Final Report

Assessment of Factors Limiting Salmon Production in Devil's Hole Creek

Prepared for

The Department of the Navy Submarine Base,
Bangor, Washington

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Introduction

The Washington Department of Fish and Wildlife Wild Salmon Production Unit was contracted by the Navy in 1998 through 2000 (Navy contract #'s N6871198LT80043, and N6871199LT90019) to provide a species and habitat assessment and corrective design project for the Devil's Hole watershed on the Naval Submarine Base, Bangor, Washington. The purpose of this project was to identify species use and determine factors negatively affecting salmon production in the Devil's Hole watershed and to recommend corrective measures for these factors.

This is the final report for the project. It describes the methods and results of the species and habitat assessment work conducted during the spring through summer periods of 1999 and 2000. Elements evaluated included current fish use of the watershed, summer stream temperatures, spawning habitat quality, macroinvertebrate indicators, bank and riparian conditions, channel morphology, stream habitat condition, fish passage conditions, and the location/impact of point source discharges for all of the stream network accessible to anadromous salmonids as well as most of that used by resident salmonids. The report also describes factors we believe are most limiting to anadromous salmonids and provides recommendations for corrective measures to improve utilization and survival of salmonids in the Devil's Hole watershed.

Site Description

The Bangor Naval Submarine Base is located adjacent to Hood Canal on the northern Kitsap Peninsula (Figure 1). The facility is 6,692-acres in size. The site was first purchased by the Navy in 1942. After serving as a U.S. Ammunition Depot for a number of years, the site was established as a submarine base in 1977. The base has grown substantially during the 1990's as a result of Base Closure and Realignment actions in 1991 and 1993.

The entire Devil's Hole Creek watershed is within the Bangor Submarine Base complex (Figure 1). The mainstem Devil's Hole Creek travels in a northerly direction before entering Hood Canal approximately 1/4-mile southwest of the Delta Pier. The watershed is located in township T26N, range R1E, sections 18, 19, 20, and 30; and township T26N, range R1W, sections 24 and 25. Total area of the watershed is 2.61 mi^2 (United States Geological Survey data).

A reservoir was created near the mouth of the stream in the 1940's when Sea Lion Road was constructed (Tom James pers. comm.). The reservoir, Bangor Lake or Devil's Hole Lake, has a surface area of about 2.6-hectares (Wolcott 1961). A fishway was constructed at the lake outlet in 1979 to provide access to the watershed for anadromous salmonids (Tom James pers. comm.). Potentially fish-bearing stream channels in the watershed include the mainstem Devil's Hole Creek and five un-named tributaries (Figure 2). Four of the tributaries are right-bank tributaries (i.e., enter Devil's Hole Creek from the right-side of the stream when looking downstream) and one is a left-bank tributary. These have been arbitrarily named for identification purposes as RB1-4 and LB1. RB1 enters Bangor Lake, while the other tributaries enter Devil's Hole Creek upstream of the reservoir.

The climate in the region has a strong maritime influence characterized by cool, dry summers and mild, wet winters. Precipitation averages 50 to 65-inches per year with over 98% falling in the form of rain (WDNR 1995). Only 5 to 10% of the annual precipitation occurs between July and September.

The watershed has been highly influenced by the advance and retreat of continental glaciers over the last two million years. Surficial sediments have been primarily influenced by the most-recent Fraser Glacier, which occurred from 15,000 to 13,500 years ago. Sedimentary deposits left by the glacier include unconsolidated outwash (comprised of sands and gravel), till, and lacustrine deposits (primarily comprised of silt and clay) (WDNR 1995). Of these, outwash deposits with a high composition of sand are particularly common in the Devil's Hole watershed and have a substantial effect on channel morphology and fish habitat.

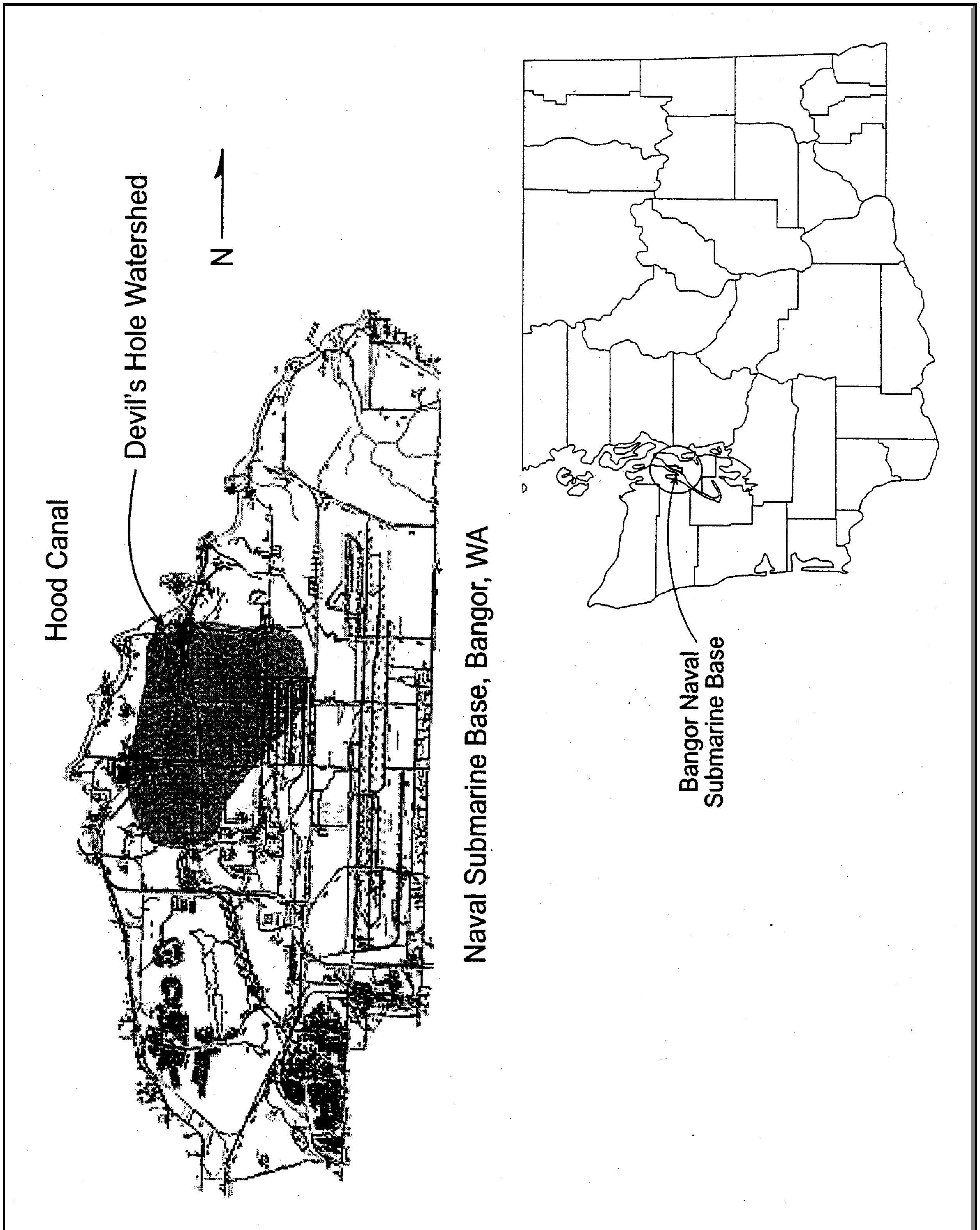

Figure 1. Location map of the Devil's Hole watershed and the Naval Submarine Base, Bangor, Washington.

