ANNUAL REPORT
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DEVELOPMENT OF ENGINEERED STREAMS FOT SALMON PRODUCTION

for

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II. ABSTRACT

This project is a demonstration of a new concept that combines the benefits of hatcheries and natural habitat to improve salmon production. In collaboration with the WDFW, development of engineered streams is proposed by UI/WSU as a long-range alternative to standard hatcheries for supplementation of weak or failing wild salmonid populations. The objectives are to provide natural-type engineered streams for coho salmon production that result in wild smolt quality and to monitor performance as a demonstration project for the new hatchery concept. The approach is to develop artificial streams for use as salmon habitat with engineering specifications based on the biological criteria of the species targeted, while maintaining genetic specificity, diversity, and natural smolt quality. The artificial stream is meant to substitute for, or be used in conjunction with, standard hatchery raceways. Natural feed is to be encouraged, supplemented with artificial diets at needed based on fish loading density and performance. The site selected is Hatchery Creek located immediately behind the WDFW hatchery on the Dungeness River. A channel was constructed with habitat structures, pools, riffles, and cover to mimic natural coho habitat. Approximately 50,000-eyed eggs were introduced in the spring of 2001 and newly emerged fry were distributed over the length of the channel by the first part of June. Monitoring will include assessment of growth, condition factor, residence patterns, relative size of fish leaving the channel compared to those in residence, and survival to migration as smolts. The distribution of fingerlings and use of the various habitat types will be quantified through snorkel surveys throughout the summer and fall. Post-migration monitoring will involve adult return success based on thermal marks applied to embryo otoliths at the eyed egg stage.

III EXECUTIVE SUMMARY

Project 00-00412 “Development of Engineered Streams for Salmon Production” was established under the Hatchery-Scientific Research Program (HSRG) and administered by the Office of the Interagency Committee to development and monitor engineered streams as part of a research effort to improve hatchery production. The University of Idaho in cooperation with the Washington State Department of Fish and Wildlife and Washington State University designed and constructed an engineered stream for rearing coho salmon. The project goal is to produce wild-type quality coho salmon using engineered habitat, and in numbers that exceed production efficiency per unit of area of natural streams.

Engineered streams are natural type channels that contain the necessary components of coho salmon rearing habitat such as pools, riffles, and large woody debris. Engineered streams are meant to combine the benefits of hatcheries and natural type stream habitat with the intention of improving the quality of hatchery fish. The channel design allows for flow control and reduction of the silt bedload passing through the system.

This project is divided into two subprojects: construction and monitoring. Construction had the primary objective of developing a channel capable of rearing coho salmon with a minimum of routine maintenance. The resulting engineered stream is 930 feet long, and has an average discharge of 3 cfs.   The monitoring portion of the project had several objectives including: 1) to measure the density of coho using the stream channel, 2) to measure the number and condition of coho produced in the engineered habitat, and 3) to compare return rates of coho produced in engineered habitat to return rates of hatchery coho.   The monitoring portion of this project was started in May, 2001 and will be funded under IAC number 01-1002N.

Fertilization with carcasses was implemented to enhance natural food production. Cursory examination indicated that the invertebrate population was responding in the new habitat with a growing biomass in the system. The impact of fertilization is uncertain, but some feeding off carcass parts was also observed. Invertebrates thus far comprised the bulk of available food during the early part of the study. However feeding

on artificial diets appears to be a major element in their feeding behavior, and in some locations is the dominant source of food sought by the fry.

IV PURPOSE

Hatcheries have been identified as one factor contributing to the decline of wild salmon stocks. There are a number of ways that hatchery operations may impact wild salmon. One way is through the release of large numbers of juveniles into rivers leading to competition with and displacement of wild juveniles already present in the system. Hatchery fish are often larger and more aggressive than there wild counterparts and as such compete for food and space. Hatchery fish are released in large numbers as smolts to compensate for the generally low return rates, compared to wild smolts . Conceptually, if hatcheries can improve the return success of adults, hatchery production could be reduced in number of juveniles released and thus reduce the impact of hatchery fish on wild stocks, and do so without reducing the number of adult fish returning to the hatchery or taken in tribal, commercial and sport fisheries.

