smolts would have emigrated from the system. The RSI contributed 693 (619-789 $CI_{95\%}$) smolts, with 611 (481-839 $CI_{95\%}$) of these migrating from above the dam. The egg tubes contributed an estimated 263-1,061 smolts.

Upper watershed production was estimated at 72.8-81.4% of naturally produced smolts, and 75.6% (0.5235-1.1641 $CI_{95\%}$) of all coho smolts migrating from the system, unadjusted for spillway mortality. Adjusting for spillway mortality, an estimated 66.4-73.5% of naturally produced smolts were contributed by the upper watershed.

Seasonal mortality to smolts caused by migrating over the dam spillway was estimated at 14.34% (-0.3083-0.5952 $CI_{95\%}$). Seasonal spillway mortality was not statistically significant (p=0.1151). One of the five sample mortality estimates was significant (p=0.0169), while the other four were not (Table 5).

Fry-to-smolt survival rate of RSI supplemented fish was calculated as 0.0263 (0.0235-0.0300 $CI_{95\%}$), unadjusted for spillway mortality. Adjusting for spillway mortality, fry-to-smolt survival was 0.0297.

Table 4. Total catch and mean fork lengths of salmonids and other species caught in upper and lower traps.

Species caught	Upper trap Number	Upper trap Fork length (mm)	Lower trap Number	Lower trap Fork length (mm)
Salmonid smolts and >1+ migrants				
Chinook	0	-	105	79.0
Chum	0	-	692	-
Cutthroat	209	154.4	222	155.1
Steelhead/rainbow	1	105	53	162.2
Coho				
RSI (adipose clipped)	195	106.5	245	107.2
natural + egg tube	3196	113.5	4718	113.9
total	3391	112.5	4963	113.1
Other catch				
Sculpin	51	-	358	-
Lamprey	244	-	48	-
Stickleback	48	-	20	-
Coho fry	182	-	2	-

Table 5. Mark-recapture results for dam spillway mortality assessment. Symbols refer to equations (1) and (3).

Release date	Above dam releases: Number marked (*m*)	Number Recaptured (*R*)	Proportion recaptured (*P*)	Below dam releases: Number marked (*m*)	Number Recaptured (*R*)	Proportion recaptured (*P*)	Sample mortality estimate (*M*)	Significance (*p*)
4/26	50	7	0.1400	50	17	0.3400	0.5882	0.0169
5/3	45	10	0.2222	45	16	0.3556	0.3750	0.1223
5/10	50	13	0.2600	50	16	0.3200	0.1875	0.3299
5/18	35	17	0.4857	35	13	0.3714	-0.3077	0.8865
5/25	27	8	0.2963	19	5	0.2632	-0.1259	0.7158
						Mean seasonal mortality:	0.1434	
						Significance (*p*):	0.1151	

DISCUSSION

Results of the study indicate that the dam restricted access of salmonids to upper watershed habitat. Chinook and chum salmon appeared most affected, with neither of these species caught above the dam. Steelhead/rainbow trout also appeared substantially impacted, with only 1 fish caught above the dam while 53 fish were caught below. Although estimates of total number of emigrants could not be made for these species, the near to total lack of them from upper trap catch coupled with the relatively high numbers caught in the lower trap points to their absence from the upper watershed.

Effects on cutthroat trout could not be assessed from this study. Cutthroat were caught in nearly equal numbers above and below the dam. However, cutthroat may exhibit an array of migratory behavior extending from sea-run to entirely resident forms co-existing in the same stream system (Northcote 1997). The methods used in this study were not designed to distinguish sea-run from less migratory forms. Thus, cutthroat caught in either trap may have been derived from sea-run or resident forms, and may or may not have been migrating across the dam. A more intensive study would be required to assess the influence of the dam on the cutthroat trout population.

Coho salmon appeared moderately impacted by the dam, both as a barrier to upstream spawner migration and as a potential source of mortality to emigrating smolts. Spawners appeared hindered in migrating beyond the dam given the seemingly low proportion of smolts produced in the upper watershed. The upper watershed contributed 73-81% of all naturally produced smolts, unadjusted for spillway mortality. Adjusting for spillway mortality, this dropped to 66-73%. Estimates of upper watershed relative production potential (Zillges 1977), coupled with differences in habitat above and below the dam (Cook-Tabor and Moore 1999), indicate that the upper watershed should probably contribute substantially more than that observed.

Relative production potential of the upper watershed was estimated at 79% of all smolts produced in the system, based on summer low-flow wetted surface area estimates provided by Zillges (1977). This estimate is almost certainly biased low based on findings of Baranski (1989) and Cook-Tabor and Moore (1999), but is likely not as unreliable as some of his other estimates (Zillges 1977; Baranski 1989). A primary source of error found in Zillges (1977) was overestimation of stream lengths arising from limitations of available maps, which showed tributaries in places where none existed, and did not indicate which streams or parts thereof were intermittent and likely to dry up at low flow (Baranski 1989). These were not factors on Goldsborough, however, since only the mainstems of Goldsborough Creek and its two forks, in addition to Coffee Creek were included. No other tributaries were considered. Also, rearing area available at low flow is physically limited by an anadromous barrier on the south fork, and, for the purposes of this study, extended only 5 km up the north fork to the vicinity of Uddenberg Pond, most likely a conservative cut-off point (Figure 1). Stream lengths used for Goldsborough Creek are therefore believed to be relatively accurate.

Despite relative reliability in Goldsborough stream lengths, three factors suggest that the 79% estimate of upper watershed relative production potential is biased low. First, beaver ponds and wetlands seem more abundant in the upper watershed than they do below the dam (William et al.