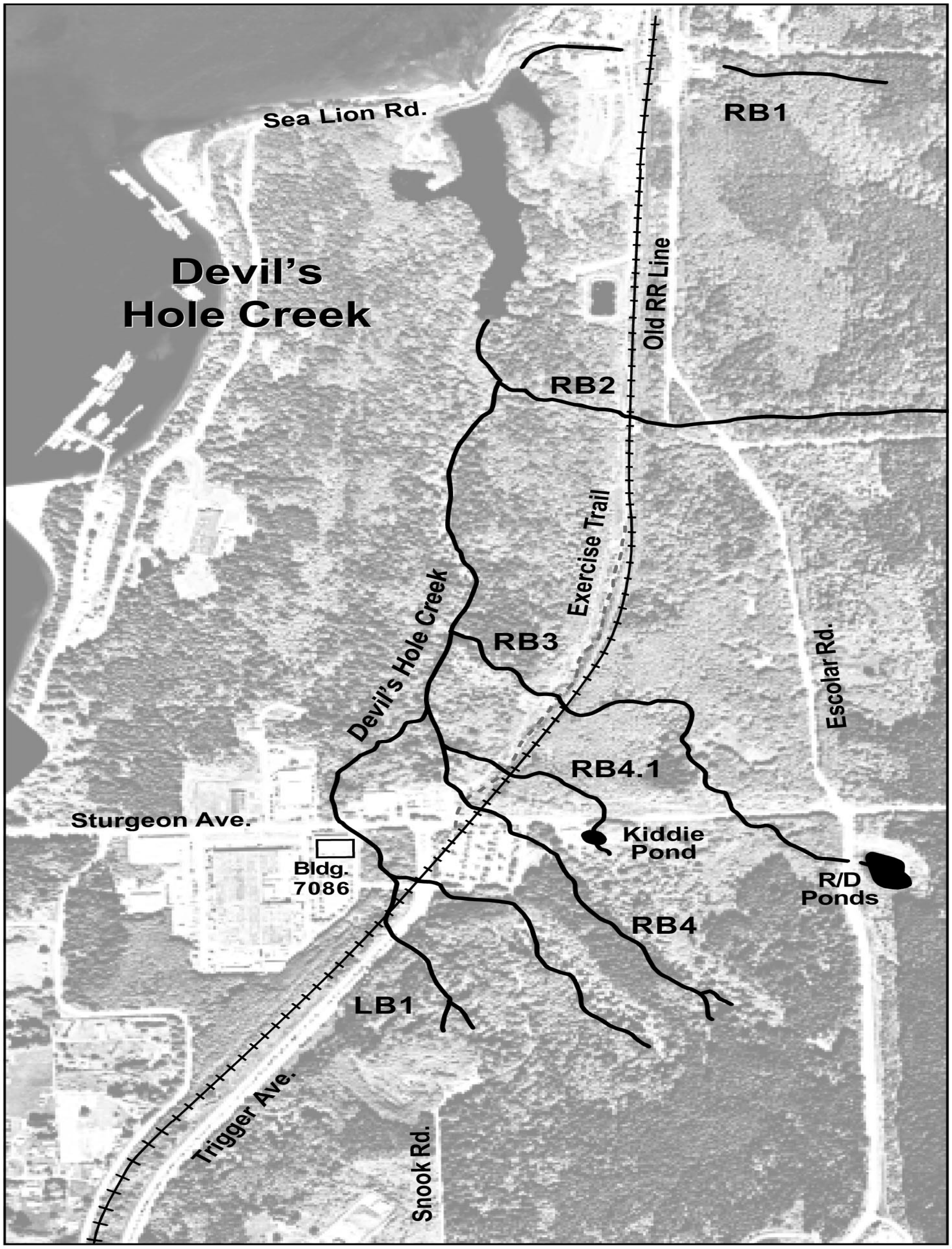

Figure 2. Streams in Devil's Hole Creek Watershed

Objectives

The overall objective of the project was to collect sufficient information on current physical and biotic conditions of aquatic resources and land-use within the Devil's Hole Creek watershed to enable our development of hypotheses regarding factors limiting salmonid production in the basin and to recommend measures to correct or improve these conditions. We carried out this work in 1999 and 2000. An assessment of current anadromous fish use and habitat conditions were completed during the late summer of 2000. Synthesis of the data collected, development of hypotheses regarding factors limiting use and freshwater survival of salmonids, and recommendations for improving conditions for salmonids was completed in the fall of 2000.

The project objectives were as follows:

Assessment

Downstream Migrant Fish Trapping - *Determine current anadromous fish use and juvenile production levels by trapping all downstream migrants.*

Lake Survey - *Evaluate current fish use of Bangor Lake.*

Summer Low Flow - *Measure base flow as a indicator of summer rearing potential.*

Stream Temperatures - *Monitor temperature through the summer to evaluate it as a potential factor affecting survival.*

Habitat Surveys - *Evaluate spawning and rearing habitat, channel, bank, and riparian condition, migration access, and point-source discharge sites for potential factors limiting survival in all or most stream habitats currently or potentially available to anadromous salmonids.*

Macroinvertebrate Sampling - *Evaluate the macroinvertebrate assemblage in the watershed to provide an indication of stream health and potential limiting conditions.*

Synthesis, Conclusions, Recommendations

Synthesis - *Analyze the data and observations to describe conditions affecting fish use of the watershed and freshwater survival.*

Conclusions - *Develop hypotheses regarding factors limiting freshwater production in the Devil's Hole watershed.*

Recommendations - *Develop a prioritized set of recommendations for actions to correct or improve conditions affecting the production of anadromous salmonids in the basin.*

Assessment

This section describes the assessment activities conducted in 1999 and 2000, the methods used, and the results of this work.

Fish Use and Productivity of Anadromous Salmonids

Two approaches were used to evaluate current anadromous salmonid production levels and fish use of Devils Hole Creek and Bangor Lake. The first approach employed a downstream-migrant fish trap in the fish ladder at the outlet of Bangor Lake to capture salmonid smolts migrating to saltwater for the marine rearing phase of their life. The trap was operated from early April through early to mid-June in 1999 and 2000. The second approach was a Standardized Lake Survey (Bonar et al. WDFW draft report) of Bangor Lake performed in September, 1999, to assess summer use by resident and anadromous fish, and to evaluate the presence of any predatory species.

Downstream Migrant Fish Trap

Methods

Water leaves Bangor Lake from two separate outlets. The primary outlet is a vertical, rectangular concrete shaft that maintains the lake level. Fifty feet north of the primary outlet is a fish ladder, or fishway. Both outlets were modified in 1999 and 2000 to enable a count of all fish emigrating from the lake during the trapping period. The fishway was modified to accept the fish trap. The primary outlet was modified to prevent fish from leaving the lake by that route. The trap was operated from April 9 to June 15 in 1999 and from April 10 to June 2 in 2000.

A trap box was installed into the top step of the fish ladder which remained fish-tight until it was removed at the end of the trapping period each year. The box consisted of a 4-ft x 4-ft x 6-ft frame constructed with aluminum angle (2-in. x 2-in. x 1/4-in.), and covered on all sides except the top with 1/8-in. thick, slotted aluminum plate (1/8-in. x 1-in. oblong slots, side-staggered). Inside the box, a net pen was hung to reduce the potential for injury during removal. The net pen measured 4-ft x 4-ft x 5-ft and was made of 1/8-in. knot-less nylon mesh.

The intake at the top of the fish ladder was blocked with a 2-ft x 4-ft aluminum-framed screen, covered with 1/8-in. slotted aluminum plate (same as trap box). The screen was open in the center where a 6-in. round aluminum coupling was welded to provide an opening for migrating fish. Fish passing through the coupling entered an attached 6-in. diameter PVC pipe which transported them to the trap box. The screen was placed into the stop log guides at the top of the fish ladder so the coupling was completely submerged by about one inch. The trap box was secured into place with 2-in. by 6-in. boards wedged between the fish ladder walls.

The water level in the top step of the ladder was about a foot lower than the lake level which caused considerable head and resulted in substantial turbulence in and around the trap box. To correct this problem, we reduced the amount of water entering the trap box by drilling holes into the bottom of the PVC pipe. We also hung a piece of aluminum plate on the outside of the box directly below the PVC pipe to deflect water entering the fishway through the intake screen.

Other modifications to the fishway include attaching a piece of plastic to the downstream end of the PVC pipe to keep the entering fish from contacting the sides of the net pen and to prevent fish already in the pen from hitting the pipe when jumping at the cascading water. In addition, two large overflow ports built into the fish ladder just north of the intake were covered with perforated aluminum plate (3/16-in. holes on 1/4-in. staggered centers) to prevent fish from escaping; however the lake level never reached these ports during the trapping period.

The primary outlet consisted of a vertical concrete rectangular shaft, approximately 9-ft deep, connected to a concrete bulkhead on shore. The shaft is 8-ft wide with a 36-in. wide stop log bay in the middle that extends the full depth of the shaft. The shaft extends 52-inches into the lake. To prevent fish from escaping, all of the water exiting the lake through the primary outlet was passed through a screen. The screening structure consisted of a 4-ft square aluminum box, covered with perforated aluminum plate, that was lowered into the stop log guides on the outside of the structure until only the top six inches remained above the water. Two inch by twelve inch boards were placed around the top outside edge of the outlet shaft to prevent water from exiting around the screen box. Two C-clamps secured the box to the stop log guides, and two cables ran from the top outside corners back to the bulk head on shore for added support. Two 6-in. stop logs were removed from the outlet from within the screened area of the box to make up for the water being retained by the timbers around the edge of the outlet .

The trap was checked periodically, generally every two or three days. At each trap check, all of the fish were removed from the net pen. The fish were identified, counted, and released into the fishway. Fork lengths were taken from a sample of the captured salmonids.

Results

In 1999, we captured 64 coho smolts and 4 cutthroat trout, along with a few freshwater sculpin and three-spine stickleback. The migration started slowly, with only 5 coho and 1 cutthroat captured in April. The coho migration peaked around the third week of May, then dropped off quickly (Figure 3). In 2000, 64 coho smolts were again captured along with 1 steelhead smolt and 2 cutthroat trout. The majority of the coho smolts (94%) were captured between April 25 and May 14 (Figure 4).