Fish raised in a hatchery experience an environment that is very different from that found in a river. Habitat is minimal, fish densities are high, water velocity is low, and there are no predators or conditioning to the natural conditions that will be experienced when released. Although survival in the hatchery is very high, when released their survival is poor at least in the riverene environment. Wild fish have low incubation and early rearing survival, but as migrants and ocean-resident fish their survival is much higher than the hatchery counterpart. This project, therefore, attempts to combine the benefits of hatcheries with the benefits of natural habitat with the goal of producing wild-type coho that demonstrate survivability as smolts comparable to wild fish, but showing presmolt survival closer to the hatchery situation.

This project is divided into two portions: construction and monitoring. First phase construction had the objective of developing an engineered stream capable of rearing coho salmon with a minimum of routine fish husbandry. Construction was completed by mid-winter, and the channel was seeded with approximately 50,000-eyed eggs in tray incubators placed at the head end of the channel.

The second portion of the project had three primary objectives: 1) to measure the density of coho using the stream channel, 2) to measure the number and condition of coho produced in the engineered habitat, and 3) to compare return rates of coho produced in engineered habitat to return rates of hatchery coho. Monitoring has been ongoing for 6 weeks. This report presents information relating to construction and early monitoring.

V APPROACH

Project Site Description

The project site is adjacent to the Dungeness Fish Hatchery near Sequim Washington. The project site was located on an inactive flood plain. The area was covered in dense vegetation including mature deciduous and coniferous trees. Water for the new channel originates from Hatchery Creek, a small return flow from an irrigation canal. Hatchery Creek is the return point for adult fish returning to the Dungeness Hatchery.

Engineered Stream Design and Construction

Site Topographic Survey

The site topographic survey was necessary to establish site elevations needed for design of the diversion and channel. A total of 2900 individual elevations were recorded. In addition, the bypass channel boundary, and water surface elevations were measured. The position of large trees was also established, to be included in the meander of the channel.

Design, Fabrication and Construction

The engineered channel consist of four components: 1) the bypass creek diversion, 2) the diffuser and settling basin, 3) the channel system, and 4) the tail works. Each is described below.

Bypass Creek Diversion

The intake structure was designed to satisfy four primary objectives: 1) pass water and fish downstream into the bypass creek, 2) deliver water to the engineered rearing channel, 3) prevent juvenile salmonids from leaving the bypass creek and entering the engineered rearing channel, and 4) meet screening requirements set forth in RCW 75.20.040 and 77.16.220.

The intake structure design criteria included: 1) a maximum bypass channel discharge downstream of the intake structure of 10 cfs, 2) a maximum rearing channel discharge of 10 to 15 cfs, 3) velocity through he screen not to exceed 0.4 feet per second (fps), 4) a maximum screen opening of 1/32 of an inch, and 5) open area of screen shall be greater than 27%.

Flows in the rearing channel must be balanced against the rearing needs, the screening specifications, and intake size. A maximum-screened flow of 6 cfs was assumed. Larger flows are possible when the screens are not in place. Based on these criteria, a screen with 41% open area and 1/16 inch holes on 3/32 inch staggered centers was chosen. With a water depth of 2 feet, a total screen area of 37 ft^2 was required. This equates to a structure length of 18.5 feet. The width is 8 feet, and the depth is four feet with a flow depth of 2 feet. The entire structure is constructed of aluminum.

The 12-inch PVC pipe used to convey water from the diversion structure to the engineered rearing channel was estimated to have a maximum capacity of 10 cfs. The elevation difference between the diversion structure and engineered rearing channel was 5 feet.

Excavation for the diversion structure required that the existing bypass creek be rerouted. A six inch corrugated flexible culvert was installed to route water around the construction site. Flow was reduced in the bypass creek from approximately 4 cfs to 1 cfs while the bypass structure was being installed. The bypass channel contained water at all times during the construction of the channel. Approximately 110 cubic yards of soil was excavated for the diversion structure and 12 inch PVC pipe installation.

Settling Basin and Diffuser

A settling basin was installed at the beginning of the engineered natural channel. A flow diffuser was fabricated from aluminum and installed at the head of the settling basin. The flow diffuser was intended to distribute energy and provide for even flow throughout the length of the settling basin. A maximum velocity of 1.5 fps was set as a design target. This velocity will be met at flows of 6 cfs or less.