1975; Corps 1999). These features provide additional wetted surface area not accounted for by Zillges (1977), and were believed to be a primary source of underestimation in his estimates of wetted surface area (Baranski 1989). Second, Cook-Tabor and Moore (1999) found considerably more pools above the dam than below (Table 6). Pools can contribute more wetted surface area per unit length of stream than other stream morphologies, indicating that the "conservative stream width estimates" used by Zillges (as quoted in Baranski 1989) may introduce more bias into stream reaches with more pools.

The third factor suggesting a low bias to the 79% estimate of upper watershed relative production potential is the difference in available rearing habitat above the dam compared to below. Cook-Tabor and Moore (1999) found upper watershed overwintering habitat to be in greater abundance and quality than below the dam. Such habitat, in the form of pools and slow-water off-channel habitat with abundant large woody debris (LWD), is thought to facilitate greater overwinter survival and smolt production than streams lacking such habitat (Bustard and Narver 1975; Tschaplinski and Hartman 1983; McMahon and Hartman 1989; Swales and Levings 1989; Quinn and Peterson 1996). Stream surveys of 1,600 m above the dam, and 3,428 m below found considerably more pools and LWD in the upper watershed (Table 6) (Cook-Tabor and Moore 1999). The greater abundance of quality habitat above the dam should promote greater productivity per unit of stream surface area, and greater overall productivity from the upper watershed.

This year's observed production indicates that the upper watershed was not seeded proportionally. The almost certainly low expectation of 79% upper watershed relative production was met only at the high end of the 73-81% observed relative production that did not account for spillway mortality. Once spillway mortality is considered, the 66-73% observed relative production falls well short of expectations. These results suggest that spawner access to the upper watershed was probably hindered by the dam.

Table 6. Abundance of pools and LWD above and below dam (adapted from Cook-Tabor and Moore 1999).

Measure of abundance	Abundance	
	Above dam	Below dam
Pools		
proportion of total habitat	57.4%	28.5%
number of pools per unit length of stream	16.67 pools/km	5.25 pools/km
pool surface area per unit length of stream	2,449 m^2/km	515 m^2/km
LWD		
pieces of LWD per unit length of stream	540 pieces/km	358 pieces/km

In addition to inhibiting upstream migration of spawners, the dam may have presented a source of mortality to smolts migrating over the dam spillway. Seasonal mortality was not verified statistically (α=0.05); however, other factors indicated it was present. First, the configuration of the spillway suggests the potential for injury or death to fish passing over it: an initial 14-foot vertical drop is followed by an approximate 15-foot cascade/waterfall over concrete and boulders, with no pools to buffer the impact of rapid descent. Second, three of the five paired-samples showed sign differences in favor mortality (Table 5), and two below dam releases used for efficiency estimates yielded recapture rates of 38% and 42% (Table 2), both well above the 30% mean recapture rate for above-dam releases (Table 5). Third, despite the relatively small sample size (N=5) and large variability between observed sample estimates (Table 5), seasonal mortality did approach significance (p=0.1151), indicating that mortality may have been obscured rather than simply not present. Although not lending conclusive evidence, these results support the hypothesis that migrating smolts were subject to mortality by passing over the dam spillway. Additional study of spillway mortality that incorporates a larger sample size would help contribute to firmer conclusions.

Although the small sample size (N=5) hindered certainty of results, the potential for mortality to smolts passing over the spillway bears significant biological. At the 14% mortality rate calculated, an estimated 1,283-1,435 naturally produced smolts could have been killed this year. Assuming a smolt-to-adult survival rate of 0.0983 (Bradford 1995), these smolts represent 127-141 future adults available for catch and escapement. Excluding fisheries impacts, these "additional" adults represent 5,675-6,348 potential future smolts, which would yield another 558-624 ocean adults. This assumes a 45:55 female-to-male ratio and a 100 smolt/female productivity rate, which is consistent with area observations of severely under-escaped streams (D. Seiler, WDFW, personal communication, September 2000). Though less dramatic when catch of fisheries is considered, the initial increase in smolt production could build on itself in this manner, contributing to a general increase in the stock. Eliminating spillway mortality would remove this potential limitation on production and facilitate natural enhancement and rebuilding of the coho population.

The relatively small number of mark-recapture samples used to calculate efficiency (N=7) and spillway mortality (N=5) were disappointing. The initial study design intended larger sample sizes; however, several sets of data had to be discarded due to difficulties encountered with the paint-marking technique and accurate recording of marked fish. Limitations were also imposed by the size of smolt run and desire to minimize biological impact. Future monitoring efforts should consider attempts to release more groups of marked fish, perhaps by including hatchery reared smolts, as well as precautions to ensure quality of the data generated.

Validity of results from this study are contingent upon meeting the four assumptions outlined in the methods. Violations of mark-recapture assumptions have been found to result in as much as 50% underestimation of trap efficiency (Polos 1997). The assumption of no post-release mortality (assumption 1) may have been violated in the present study. The other three assumptions were probably not violated to any considerable degree. Few marked smolts were captured after 5 days of release (Appendix D), implying that virtually all marked smolt migrated through the trapping sites within the 10 days allotted (assumption 2). The assumption of equal distribution, and hence equal capture probability of marked and unmarked smolts (assumption 3) was aided by small stream size and weir configuration. The assumption that all marks were observed and recorded (assumption 4) was enhanced by the use of highly visible, unmistakable and relatively permanent marks (i.e., paint injected into caudal fin rays).

Violation of the assumption of no mortality can be a substantial contributor to underestimation of trap efficiency. In extreme cases, such underestimation may reach 50% where abundant populations of predators are able to take advantage of marked fish not fully recovered from handling stress (Polos 1997). Although not scientifically verified, no such abundance of predators is believed to exist in Goldsborough Creek. Thus, although some predation probably occurred, it is not believed to be as severe as that observed by Polos (1997).