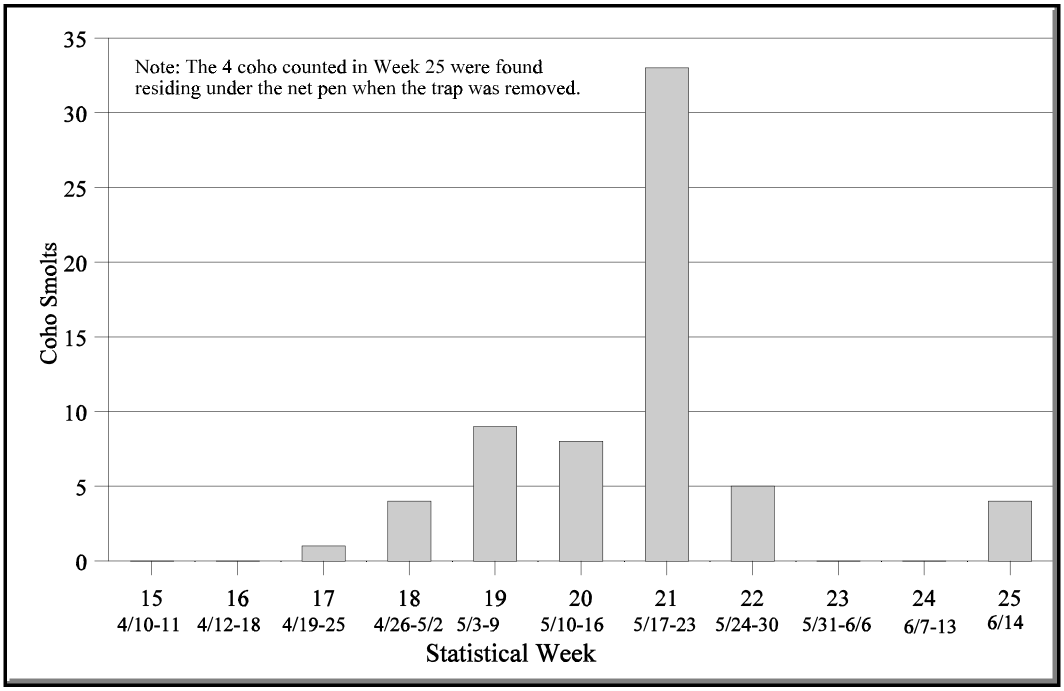

Figure 3. Weekly juvenile coho migration from Bangor Lake, 1999.

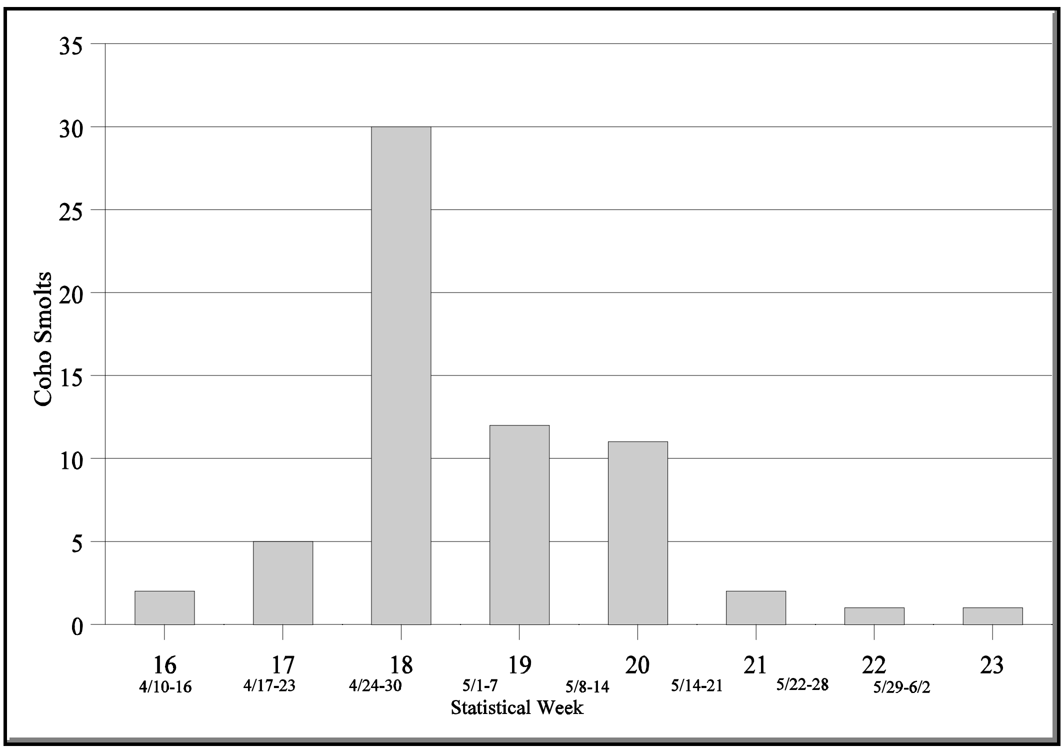

Figure 4. Weekly juvenile coho migration from Bangor Lake, 2000.

All of the coho captured over both seasons were very large. Scale samples were taken to determine the age of the four largest fish captured in 1999. Coho salmon typically emigrate from Washington streams as 1-year olds. Scale analysis showed that only the very largest fish sampled (192 mm) was a two-year old, so we believe that the majority of the migrating coho were simply large one-year olds. In 2000, a 300-mm coho smolt was captured in the fish trap. An exact age determination was not made for this fish, however, it was likely two to three years old. It was the only coho sampled in 2000 that we believed was two years old or older.

In 1999, the coho smolts ranged from 141 to 192 mm, and their mean size was 164-mm (Figure 5). In 2000, yearling coho smolts ranged from 138 to 188-mm and averaged 164-mm. By comparison, the largest mean size for coho smolts migrating from the four other east side Hood Canal streams which WDFW trapped in 1999 (Little Anderson Cr., Big Beef Cr., Seabeck Cr., and Stavis Cr.), was 111-mm (Big Beef Creek). The extremely large average size is most likely attributed to low population densities and a fertile rearing environment found in Bangor Lake.

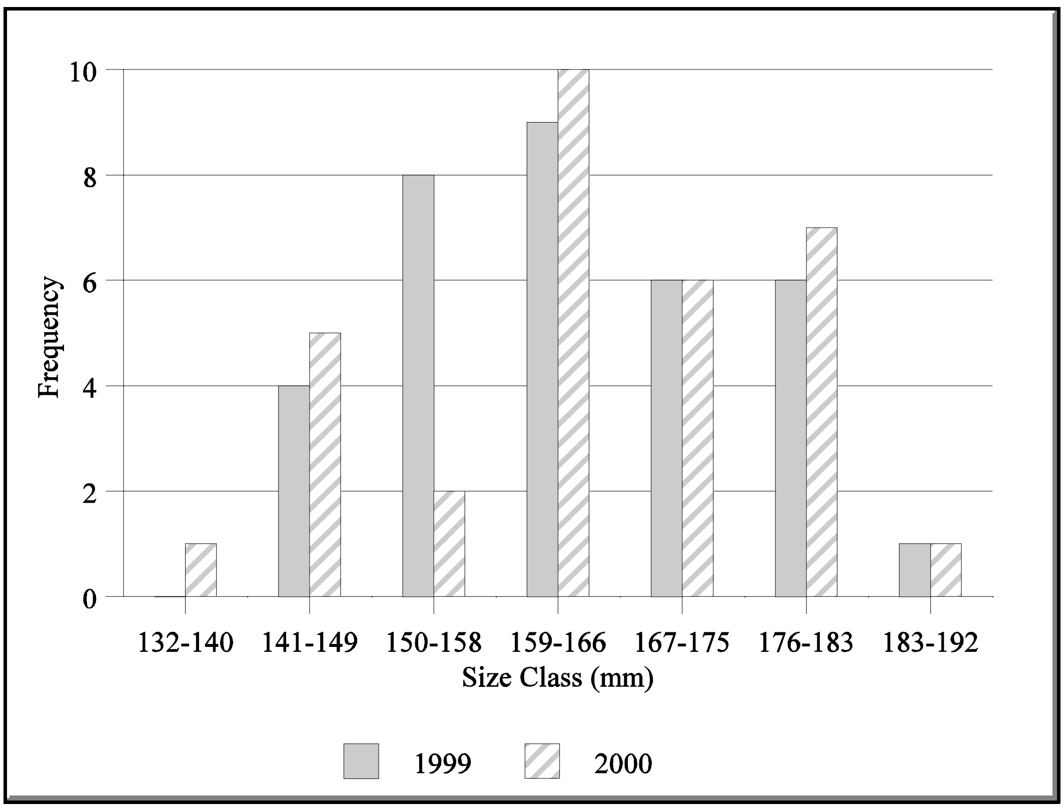

Figure 5. Length-frequency distribution of smolt fork lengths from coho captured in the Devil's Hold fishway trap, 1999 and 2000.