The settling basin was designed for a maximum flow of 6 cfs with a length of 24 feet and width of 12 feet. Average velocity was calculated at 0.4 fps with a detention time of 60 seconds. A particle size of 0.3 mm was assumed to be the minimum size requiring removal from the water supply. Stokes Law was used to estimate the settling velocity of this size particle. With a detention time of 60 seconds, a 0.3 mm particle will settle 2.4 ft which is greater than the design depth of 1.25 feet. The result is that particles of 0.3 mm or larger will be settled in the settling basin at flow of 6 cfs or less. Flows greater than 6 cfs will reduce the effectiveness of the settling basin.

The total storage volume of the settling basin was calculated to be 384 ft^3. Based on evaluation of the critical tractive force on deposited sediment, it was determined that sediment will not be resuspended when the storage capacity is reached. Construction of the settling basin required the excavation of approximately 40 yd^3 of soil.

Engineered Stream

Discharge of the bypass channel was equal to 4.24 cfs in June of 2000. Based on discussions with hatchery personal this was estimated to be a typical flow for the bypass channel. The bypass channel was estimated to be able to convey a maximum flood flow of 25 cfs. A minimum of approximately 4.5 cfs is available for the bypass channel year around, with more available during high flow periods in the Dungeness River. The amount of water available for the engineered rearing channel is limited by the amount of water in the bypass channel. A characteristic flow was developed for the engineered rearing channel based on hydrograph data for the Dungeness River and the amount of water available from the bypass creek. The characteristic flows used to design the engineered rearing channel were the seven day average low flow (Q7L), average annual flow (QAA), and one day average flood flow (Q1F). The typical operating flow for the engineered rearing channel was assumed to be the QAA.

Based on the Dungeness River hydrograph, the Q7L is 0.3QAA, and the one-day average flood flow is 5.05 QAA. Design flows for the rearing channel were calculated based on these ratios, and a chosen QAA. The QAA chosen for the engineered rearing channel was 3 cfs. Based on the average monthly discharge for the Dungeness River, ratios of the QAA monthly target flows were developed (Table 1).

Table 1: Monthly average flows shown as a ratio to average annual flow for the Dungeness River.

Flow	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mon Max	1.48	2.30	2.43	2.85	2.76	2.17	1.38	2.37	3.17	2.22	1.38	0.96
Mon Mean	0.49	0.73	0.99	0.94	0.84	0.64	0.80	1.48	1.84	1.30	0.68	0.45
Mon Min	0.26	0.23	0.31	0.20	0.28	0.35	0.45	0.77	0.77	0.47	0.34	0.25

For the engineered rearing channel, a QAA of 3 cfs was used to calculate the average monthly flow (Table 2) based on the ratios in Table 1. Channel cross sections were initially developed using hydraulic geometry relationships for the Dungeness (Table 3).

Table 2: Monthly average flows (cfs) for the engineered rearing channel

Flow	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mon Max	4.44	6.90	7.29	8.55	8.28	6.51	4.14	7.11	9.51	6.66	4.14	2.88
Mon Mean	1.47	2.19	2.97	2.82	2.52	1.92	2.40	4.44	5.52	3.90	2.04	1.35
Mon Min	0.78	0.69	0.93	0.60	0.84	1.05	1.35	2.31	2.31	1.41	1.02	0.75

Table 3: Hydraulic geometry relationships for the Dungeness River.

Flow	Width	Depth	Velocity
Q7L	$W=9.55(Q)^{0.5}$	$D=0.32(Q)^{0.30}$	$V=0.33(Q)^{0.19}$
QAA	$W=4.82(Q)^{0.47}$	$D=0.26(Q)^{0.35}$	$V=0.80(Q)^{0..18}$
Q1F	$W=3.44(Q)^{0.42}$	$D=0.13(Q)^{0.44}$	$V=2.24(Q)^{0.14}$

For a QAA of 3cfs, the dimensions obtained using these relationships were unrealistic since channel width for Q7L was consistently estimated to be larger than for QAA. In fact, the channel width for Q7L is closer to the Q1F than to QAA. The end result was that the channel cross section had to be estimated assuming a QAA of 3 cfs and a maximum flood flow of approximately 10 cfs. For a straight reach of channel, the bottom width was set at 2.5 feet and the top width set at 6.5 feet. Assuming a velocity of 3.3 fps this channel would carry 14.5 cfs, which is below the estimated flood flow of 10 cfs.