Some mortality may have occurred as a result of using hypodermic needles to apply paint marks to coho smolts. Paint marks were used to minimize concern over volunteers potentially miscounting marks: fin clips can easily be overlooked, and damaged caudal fins can be mistaken for fin clips. Relative to fin-clipping, however, needle-injection seemed to require greater agility and dexterity, and generally required the fish to be more heavily sedated. At times, though not always, this appeared to contribute to increased handling time (including time out of water and time spent anesthetized), recovery time, and post-marking/pre-release mortality. Some paints seemed more difficult to apply than others, and fin clips generally required the least handling time and sedation.

To the extent that it was present, mortality likely had minimal impact on estimates of upper watershed relative production, the primary interest of this study: factors influencing mortality as it related to trap efficiency probably biased both traps similarly. Regarding spillway mortality, however, it is possible that sample estimates were biased by a reduced ability of handled smolts to survive and recover subsequent high-stress events such as passing over the spillway. It is uncertain to what extent this influenced results. In addition, estimates of absolute production are probably biased high, though it is difficult to determine to what degree. Recapture rates of paint-marked fish generally appeared lower than fin-clipped fish (Tables 1 and 2); however, the latter may have been biased high by damaged fins mistakenly being identified as fin-clips. Chi-square contingency table analysis also showed that all rates of recapture were similar (α=0.05), albeit with an exceedingly low number of samples to compare.

This study successfully sampled the entire smolt migration moving through each trapping site. The presence of coho smolts in each trap after the first 24-hour fishing period (11 smolts in the upper trap, and 1 smolt in the lower trap) indicated that the smolt migration had begun prior to installation of traps. Lack of data from previous years precluded adjustment of total seasonal migration to account for this; however, the unsampled portion was most likely small and its absence from the data negligible. At the time trap operation ceased, one coho had been caught in the upper trap during the previous seven 24-hour fishing periods, indicating that the migration was sampled to its conclusion.

The lower trap experienced a dramatic change in sampling conditions between trap visits on June 11 and 12. First, a high water event pushed the entire weir over, minimizing its effectiveness in guiding smolts toward the trap. In addition, a log had lodged in the trap, rendering it inoperative for at least a portion of the June 11 to June 12 fishing period. The log was removed on June 12, and the trap put back in service, but the weir was never restored to its fully functional position. Although these events occurred prior to the conclusion of the smolt migration, few smolts were moving downstream at this time (Appendix A). It was therefore concluded that these events had a negligible influence on the study results.

The lower trap weir breach that occurred in May did not reduce efficiency of the trap. This was probably the result of only two blowout panels being completely dislodged, leaving the lower, secured panels of all sections intact and functioning. With much of the weir remaining functional, smolts continued to be guided toward the trap entrance. Had a greater part of the weir been breached, a noticeable drop in efficiency probably would have been observed. This is evidenced by the 1999 Squaxin Island Tribe study, which showed weired and unweired efficiencies of 20.9% and 12.1%, respectively (Bernard 1999).

Despite reports showing that trap efficiency can be negatively correlated with discharge (Thedinga et al. 1994; Polos 1997), no such relationship was evident here (Appendix C). This was likely the result of relatively low and somewhat constant flows during efficiency assessments (Table 2), coupled with small sample sizes (N=7) and high variability in screw and smolt trap efficiency at similar flows (Seiler et al. 1984; Kennen et al. 1994; Polos 1997).

The 2000 total coho outmigration mean estimate of 14,048 (12,537-15,982 $CI_{95\%}$) was slightly higher than that of 12,895 (8,102-17,688 $CI_{95\%}$) observed in 1999 (Bernard 1999). A lower 2000 estimate may have been expected given the decrease in both artificial supplementation efforts and escapement.

Artificial supplementation efforts declined from 122,492 fry and 65,000 eggs contributing to the 1999 smolt migration, to 26,306 fry and 20,000 eggs to that in 2000. This represents 79% and 69% reductions in supplemented fry and eggs respectively. Although smolt production from artificial supplementation likely decreased, natural production may have increased as a result. Peters et al. (1996) observed that supplemented coho fry tended to emigrate downstream earlier than wild fish, and that wild fish "followed" the early migrants downstream. Although the fate of these early emigrants is uncertain, this phenomenon may have some bearing on the generally low survival observed in supplemented fry, including the RSI supplemented fish in the present study (QIA 1992; Peters et al. 1996; C. Baranski, WDFW, personal communication, August 2000). By following the supplemented fry downstream, naturally produced fry may be exposed to the same diminished survival observed in the former. Reducing the impetus for early migration (i.e., the supplemented fry) may have contributed to greater survival of the stream's naturally produced fish.

Escapement estimates in 1997 and 1998 showed a decrease from 3,600 to 2,600 wild coho into Area 13B of Puget Sound ("extreme south Sound"), which includes Oakland Bay and the mouth of Goldsborough Creek (C. Baranski, WDFW, personal communication, September 2000). In addition, 1997 spawner surveys conducted by WDFW on the south fork Goldsborough index section observed 18 coho, which was expanded to 128 fish days (WDFW, unpublished data).

This dropped to 5 fish observed and 47 fish days in 1998. Although coho spawner surveys generally do not provide an accurate measure of spawner abundance, these data supported the expectation for a smaller smolt run in 2000.