We believe that the 128 coho smolts captured represents virtually all the coho smolts produced from Devils Hole Creek in 1999 and 2000 as the entire outflow was continuously screened over the trapping intervals. No coho were captured during the first ten days or during the final fifteen days of trapping in 1999 nor during the first four days or final five days trapped in 2000 indicating little if any migration before or after trapping. Coho production this low could have been produced by as few as a single spawning pair each year.

Besides coho, 4 cutthroat were captured in 1999 and 1 steelhead and 2 cutthroat were captured in 2000. No other salmonids were observed trying to migrate either upstream or downstream. June 15, 1999, the day the fish ladder trap was removed, was opening day of lake fishing on the base. We interviewed three fishers that had been fishing for approximately 3 hours. Their catch consisted of four wild cutthroat, ranging from 16 to 20-inches, and one hatchery-reared rainbow trout, identified as being of hatchery origin by its deformed fins. The rainbow may have escaped from the Kiddie Pond, a small stocked fishing pond, located near Sturgeon Street, that drains into the RB4.1 tributary (Figure 2).

Lake Survey

Methods

WDFW's Standardized Lake Survey was performed in 1999 to identify lake-resident fish species, anadromous salmonids using the lake for summer rearing, or otherwise, any species not encountered during the downstream trapping season (Bonar et al., WDFW draft report). The survey employed electrofishing, baited traps, and a sinking gillnet to sample fish present in the lake.

The survey was conducted on the evening of September 21, 1999. A WDFW electro-fishing boat was used to collect a representative sample of fish found along shoreline habitats to determine the species composition of these habitats. The electro-fishing was conducted at night, because many species of fish have a tendency to move into the shallow shoreline areas at night, making them easier to capture using electro-fishing gear (Scott Bonar, pers. comm.). Fork length and weight were measured from a subsample of the captured fish. After collecting biological information, fish were revived in freshwater and released. To capture the fish in the middle of the lake and in water too deep for the electro-fishing, we deployed a gill net and eighteen baited minnow traps (fyke traps). The gillnet was retrieved after approximately 2-hours of fishing time. The minnow traps were retrieved the next morning after fishing for 14-hours. Fish captured with the gillnet were also measured and weighed prior to release. Minnow trap captured fish were identified, counted, and released.

Results

Fish captured by electrofishing included 21 cutthroat trout, 6 coho salmon, 1 rainbow trout, 41 sculpin, and 6 three-spine stickleback (Table 1). The juvenile coho were large with an average length and weight of 170-mm and 55-g, respectively. Cutthroat trout were also large, with an average fork length of 267-mm. Cutthroat ranged from 205-mm to 392-mm (Figure 6). The gillnet and minnow traps appeared to be more species selective. Only two cutthroat were captured in the gillnet. Fish captured in the minnow traps included 98 sculpin and 1 stickleback.

Table 1. Species, average size, and average weight of fish captured during the Standardized Lake Survey, Bangor Lake 1999.

Species	Statistic	Electrofishing	Gillnet	Minnow Trap
Cutthroat	# Caught	21	2	0
	Avg Length (mm)	261	335	n/a
	Avg Weight (g)	145	n/a	n/a
Coho	# Caught	6	0	0
	Avg Length (mm)	170	n/a	n/a
	Avg Weight (g)	55	n/a	n/a
Rainbow	# Caught	1	0	0
	Avg Length (mm)	89	n/a	n/a
	Avg Weight (g)	9	n/a	n/a
Sculpin	# Caught	41	0	98
	Avg Length (mm)	104	n/a	Not Measured
	Avg Weight (g)	17	n/a	Not Measured
	Avg #/Trap			5.4
Stickleback	# Caught	6	0	1
	Avg Length (mm)	47	n/a	Not Measured
	Avg Weight (g)	2.5	n/a	Not Measured

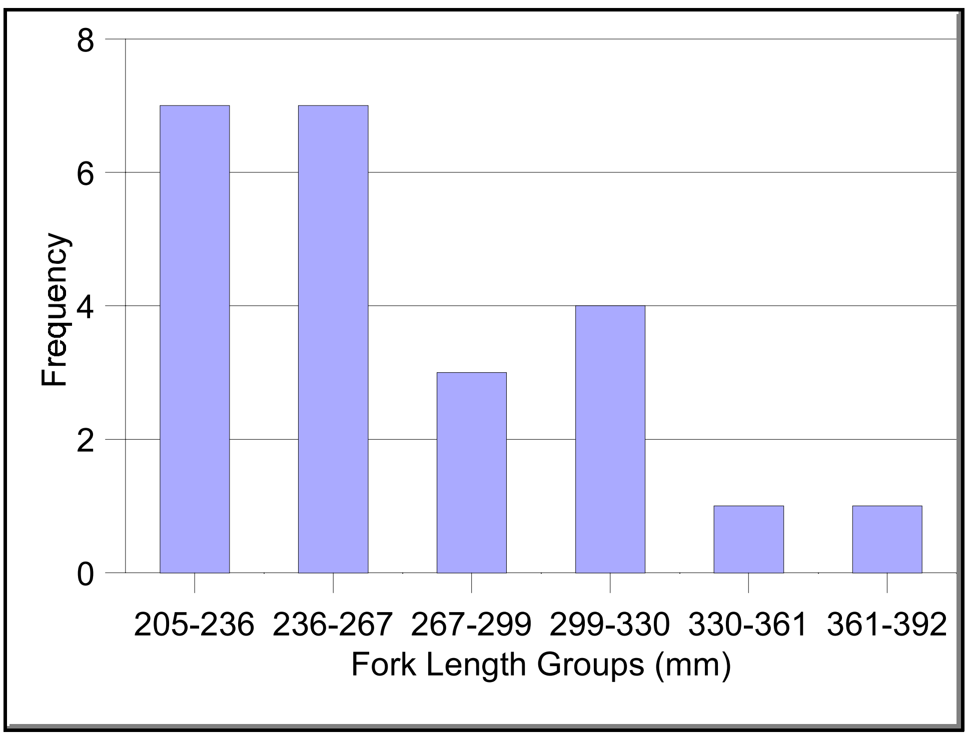

Figure 6. Length frequency distribution for cutthroat trout captured by electrofishing and gillnet, Bangor Lake, 1999.

The maximum depth found in the lake was 3-meters. Temperatures at the time of the survey ranged from nearly 16C at the surface to 13.6C at 3-meters in depth.

Summer Low Flow

Methods

Summer base flow was measured in the mainstem Devil's Hole Creek and in RB1 on September 24, 1999. Flows were not recorded during the 2000 field season. Flow on the mainstem Devil's Hole Creek was measured approximately 130-meters upstream from its confluence with Bangor Lake, just downstream from the mouth of RB2. Flow in RB1 was taken at the downstream end of the first culvert upstream from the mouth of the creek. Flows at both sites were taken using a Swoffer model 2100 flow meter using wadable discharge measurement techniques (Pleus 1999). The purpose of these measurements was to quantify and document summer low-flow and the stage at which stream habitat surveys were performed.

Results

Flow in Devil's Hole Creek and RB1 measured 3.89-ft^3/sec (cfs) and 0.93-cfs, respectively. Both streams appeared to have substantial flow given the size of their respective catchments. For example, average minimum annual flow in Big Beef Creek, which has a catchment of 13.23 mi^2, is 3.1 cfs. Interestingly, at the conclusion of taking flow measurements in RB1, flow in the stream increased dramatically for about one minute as we removed the equipment from the site. The magnitude of increase appeared to double the ambient stream flow and the water became more turbid. After about a minute, flow subsided to the background discharge level. These observations suggest a brief human-caused fluid discharge into the stream occurred. The origination of this discharge was not determined, but was reported to Tom James, SUBASE Bangor Wildlife Biologist by WDFW biologist Pete Topping a few days after the observation was made.

While stream flow was not measured in 2000, summer flows appeared similar to those observed in 1999. The relatively high summer stream flow in Devil's Hole Creek relative to other streams in the area suggest that the stream is well fed by groundwater.

Stream Temperatures

Methods

Stream temperatures were recorded in both 1999 and 2000. Temperature loggers manufactured by Onset were deployed in two locations within the basin on August 13, 1999. The first temperature logger was placed in Devil's Hole Creek approximately 125-meters upstream of

Bangor Lake. It remained in place until September 23, 1999. The second temperature logger was placed in RB4 approximately 10-meters upstream of the culvert at the Sturgeon Street crossing. This temperature logger remained in place until October 3, 1999. The loggers recorded stream temperatures every hour throughout the placement period with a resolution of +/- 0.2C.