The final plan form of the engineered rearing channel was a combination of straight and curved reaches with transitions between the two reaches. The straight reaches were characterized as runs and riffles, while the curved portions were deep pools. The total channel length is approximately 900 feet, and total area is 8,600 ft^2. The mix of habitat and area are shown in Table 4. Figure 1 presents a schematic of the channel.

Tail Works

A tail works was fabricated from aluminum and installed at the bottom end of the engineered channel. There are two removable screens installed in the tail works that are intended to minimize juvenile fish movement from the engineered rearing channel. In addition, a fyke net was installed at the tail works to capture fish leaving the channel thus allowing enumeration of daily out migration.

Table 4: **Habitat developed in the engineered stream.**

Habitat Type	Total Length (%)	Total Area (%)
Run	31.4	21.1
Riffle	17.1	10.3
Pool	12.4	19.8
Alcove	20.5	7.3
Pond	18.5	41.5

Egg seeding

Approximately 50,000 eggs were planned for the initial seeding of the channel. Eyed coho eggs were obtained from the Dungeness Hatchery, and thermally treated to mark the otoliths of the developing embryos. The eggs were placed in screen bottom trays stacks over the inlet diffuser just beneath the water surface.

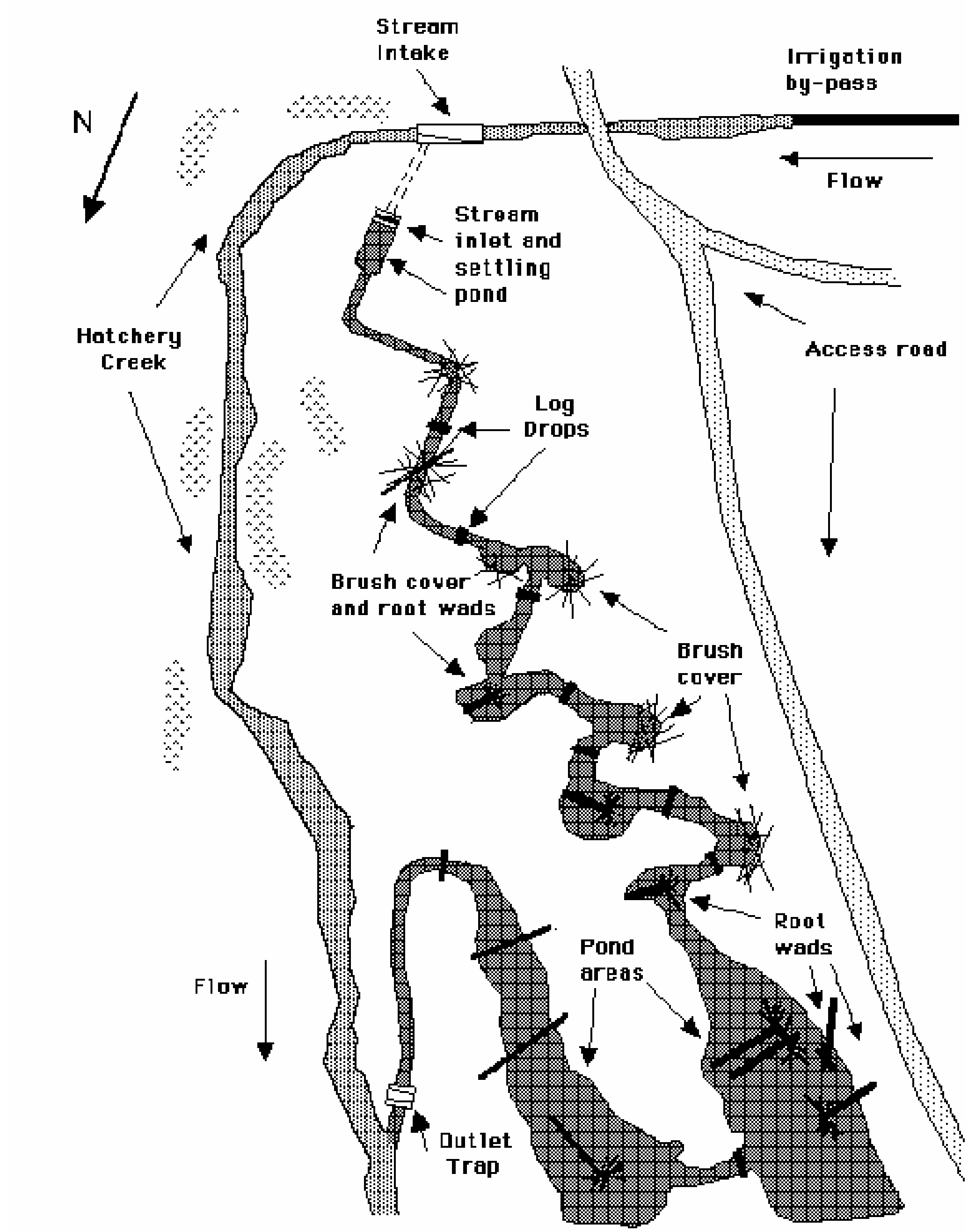

Figure 1: Schematic of the engineered stream

Project Management

The project team consisted of The University of Idaho, Washington State University, Washington State Department of Fish and Wildlife, and River Masters Engineering. The University of Idaho was the primary contractor and provided project coordination, planning, design, construction, and monitoring. Washington State

University provided guidance on hydraulics and channel evaluation. The Washington State Department of Fish and Wildlife provided the project site, permits, and daily monitoring. Specifically, the Dungeness River hatchery complex manager is providing daily monitoring and maintenance. The habitat division will be participating in density surveys. Finally, River Masters Engineering (Pullman WA) provided channel design, intake and tail works design and fabrication, and participated in construction of the project.

VI FINDINGS

The first portion of the project (construction) is complete. There were no significant problems. Additional work that may include modification of the intake structure, and additional habitat improvement such as more cover and woody debris.