The apparent increase in production relative to escapement observed at Goldsborough Creek appears consistent with trends observed in other area streams. Preliminary results of smolt trapping on Mill Creek and Cranberry Creek, both of which also drain into Oakland Bay, show a larger smolt run in 2000 than in 1999 (M. Henderson, Squaxin Island Tribe, personal communication, September 2000). Preliminary estimates of other western Washington streams also appear to show increases in coho smolt runs between 1999 and 2000 (D. Seiler, WDFW, personal communication, September 2000). More favorable environmental conditions during the incubation and rearing of the latter brood may be cause for this general increase in smolt production.

Survival rate of RSI supplemented fry is consistent with other studies on fry enhancement. WDFW found a 2.52% fry release-to-smolt survival at Gorst Creek for a 1982 brood (C. Baranski, WDFW, personal communication, August 2000). In addition, the Quinault Indian Nation's Department of Natural Resources found supplemented fry-to-smolt survival rates of 1.4% to 10.8%, with an approximate average of 3.8% on various tributaries of the Clearwater River during the 1980's (QIA 1992). They concluded that marking technique and size at marking could influence survival, and further speculated that the supplemented fry may not have been suited to the habitat present.

Contribution from egg tubes introduced uncertainty and potential bias into evaluation of natural production from the upper watershed. First, post-emergence assessment of mortality was a rough approximation, was not thorough, and was not performed by or under supervision from fisheries professionals. Furthermore, individuals familiar with egg tube incubation indicate that survival to emergence may vary from 0% to near 100% (J. Fraser, WDFW, personal communication, August 2000). In addition, research by Maret et al. (1993) in central Idaho found an 18-83% range, and 48% mean survival to emergence for brown trout incubated in artificial egg pockets, which offer similar protections from scour and predation as egg tubes. Thus, though the range of 50-70% survival to emergence selected for this study was not entirely arbitrary, it may not have reflected actual survival.

Uncertainty surrounding fry-to-smolt survival and egg tube placement compounded the problem. Due to different incubation and emergence conditions, survival estimates of other supplementation techniques (i.e., the RSI) may not be applicable to egg tubes. Furthermore, egg tubes were placed within 20 m upstream of the upper trap, making it likely that many of the fry emigrated below the upper trap and over the dam prior to overwintering and smolting. Attempts were made to incorporate these uncertainties by calculating estimates under different scenarios, including low and high survival rates. Assumptions regarding whether or not egg tube fry migrated past the dam and out of the upper trap study site before smolting were also used for these reasons. Given the relatively small number of eggs planted (20,000 eggs), however, any bias introduced here probably had a minor influence on the results.

SUMMARY/RECOMMENDATIONS

Results of the current years monitoring suggest that salmonids are moderately to severely restricted from accessing upper watershed habitat. Virtually all chinook salmon, chum salmon, and steelhead/rainbow trout production occurred below the dam. Cutthroat trout were found above and below, but uncertainty regarding migratory patterns of this population precluded assessment of these data with respect to migrations across the dam. Without considering spillway mortality, observed relative production of coho salmon smolts from the upper watershed was 73-81% of all naturally produced coho smolts in the entire system. This dropped to 66-73% when spillway mortality was considered. Given differences in habitat above and below the dam, these figures of observed relative production were lower than would be expected if spawners had uninhibited access to the upper watershed. Spillway mortality may pose an additional restriction on the coho salmon population. Biological significance of spillway mortality was considerable, claiming approximately 14% of exposed smolts in this study. This could not be verified statistically (p=0.1151), however, due largely to the small sample size (N=5).

Rotary-screw smolt traps provided an effective means for generating monitoring data on coho salmon, chinook salmon, chum salmon, and steelhead trout above and below the dam in Goldsborough Creek. They were not effective for cutthroat trout. Similar methods are recommended for future pre- and post-dam removal monitoring. Screw traps were also useful for assessing spillway mortality, despite the difficulties and uncertainties encountered. Future monitoring efforts should include more releases of marked smolts to compensate for the high variability observed in screw trap efficiency, to better assess any influence of discharge on trap efficiency, and to generally increase the statistical validity of results. A large number of smolts released per release group would also benefit the study. All aspects of the study would benefit from the use of a Panjet in place of a hypodermic needle to apply paint marks. This would likely reduce handling stress, minimizing this as a potential source of bias.

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APPENDICES

Appendix A.1. Daily catch of salmonids (*Oncorhynchus* spp.) and other species in the upper trap.