Temperature loggers were again deployed in 2000. On May 11, 2000 a temperature logger was placed in Devil's Hole Creek approximately 5-meters downstream of the LB1 tributary confluence. It was retrieved October 5, 2000. On May 11, a second temperature logger was placed in Bangor Lake, approximately 12-meters north of the fishway, at a depth of about 2-meters. This logger was retrieved September 8, 2000.

Results

Temperature data shows Devil's Hole streams to be at near optimum temperatures for salmonids with little temperature variation (Figures 7, 8, and 9)(Spence et al. 1996, Bell 1991). The loggers were in place during the lowest flow period of the year. In 1999, the deployment period missed the hottest days of the year, however, periods of warm weather occurred while the loggers were in place with little response in stream temperature. The 2000 deployment in Devil's Hole Creek at the mouth of LB1 also showed little variation in temperature throughout the summer. The summer of 2000 was characterized as abnormally warm and dry, however, stream temperatures ranged between 9 and 12C.

Temperature in Bangor Lake ranged from 11 to 17C over the summer (Figure 10). The logger's location influenced the temperatures recorded. Based on temperatures recorded during the lake survey, surface temperatures are expected to be one to two degrees higher than temperatures found at two meters. Therefore, surface temperatures in the lake may reach 19C over the summer. Devil's Hole Creek and its tributaries are classified as Class A waters. Surface temperatures should not exceed 18C in streams, nor in reservoirs with a mean detention time of 15-days or less. We estimate a mean detention time of 4-days for Bangor Lake during the summer months. The detention time would be shorter during other times of the year; therefore, the 18C temperature criteria applies to the reservoir. Although the evidence is not conclusive, it is likely that the surface layer of Bangor Lake exceeds the state temperature criteria during periods of hot summer weather. Moreover, temperatures above optimal levels for salmonids may effect growth and fitness. Spence et al. (1996) suggest temperatures above 15.6C indicate a potentially degraded condition.

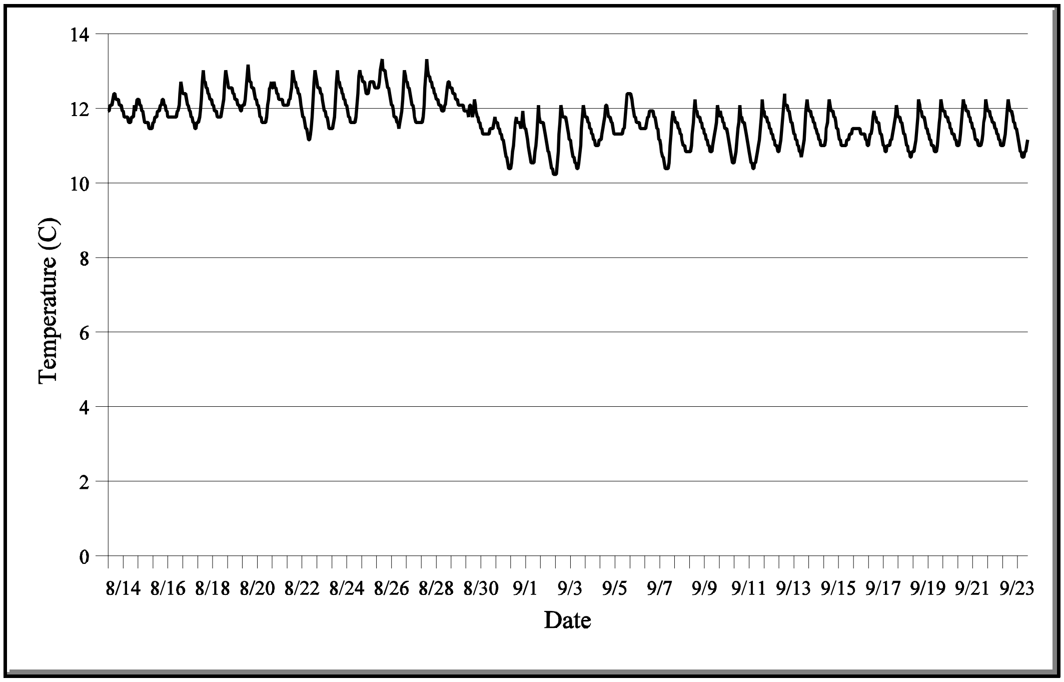

Figure 7. Summer stream temperature profile for Segment 3, Devil's Hole Creek, 1999.

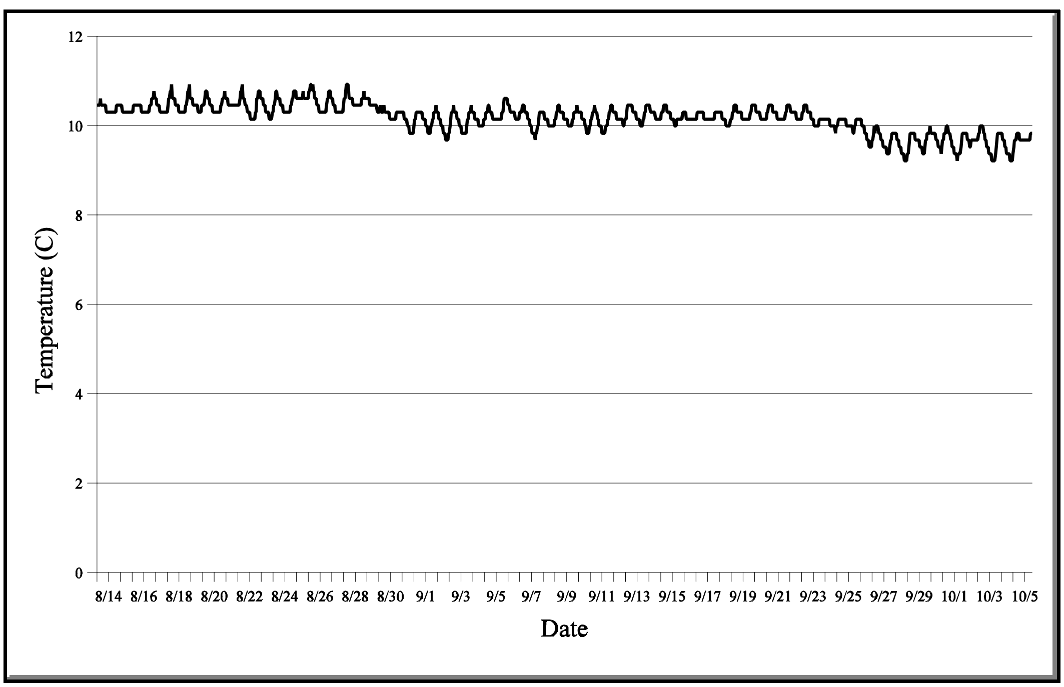

Figure 8. Summer stream temperature profile for Segment 2, RB4 tributary to Devil's Hole Creek, 1999.

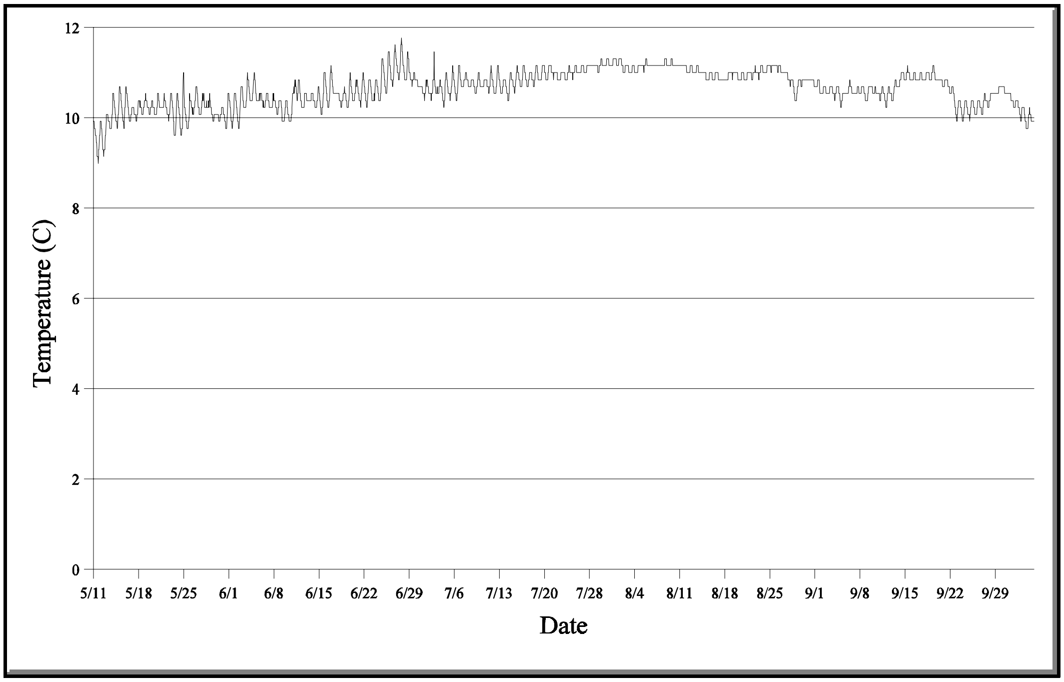

Figure 9. Summer stream temperature profile for Segment 6, Devil's Hole Creek, 2000.