The second portion of the project has now started. Monitoring is planned to assess: 1) habitat use, 2) daily out-migrant counts 3) monthly estimates of growth, 4) relative size and condition of out-migrants versus resident fish, 5) snorkel survey to determine density of fish in the channel, and 6) evaluation of adult return rates. Juveniles emerged approximately on May 15th, 2001. The newly emerged fish quickly dispersed throughout the channel. Fish caught in the trap were transported back to the top of the channel for the first three weeks. Thereafter, the fish caught in the trap are enumerated and released downstream of the trap. Daily fish counts are shown in Figure 2. Evacuation from the channel is expected to continue as biomass increases.

The final assessment of residence prior to smoltification next spring will provide the basic carrying capacity estimate under the present conditions provided in the channel. One monthly estimate of fish weight and length has been made. This is accomplished by placing six minnow traps in the channel, and fishing them for 90 minutes. A minimum of 30 fish are collected from the entire channel, and then measured. The results of the first month’s growth are shown in Figure 3 compared to fish caught in the out-migrant trap. There is a statistically significant difference between fish leaving the channel and fish remaining in the channel. Fish that remain in the channel are longer and weigh more. The largest fish are a gram in weight, which demonstrates a rapid growth. A large amount of variability is apparent among the fry, which is no doubt related to the range of time between the first and last of the emergence period, and the variability in feeding aggression among the cohorts.

The snorkel survey is planned for the summer of 2001. This survey will estimate the total number of fish in the channel, as well as how the channel is being used. Estimates of return rates cannot be made until adults return. Fish in the channel now will leave in the spring of 2002 as smolts and will not return until the fall of 2003. At that time it will be possible to estimate return rates.

VII EVALUATION

The goal of constructing an engineered stream suitable for rearing coho salmon was achieved. There were no modifications to this portion of the projects goals or objectives. The process of evaluating the channel has just started. Next years report will allow evaluation of the all objectives, excluding adult return rates.