			Salmonid (*Oncorhynchus* spp.) smolts and other emigrants ≥ 1+ in age							Other catch			
			Coho							Non-salmonids			
Date	Gage height (m)	Discharge (cfs)	Total catch[1]	Natural + egg tube	RSI[2]	Chinook	Chum	Steelhead	Cutthroat	Sculpin	Lamprey	Stickleback	Coho fry
4/10/00			11	11	0	0	0	0	6	0	0	0	0
4/11/00			14	13	1	0	0	0	3	2	3	0	0
4/12/00			17	17	0	0	0	0	3	0	2	0	0
4/13/00			19	19	0	0	0	0	3	0	0	0	0
4/14/00			9	9	0	0	0	0	4	1	0	0	0
4/15/00	0.25	134	15	15	0	0	0	0	3	1	2	0	0
4/16/00	0.2	96	48	48	0	0	0	0	3	5	2	0	0
4/17/00	0.19	90	28	28	0	0	0	0	2	0	0	0	0
4/18/00			47	47	0	0	0	1	3	3	2	0	1
4/19/00			108	108	0	0	0	0	1	0	8	0	0
4/20/00	0.18	84	46	46	0	0	0	0	6	0	4	0	0
4/21/00	0.18	84	58	58	0	0	0	0	4	0	0	0	0
4/24/00	0.2	96	281	274	7	0	0	0	9	0	0	0	0
4/25/00			46	43	3	0	0	0	1	0	1	0	0
4/26/00	0.2	96	120	119	1	0	0	0	2	0	0	0	0
4/27/00	0.18	84	130	127	3	0	0	0	6	0	0	0	0
4/28/00	0.19	90	161	160	1	0	0	0	4	0	0	0	0
5/1/00	0.19	90	359	350	9	0	0	0	8	0	0	0	0
5/2/00	0.19	90	137	129	8	0	0	0	8	2	0	0	0
5/3/00	0.2	96	96	92	4	0	0	0	9	1	2	0	0
5/4/00	0.2	96	223	213	10	0	0	0	6	0	1	0	0
5/5/00	0.19	90	121	121	0	0	0	0	6	0	4	0	1
5/6/00	0.19	90	91	89	2	0	0	0	6	0	4	1	2
5/7/00	0.19	90	140	133	7	0	0	0	3	1	1	0	1
5/8/00			109	105	4	0	0	0	2	0	0	0	0
5/9/00	0.19	90	70	67	3	0	0	0	6	0	3	0	0
5/10/00	0.3	187	124	111	13	0	0	0	8	0	2	1	0
5/11/00	0.22	110	148	137	11	0	0	0	6	0	0	0	1
5/12/00	0.2	96	94	81	13	0	0	0	9	0	3	0	2
5/14/00	0.18	84	102	95	7	0	0	0	1	0	8	1	1
5/15/00	0.16	74	54	47	7	0	0	0	3	1	3	0	0
5/16/00	0.15	69	30	26	4	0	0	0	5	1	5	0	0
5/17/00	0.15	69	42	42	0	0	0	0	7	0	4	0	0

Appendix A.1. Daily catch of salmonids (*Oncorhynchus* spp.) and other species in the upper trap. (continued)

			Salmonid (*Oncorhynchus* spp.) smolts and other emigrants ≥ 1+ in age							Other catch			
			Coho							Non-salmonids			
Date	Gage height (m)	Discharge (cfs)	Total catch[1]	Natural + egg tube	RSI[2]	Chinook	Chum	Steelhead	Cutthroat	Sculpin	Lamprey	Stickleback	Coho fry
5/18/00	0.14	65	32	29	3	0	0	0	7	0	2	0	0
5/19/00	0.16	74	23	18	5	0	0	0	5	2	2	0	3
5/20/00	0.16	74	48	42	6	0	0	0	3	0	3	0	3
5/21/00	0.16	74	26	17	9	0	0	0	3	1	4	0	0
5/22/00			26	19	7	0	0	0	2	1	0	0	1
5/23/00			23	14	9	0	0	0	2	2	7	0	1
5/24/00	0.12	57	14	11	3	0	0	0	2	3	5	0	4
5/25/00	0.12	57	13	9	4	0	0	0	3	1	4	0	1
5/26/00	0.12	57	12	9	3	0	0	0	2	0	4	0	3
5/28/00	0.21	103	25	13	12	0	0	0	3	3	12	1	12
5/30/00	0.15	69	19	13	6	0	0	0	1	0	9	2	0
5/31/00	0.14	65	3	3	0	0	0	0	1	1	2	0	7
6/1/00	0.12	57	5	4	1	0	0	0	0	1	7	0	4
6/2/00	0.12	57	2	2	0	0	0	0	0	1	4	1	2
6/4/00	0.11	53	7	3	4	0	0	0	3	2	14	3	5
6/5/00	0.1	50	3	1	2	0	0	0	3	0	12	3	0
6/6/00			1	1	0	0	0	0	1	1	8	0	8
6/7/00	0.16	74	4	3	1	0	0	0	0	0	9	2	4
6/9/00	0.12	57	3	2	1	0	0	0	1	3	8	0	30
6/11/00	0.18	84	1	1	0	0	0	0	1	1	12	0	50
6/12/00	0.6	1368[3]	0	0	0	0	0	0	0	0	0	5	0
6/13/00	0.5	705[3]	0	0	0	0	0	0	0	0	4	1	0
6/14/00	0.34	244	2	1	1	0	0	0	0	0	15	6	10
6/16/00	0.26	144	1	1	0	0	0	0	3	3	12	8	15
6/18/00	0.2	96	0	0	0	0	0	0	1	4	7	8	5
6/20/00	0.18	84	0	0	0	0	0	0	2	1	8	4	4
6/23/00	0.14	65	0	0	0	0	0	0	4	2	6	1	1
Total			3391	3196	195	0	0	1	209	51	244	48	182

1 Includes unmarked and adipose-clipped smolts only. Does not include recaptured smolts marked for trap efficiency estimates.

2 Coho smolts originating from remote site incubator (RSI), as indicated by clipped adipose fin.

3 These figures are probably not accurate. Only 3 stages were used to establish the stage-discharge correlation (Appendix B), and these were much lower than those observed on these dates.

Appendix A.2. Daily catch of salmonids (*Oncorhynchus* spp.) and other species in the lower trap.