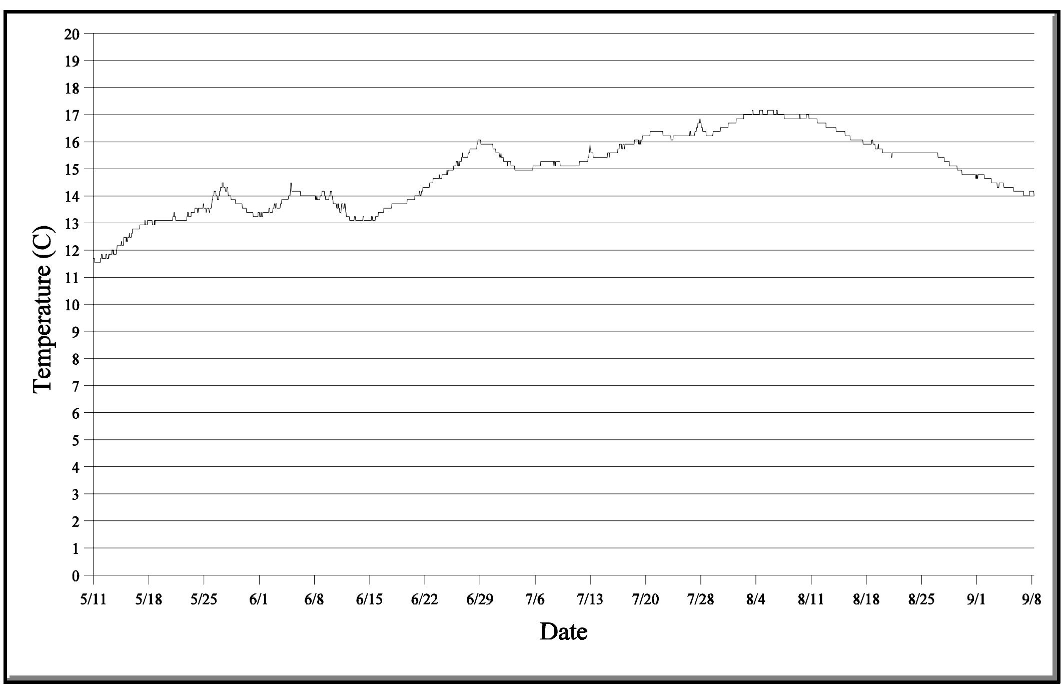

Figure 10. Summer temperature profile at 2-meters below the surface for Bangor Lake, 2000.

Habitat Surveys

Methods

The Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP) database was consulted to identify stream sections (or segments) within the Devil's Hole watershed with similar channel characteristics. Using the database, stream segments of similar size, gradient, and channel confinement were identified to facilitate the survey of discreet sections of stream with like conditions. These segments were then adjusted in the field based on actual conditions encountered.

Habitat assessment work was completed on the mainstem Devil's Hole Creek, LB1, and on part of RB4 during the 1999 field season. In 2000, RB2, 3, and 4 were completed. We did not survey RB1 since there is very little habitat available to salmonids. Habitat surveys progressed in an upstream direction on each stream until the stream became too small for use by anadromous salmonids or salmonids were no longer observed using the channel (Figure 11). Where the later condition occurred, surveys typically continued to the end of the reach above the point where fish were no longer observed. Seven segments were identified along the mainstem Devil's Hole Creek, two along LB1, one along RB2, two along RB3, two along RB4, and one along a right bank tributary to RB4.

Beginning at the downstream segment boundary, segments were broken into 100-meter long stream reaches to enable subsampling. Given that segments were delineated to include sections of the channel with similar flow, gradient, valley shape, and disturbance, reaches were fairly representative of the segment as a whole. During the survey of each segment, signs of human disturbance were noted. The channel was classified and the stream bank and stream bed substrates were noted for each reach. In addition, habitat condition, bank and stream-bed condition, and riparian condition were assessed by systematically sampling every third reach in the segment. Segments varied in length, therefore the total number of reaches within segments also varied (Table 2).

Reach-Scale Attributes

Attributes measured along reaches included channel classification, bank and stream bed conditions and substrates encountered, riparian conditions, and stream habitats (e.g., pools, riffles). Channel morphological variables that were measured by systematically sampling reaches within each segment were generally representative of conditions in the segment as a whole. This was not surprising since segments are defined by channel morphological features (i.e., gradient, confinement, flow) which are major determinants of habitat condition. Other major determinants include sediment supply, large woody debris (LWD), and riparian condition. Measures of riparian condition and the effects of sediment are described below. LWD was not measured during the assessments; however, the degree to which wood interacted with the channel to develop pools within each reach was rated as low, medium, and high.

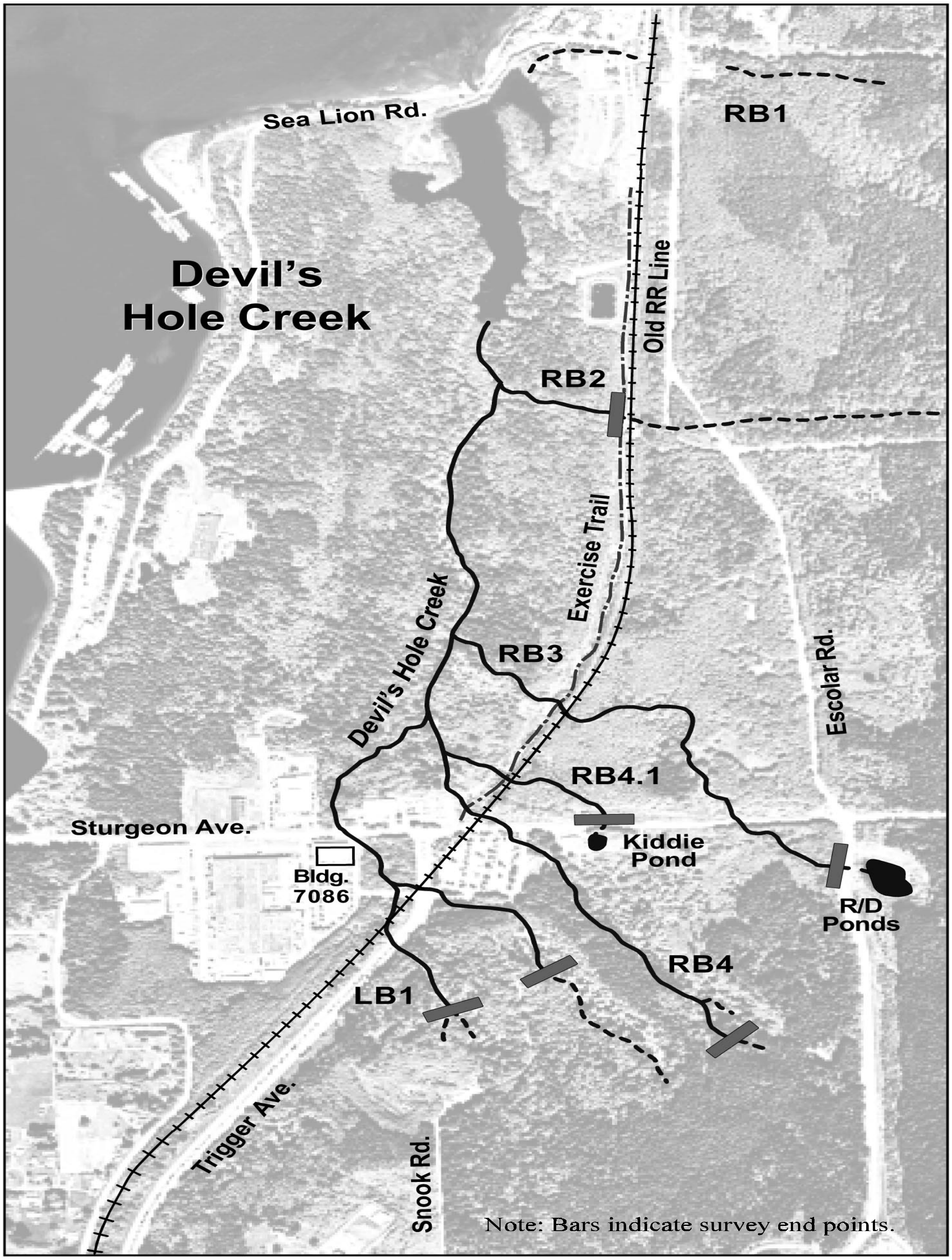

Figure 11. Devil's Hole Creek and tribuataries surveyed in 1999 and 2000.