The results of this project will be disseminated via per reviewed literature, graduate thesis, and on the University of Idaho Aquaculture Research Institute web page

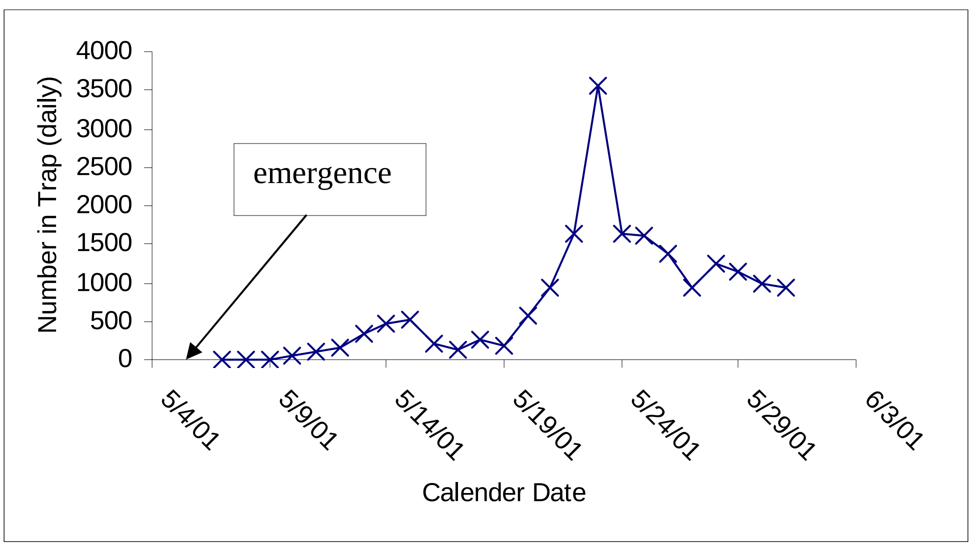

Figure 2: Daily trap counts for the Dungeness hatchery engineered stream.

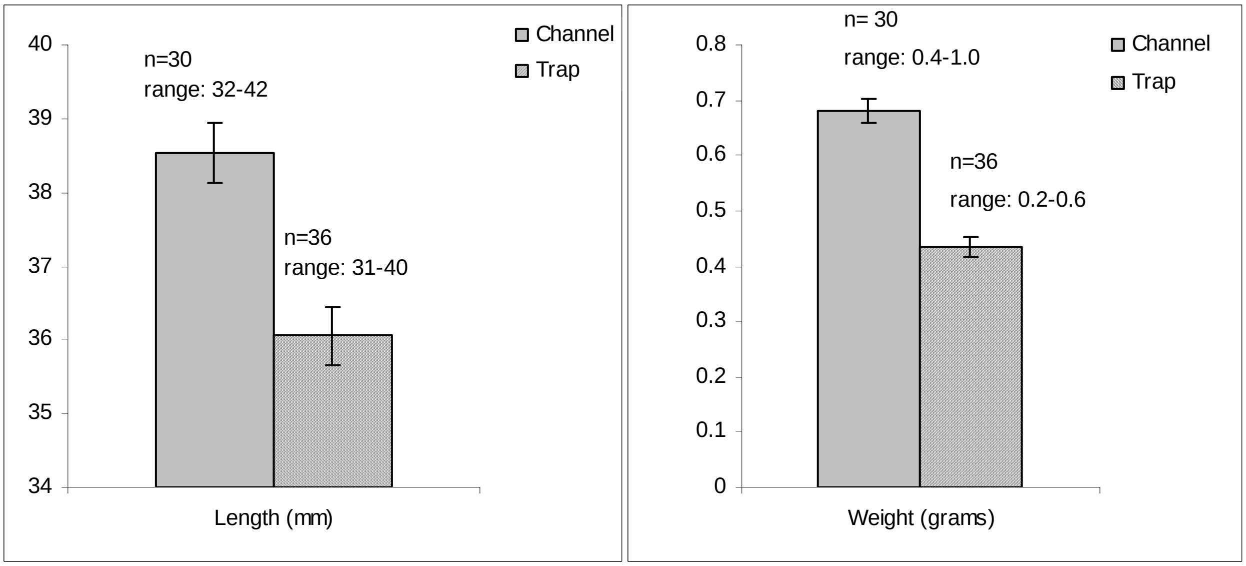

Figure 3: **Weight and length comparisons for fish leaving the engineered stream (trap) versus fish measured in the channel (channel). Error bars are standard error. Differences are significant ($p < 0.001$) using the Wilcoxon rank sum test.**