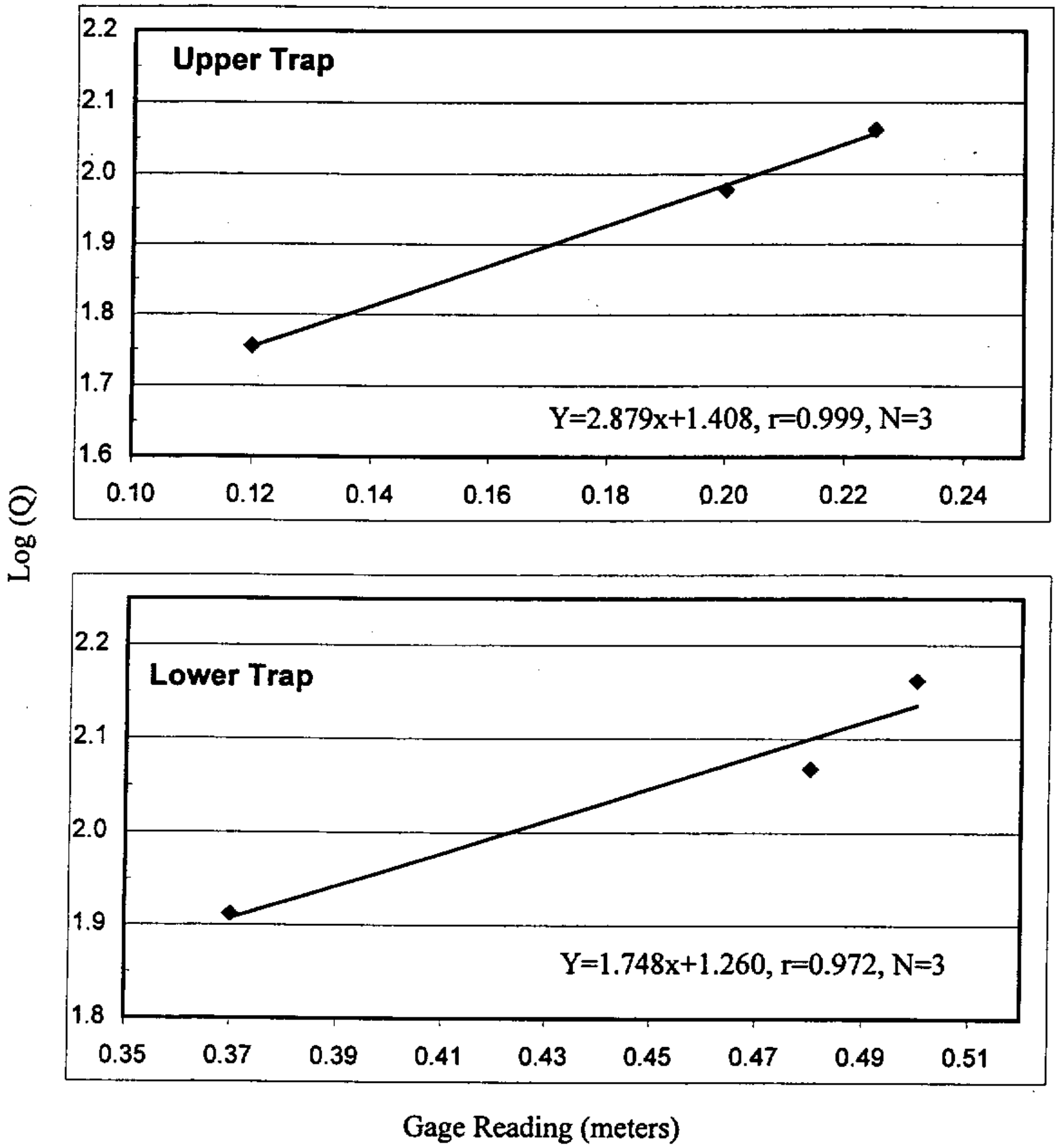
			Salmonid (*Oncorhynchus* spp.) smolts and other emigrants ≥ 1+ in age							Other catch			
			Coho							Non-salmonids			
Date	Gage height (m)	Discharge (cfs)	Total catch[1]	Natural + egg tube	RSI[2]	Chinook	Chum	Steelhead	Cutthroat	Sculpin	Lamprey	Stickleback	Coho fry
4/11/00			1	1	0	0	220	0	0	6	1	0	0
4/12/00			4	4	0	0	94	0	1	10	0	0	0
4/13/00			8	8	0	0	70	0	8	0	0	0	0
4/14/00	0.46	116	4	4	0	0	57	0	1	1	4	0	0
4/16/00	0.46	116	13	13	0	0	48	0	2	0	0	0	0
4/17/00	0.42	99	14	14	0	0	27	0	1	5	0	0	0
4/18/00			14	14	0	0	48	0	1	5	1	0	0
4/19/00			37	37	0	0	24	0	5	5	0	0	0
4/20/00	0.40	91	21	21	0	0	19	0	1	6	0	0	0
4/21/00	0.40	91	110	110	0	0	0	0	1	18	0	0	0
4/24/00	0.45	111	299	295	4	2	40	2	6	30	9	3	0
4/25/00			68	68	0	0	3	0	0	5	0	0	0
4/26/00	0.45	111	171	167	4	2	10	1	2	7	1	0	0
4/27/00	0.45	111	153	152	1	0	5	0	6	7	0	0	0
4/28/00	0.46	116	197	194	3	2	4	3	1	17	0	0	0
4/30/00	0.45	111	287	285	2	2	4	1	7	26	4	0	0
5/1/00			107	104	3	3	1	2	3	9	0	0	0
5/2/00			280	277	3	7	0	1	9	5	3	1	0
5/3/00	0.47	121	234	233	1	2	6	4	6	10	0	0	0
5/4/00	0.45	111	359	359	0	10	0	3	13	8	2	1	0
5/5/00	0.45	111	155	151	4	0	2	3	7	6	0	0	0
5/6/00	0.45	111	178	172	6	9	3	6	3	6	1	0	0
5/7/00	0.45	111	214	204	10	5	2	0	3	8	1	0	0
5/8/00			99	99	0	2	0	4	1	3	0	0	0
5/9/00	0.46	116	179	168	11	2	1	1	2	10	0	0	0
5/10/00	0.60	204	272	258	14	9	0	8	7	9	0	0	0
5/11/00	0.48	126	242	222	20	3	0	2	7	3	1	0	0
5/12/00	0.45	111	176	161	15	7	1	0	5	3	1	0	0
5/14/00	0.45	111	214	197	17	3	0	3	10	16	0	0	1
5/15/00	0.42	99	102	92	10	0	0	3	7	11	0	0	0
5/16/00	0.41	95	82	76	6	0	0	3	6	3	0	1	0
5/17/00	0.40	91	82	77	5	0	0	1	13	6	0	0	0
5/18/00	0.40	91	65	53	12	2	0	1	3	8	1	0	0
5/19/00	0.44	107	57	49	8	1	0	0	3	3	0	1	0