Table 2. Segments and reaches identified and sampled during habitat assessments occurring in the Devil's Hole Creek watershed in 1999 and 2000.

Stream	Segment #	Length (m)	# of Reaches	Reach # Assessed	% of Segment Assessed
Devil's Hole Creek	003[1]	135	2	1	74%
	004	541	6	1, 4	37%
	005	190	2	1	53%
	006	812	8[2]	1, 4, 7	37%
	007	84	1	1	100%
LB1	001	200	2	1	100%
	002	100	1	1	50%
RB4	001	358	3[3]	1	28%
	002	543	6	1, 4	37%
RB4.1	001	276	3	1	36%
RB3	001	590	6	1, 4	34%
	002	222	3[4]	1, 2	62%
RB2	001	292	3	1	35%

[1] Segments 001 and 002 on Devil's Hole Creek included the fishway below the Bangor Lake and the lake itself, respectively. These were not part of the habitat assessment.
[2] Reach 8 was lengthened to 112-meters to avoid ending the reach within a culvert.
[3] Reach 3 was lengthened to 158-meters to avoid ending the reach within a culvert.
[4] Reach 1 was 38-meters and ended where the creek left the Sturgeon Street roadside ditch. Reach 3 was 83-meters and stopped at the Escolar Road crossing.

Channel Classification

Reach-scale assessment included channel classification. Montgomery and Buffington (1993) was used to classify reaches. This approach divides alluvial channels into six channel types based on bed morphology and LWD. These channel types, in order of increasing channel gradient include: regime, braided, pool-riffle, plane bed, step-pool, and cascade. The benefit of channel classification is that it enables a prediction of the channel response to change or perturbation of channel inputs such as LWD, sediment, and water quantity.

Pool-riffle channels are typically preferred by most salmonids for spawning and rearing. Pool-riffle channels often develop naturally in larger streams where the channel gradient is less than 2%. In smaller streams such as Devil's Hole Creek and its tributaries, pool-riffle channels may not develop unless "forced" by hydraulic controls such as rocks and logs which trap sediment and cause the scouring of pools. Reduced recruitment of LWD or increased sediment input may cause the forced pool-riffle segment to revert to a plane-bed or braided channel configuration.

Results

Channel types found in the Devil's Hole watershed include regime, braided, forced pool-riffle, plane-bed, and step-pool channels (Table 3). The regime channel type was found in Devil's Hole Creek Segment 3, just upstream from Bangor Lake. Regime channels are characterized by sandy bottoms with a dune ripple pattern forming in the sand. The channel is wide and unconstrained by valley walls, with very low gradient (0.5%), therefore, fine sand and other material that is transported from higher energy reaches upstream deposit in this channel type.

Further upstream, Segment 4 Reach 1 assumes a braided channel configuration (Table 3). The stream has a little more gradient than in the regime channel (1.1%) and is somewhat more constrained in its valley. Consequently, it has more energy to transport some of the more finer materials downstream to the regime channel. However, the net result of sediment input is an accumulation of transported sediment into this reach.

In Segment 7 Reach 1, just downstream of the Snook Road culvert, Devil's Hole Creek assumes a step-pool channel morphology. This channel type occurs in higher gradient channels where the stream energy organizes fairly regular accumulations of larger substrates and wood at intervals approximately equal to the width of the channel. The stream spills over these accumulations scouring a pool that terminates at the next accumulation. The gradient in Segment 7 Reach 1 is 7%. Another reach was found, RB2 Segment 1 Reach 3, that also has a step-pool morphology. This reach is located just downstream of the Exercise Trail culvert and has nearly a 9% gradient.

The remaining reaches surveyed were classified as either plane-bed or forced pool-riffle channels (Table 3). Plane-bed channels are characterized by long continuous riffle sections with very few pools. Their name comes from the geometric plane-like configuration that this very simple channel assumes. With the addition of LWD or reduction in sediment supply, plane-bed channels may assume a pool-riffle configuration. The forced pool-riffle reaches observed in the Devil's Hole watershed are a result of the hydraulic control provided by LWD. If the LWD were not present in these channels, they would quickly revert to plane-bed channels given the high sediment load carried in the Devil's Hole watershed.

When trying to assign a channel to either a plane-bed or pool-riffle category, it is often difficult because streams gradate from one class to the other. A channel with frequent pools is a pool-riffle channel. A channel characterized by continuous riffle habitats is a plane-bed channel. However, where a 100-meter reach has two or three pools in what is otherwise a riffle dominated channel, is that a plane-bed channel or a pool-riffle channel?

To help overcome this dilemma, we assigned a low, medium, or high (L, M, H) degree of forcing to each reach to indicate the level of wood or large substrates that are interacting with the channel to form pool habitats. Therefore, a channel assigned to the pool-riffle channel class that has a low degree of forcing will have few forced pool habitats in it, relative to a pool-riffle channel with a moderate or high degree of forcing. Low forcing was assigned to 73% of all reaches surveyed and 50% of reaches classified as pool-riffle channels. Moderately and highly forced conditions were found in 21% and 6% of reaches for all channel types and 33% and 17% of pool-riffle reaches, respectively.

Table 3. Channel classification and response to sediment input of reaches surveyed in the Devil's Hole watershed in 1999 and 2000.

Stream	Segment	Reach	Channel Classification	Degree Forced	Response to Sediment Loading
Devil's Hole Creek	3	1	Regime	Low	High deposition, low transport energy
	4	1	Braided	Low	High deposition, med-low transport energy
	4	2	Pool-Riffle	Low	Medium deposition, medium transport energy
	4	3	Pool-Riffle	Low	Medium deposition, medium transport energy
	4	4	Plane-Bed	Low	Med-low deposition, medium transport energy
	4	5	Pool-Riffle	Medium	Medium deposition, medium transport energy
	4	6	Pool-Riffle	High	Medium deposition, medium transport energy
	5	1	Plane-Bed	Medium	Med-low deposition, medium transport energy
	5	2	Pool-Riffle	High	Medium deposition, medium transport energy
	6	1	Pool-Riffle	Medium	Medium deposition, medium transport energy
	6	2	Pool-Riffle	High	Medium deposition, medium transport energy
	6	3	Pool-Riffle	Medium	Medium deposition, medium transport energy
	6	4	Pool-Riffle	Low	Medium deposition, medium transport energy
	6	5	Pool-Riffle	Low	Medium deposition, medium transport energy
	6	6	Pool-Riffle	Low	Medium deposition, medium transport energy
	6	7	Pool-Riffle	Low	Medium deposition, medium transport energy
	6	8	Pool-Riffle	Low	Medium deposition, medium transport energy
	6	9	Pool-Riffle	Low	Medium deposition, medium transport energy
	7	1	Step-Pool	Low	Low deposition, high transport energy
	7	2	Plane-Bed	Low	Med-low deposition, medium transport energy

Table 3. Continued

Stream	Segment	Reach	Channel Classification	Degree Forced	Response to Sediment Loading
LB1	1	1	Pool-Riffle	Low	Medium deposition, medium transport
	1	2	Plane-Bed	Low	Med-low deposition, medium transport
	1	3	Plane-Bed	Low	Med-low deposition, medium transport
	2	1	Pool-Riffle	Medium	Medium deposition, medium transport
RB4	1	1	Pool-Riffle	Medium	Medium deposition, medium transport
	1	2	Plane-Bed	Low	Med-low deposition, medium transport
	1	3	Plane-Bed	Low	Med-low deposition, medium transport
	2	1	Plane-Bed	Low	Med-low deposition, medium transport
	2	2	Plane-Bed	Low	Med-low deposition, medium transport
	2	3	Plane-Bed	Medium	Med-low deposition, medium transport
	2	4	Pool-Riffle	Medium	Medium deposition, medium transport
	2	5	Plane-Bed	Medium	Med-low deposition, medium transport
	2	6	Plane-Bed	Medium	Med-low deposition, medium transport
RB4.1	1	1	Plane-Bed	Low	Med-low deposition, medium transport
	1	2	Plane-Bed	Low	Med-low deposition, medium transport
	1	3	Pool-Riffle	Medium	Medium deposition, medium transport
RB3	1	1	Pool-Riffle	Medium	Medium deposition, medium transport
	1	2	Plane-Bed	Medium	Med-low deposition, medium transport
	1	3	Plane-Bed	Low	Med-low deposition, medium transport
	1	4	Plane-Bed	Low	Med-low deposition, medium transport
	1	5	Plane-Bed	Low	Med-low deposition, medium transport