Appendix A.2. Daily catch of salmonids (*Oncorhynchus* spp.) and other species in the lower trap. (continued)

			Salmonid (*Oncorhynchus* spp.) smolts and other emigrants ≥ 1+ in age							Other catch			
			Coho							Non-salmonids			
Date	Gage height (m)	Discharge (cfs)	Total catch[1]	Natural + egg tube	RSI[2]	Chinook	Chum	Steelhead	Cutthroat	Sculpin	Lamprey	Stickleback	Coho fry
5/20/00	0.41	95	76	68	8	3	0	0	3	7	0	0	0
5/21/00	0.40	91	54	48	6	4	0	1	6	4	1	0	0
5/22/00			29	23	6	1	0	0	3	0	1	0	0
5/23/00	0.38	84	55	45	10	0	0	0	2	7	0	0	0
5/24/00	0.38	84	26	20	6	4	0	0	7	2	0	0	0
5/25/00	0.37	81	28	28	0	1	0	0	4	6	0	0	0
5/26/00	0.38	84	17	16	1	2	0	0	4	2	0	0	0
5/28/00	0.46	116	76	64	12	6	0	0	13	5	2	2	0
5/30/00	0.40	91	38	23	15	0	0	0	6	4	0	0	0
5/31/00	0.38	84	5	1	4	0	0	0	1	5	0	1	0
6/1/00	0.38	84	9	6	3	1	0	0	0	2	0	0	0
6/2/00	0.38	84	6	6	0	1	0	0	2	4	0	0	0
6/4/00	0.37	81	3	1	2	2	0	0	0	4	0	0	0
6/5/00	0.35	75	6	5	1	0	0	0	3	4	1	0	0
6/6/00			7	6	1	0	0	0	4	4	0	0	0
6/7/00	0.40	91	10	7	3	1	1	0	2	2	0	0	0
6/9/00	0.37	81	10	5	5	0	0	0	0	7	0	0	0
6/11/00	0.44	107	5	4	1	3	0	0	0	2	0	0	0
6/12/00	0.85	558[3]	5	3	2	0	2	0	0	0	0	0	0
6/14/00	0.57	181[3]	0	0	0	0	0	0	1	0	0	0	0
6/16/00	0.48	126	0	0	0	0	0	0	0	4	4	2	1
6/18/00	0.44	107	0	0	0	1	0	0	1	3	2	6	0
6/20/00	0.42	99	0	0	0	0	0	0	3	2	2	1	0
6/23/00	0.39	88	0	0	0	0	0	0	6	3	5	1	0
Total			4963	4718	245	103	692	53	222	358	48	20	2

1 Includes all unmarked, adipose-clipped, and marked smolts, including those marked for trap efficiency estimates and spillway mortality estimates.
2 Coho smolts originating from remote site incubator (RSI), as indicated by clipped adipose fin.
3 These figures are probably not accurate. Only 3 stages were used to establish the stage-discharge correlation (Appendix B), and these were much lower than those observed on these dates.

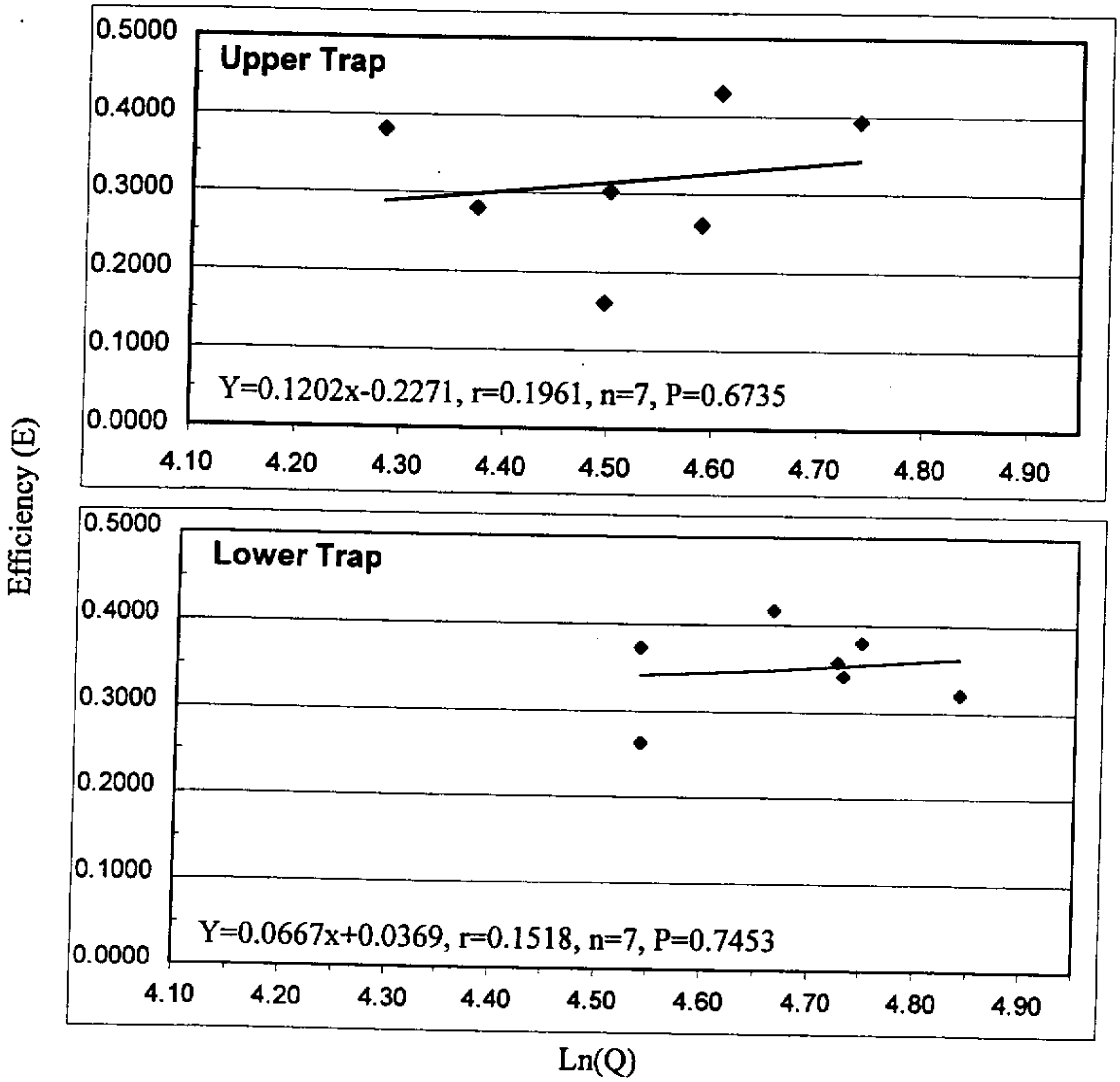
Appendix B. Results of linear regression correlating discharge with gage height.



Gage readings and corresponding discharge estimates used for regression.

Upper Trap		Lower Trap	
Gage (m)	Discharge (cfs)	Gage (m)	Discharge (cfs)
0.200	94.93	0.480	116.87
0.225	115.24	0.500	145.07
0.120	56.97	0.370	81.70

Appendix C. Trap efficiency versus natural log of stream discharge (Ln(Q)), with regression, for upper and lower traps on Goldsborough Creek, April-June 2000.



Influence of discharge on trap efficiency was evaluated with simple linear regression, which used results of mark-recapture efficiency samples (Table 2), and average discharge estimates for the time period between release and 80% cumulative recapture (Appendix D). Average discharges were natural log (Ln) transformed, and analysis of variance (ANOVA) for regression used to assess the significance of the relationship (α=0.05).

Appendix D. Daily catch of marked fish used for efficiency and mortality estimates. See Table 1 for release locations.

Release date	Recapture Dates	Number caught
Upper trap		
4/14	4/15	4
	4/16	3
	4/17	4
Total		11
4/17	4/20	3
	4/21	4
	4/24[1]	10
	4/26	2
	5/2[1]	1
	5/5	1
	5/17[1]	1
	5/20	1
Total		23
4/27	4/28	4
	5/1[1]	2
	5/2	1
	5/5	1
Total		8
5/5	5/6	26
	5/7	12
	5/10	2
	5/12	1
	5/14[1]	1
	5/18	1
Total		43
Upper trap (cont.)		
5/11	5/12	7
	5/14[1]	6
Total		13
5/20	5/21	13
	5/22	10
	5/23	4
Total		27
5/28	5/30[1]	5
	5/31	1
	6/4[1]	1
Total		7
Lower trap		
4/26	4/27	1
	4/28	2
	5/1[1]	3
	5/3	1
Total		7
4/26	4/27	1
	4/28	12
	4/30[1]	2
	5/2	1
	5/3	1
Total		17
Lower trap (cont.)		
4/28; 5/1	4/30	38
	5/1[1]	8
	5/2	57
	5/3	47
	5/4	34
	5/5	2
	5/6	4
	5/7	2
	5/9	3
	5/10	2
	5/11	3
Total		200
5/3	5/4	1
	5/5	4
	5/6	2
	5/7	1
	5/12	2
Total		10
5/3	5/4	4
	5/5	4
	5/6	3
	5/8	2
	5/10	1
	5/12	1
	5/14[1]	1
Total		16
Lower trap (cont.)		
5/10	5/12	6
	5/14[1]	6
	5/25	1
Total		13
5/10	5/11	1
	5/12	9
	5/14[1]	3
	5/15	1
	5/20	1
	5/25	1
Total		16
5/11	5/12	3
	5/14[1]	14
	5/15	2
	5/17	3
	5/18	1
	5/20	2
Total		25
Lower trap (cont.)		
5/18	5/19	3
	5/20	8
	5/21	2
	5/23	1
	5/25	1
	5/26	1
	5/28[1]	1
Total		17
5/18	5/19	2
	5/20	2
	5/21	2
	5/22	2
	5/23	2
	5/25	1
	5/26	1
	5/28[1]	1
Total		13
5/25	5/26	1
	5/28[1]	3
	5/30[1]	1
Total		5
5/25	5/28[1]	7
	5/30[1]	1
Total		8

[1] Traps were not checked every day prior to this. Neither trap was checked on the following days: April 22, 23, 29; May 13, 27, 29; July 3, 8, 10, 15, 17, 19, 21, 22. In addition, the lower trap was not checked on April 15 or July 13. The upper trap was not checked on April 30.