Table 3. Continued

Stream	Segment	Reach	Channel Classification	Degree Forced	Response to Sediment Loading
RB3	1	6	Plane-Bed	Low	Med-low deposition, medium transport energy
	2	1	Plane-Bed	Low	Med-low deposition, medium transport energy
	2	2	Plane-Bed	Low	Med-low deposition, medium transport energy
	2	3	Plane-Bed	Low	Med-low deposition, medium transport energy
RB2	1	1	Pool-Riffle	Low	Medium deposition, medium transport energy
	1	2	Plane-Bed	Low	Med-low deposition, medium transport energy
	1	3	Step-Pool	Low	Low Deposition, high transport energy

Bank Condition

The Stream Reach Inventory and Channel Stability Evaluation developed by the US Forest Service was used to visually assess stream bank and channel bed conditions. Using this approach, fifteen indicators are numerically rated and the ratings summed to yield a total channel stability rating. These total ratings are groups into four classes: Excellent (# 38 pts.); Good (39 - 76 pts.); Fair (77 to 114 pts.); and Poor ($115 pts.). These classes are derived as a convenient way to group results for discussion. The rating itself is a continuum rather than one of four classes. The fifteen items that are rated are grouped into three channel strata: upper banks (floodplain), lower banks (from the wetted channel edge at low flow to the bankfull channel edge), and channel bottom (below the wetted edge). This rating was done for every third reach surveyed. In addition, the distribution of substrate sizes in the upper banks and lower banks/channel bottom were estimated for all reaches. Visual estimation was used to estimate the percentage composition of the substrate in each of the following size categories:

Category	Size Range
Boulder	>130-mm
Cobble	64-mm to 130-mm
Gravel	2-mm to 64-mm
Sand	0.85-mm to 2-mm
Silt/Clay	<0.85-mm

Results

Of the eighteen reaches scored, bank and bed condition was rated as “excellent” for zero reaches, five reaches (28%) were rated as “good”, eleven (61%) were rated as “fair” and two (11%) were rated as “poor” (Table 4). The main impacts to the scores were associated with lower bank cutting and channel bed scour and deposition. These features were less evident in the reaches receiving the “good” rating. For example, Devil’s Hole Creek Segment 6 Reach 7 passed through a grassy swale adjacent to a parking area located on the south side of Sturgeon Street. Banks and the channel were well protected from scour by the root strength and roughness provided by the grasses and other aquatic plants. While these features provided for adequate bank protection, they failed to provide for other riparian functions at this location (see Recommendation # 4).

Similarly, RB4 Segment 1 Reach 1 had a gradient of 4% which was steeper than most other reaches. Although bank cutting was evident, unlike other reaches, this reach appeared to transport most of the fine sand downstream probably as a result of the higher stream energy afforded by the higher channel gradient.

Table 4. Bank and channel bottom stability assessment scores for reaches withing the Devil's Hole watershed surveyed in 1999 and 2000.

	Assessed Reaches (segment/reach)																	
	Devil's Hole Creek							LB1		RB4			RB4.1	RB3				RB2
Element	**3/1**	**4/1**	**4/4**	**5/1**	**6/1**	**6/4**	**7/1**	**1/1**	**2/1**	**1/1**	**2/1**	**2/4**	**1/1**	**1/1**	**1/4**	**2/1**	**2/2**	**1/1**
Upper Channel Banks																		
Landform Slope	2	2	6	6	4	2	2	2	2	2	2	2	2	6	8	2	2	4
Mass Wasting Hazard	3	2	6	6	3	3	3	3	3	3	3	6	6	9	6	3	6	3
Debris Accumulation in Floodplain	2	2	2	2	6	4	6	6	4	4	4	4	2	6	4	2	4	2
Vegetative Bank Protection	3	3	6	6	6	9	3	3	6	6	12	6	9	9	12	3	6	3
Lower Channel Banks																		
Channel Capacity	4	3	2	1	1	1	2	3	1	1	1	2	1	1	1	1	1	2
Bank Rock Content	8	8	6	8	8	8	8	8	8	8	8	8	8	6	8	8	8	8
Obstructions and Flow Deflectors	8	8	6	4	6	6	4	4	4	4	6	4	6	4	6	4	4	4
Cutting	8	0	8	8	16	16	8	8	12	12	16	8	12	12	16	4	8	4
Deposition	8	8	8	8	4	6	4	4	4	4	12	8	4	4	16	4	4	4
Channel Bottom																		
Angularity	3	3	4	3	3	4	3	3	3	3	4	4	4	4	4	4	4	4
Brightness	4	4	3	4	4	4	2	4	3	3	3	3	1	3	3	2	2	2
Consolidation	8	8	6	6	8	8	6	8	8	4	6	8	4	6	8	4	4	4
Percent Stable Bottom Materials	0	8	8	12	16	16	8	16	8	8	16	16	8	8	12	12	12	8
Souring and/or Deposition	18	18	12	12	18	18	12	18	18	6	18	12	12	12	18	6	6	12
Aquatic Vegetation	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Total	**83**	**81**	**87**	**90**	**107**	**109**	**75**	**94**	**88**	**72**	**115**	**95**	**83**	**94**	**126**	**63**	**75**	**68**

Scoring: Excellent (# 38 pts); Good (39 - 76 pts); Fair (77 - 114 pts); Poor ($ 115 pts).

RB2 Segment 1 Reach 1 and RB2 Segment 2 also scored in the "Good" category. These reaches experienced little bank cutting relative to other parts of the Devil's Hole Creek watershed.

On the other hand, bank condition for RB3 Segment 1 Reach 4 and RB4 Segment 2 Reach 1 were rated as "poor". The reach on RB3 had very sandy banks. The channel was deeply incised, having downcut approximately three feet over much of its length. A similar situation existed on RB4 Segment 2 Reach 1 where the channel had downcut in places. A large blackberry thicket effected the stability of the banks by shading out plants that better anchor stream banks.

Throughout the watershed, sand and soil covered much of the banks. Sand accounted for 40% to 100% of the upper bank material and averaged 81% across the basin. Soil, silt, and clay averaged 8% of the bank substrate and ranged in composition from 0% to 60%. Gravel averaged 11% and cobbles represented 2% of the bank substrate across the basin. We observed few boulders and no bedrock in the banks.

Riparian Condition

During the survey of every third reach, an assessment of riparian condition was made for both banks of the stream. The assessment was designed to estimate average conditions for each bank over the reach using a visual estimation approach. Looking both downstream and upslope from the upstream end of each sampled reach, we recorded an estimate of the width of the riparian zone and the percentage of riparian coverage in each of five vegetation categories: conifer, hardwood, shrubs, brush, and grasses/forbs for each side of the stream. The width of the riparian zone was recorded as the number of meters upslope that could be inspected from the stream channel where the riparian zone was contiguous with the forested upland, or as the number of meters of riparian vegetation present before reaching a human-altered landscape (e.g., parking lot, landscaping, etcetera). Shrubs were considered to be native vegetation less than 10 to 15-ft high. Brush was considered to be non-native or vine-like vegetation such as Himalayan blackberry.

Results

Riparian condition in most areas was considered adequate for stream health. Most reaches had a mixed conifer/hardwood riparian zone consisting of mature or nearly mature trees. Conifer trees are particulary desirable in the riparian zone because they better provide for shade and large woody debris than other riparian taxa. Conifer composition was generally highest on the mainstem Devil's Hole Creek, where it ranged from 5 to 80%, and averaged 38%. Conifer trees made up a high percentage of the riparian zone in Segments 4 and 5. Upstream, riparian zone modification in the vicinity of Sturgeon Street and naturally wet areas resulted in a much reduced conifer component.

The conifer component in LB1, RB2, RB3, and RB4, averaged 15% across all streams. The riparian zones for the sampled reaches of these streams were affected by human modification in the vicinity of Sturgeon Street, Trigger Avenue, and the exercise trail/railroad line. In one reach of LB1, Segment 1, Reach 1, the stream traveled along the edge of a parking lot near Building 7086 (Figure 12) and was surrounded primarily by hardwoods and shrubs. The conifer component in this reach was 0%. The conifer component was also 0% or nearly so on RB3, upstream of the railroad crossing and upstream of Sturgeon Street where the stream travels adjacent to the road in a roadside ditch.

In some areas, the conifer component was naturally low. The best example is in the right bank tributary to RB4, downstream of Sturgeon Street and the Kiddie Pond. The stream flows through a wetland with a riparian zone consisting of reed canary grass, Himalayan blackberries, and hardwood trees adjacent to Sturgeon Street. Further downstream, the riparian zone includes more native vegetation such as alders, bear grass, and skunk cabbage. Soils in this area are too wet for conifer growth.

While the conifer component was moderate to low in some reaches, most reaches had a high tree component. Conifer and hardwood trees, together, averaged 70% coverage across all reaches surveyed. Blackberry canes were the dominant riparian vegetation in a few areas (Figure 12). Blackberries dominated the riparian vegetation on Devil's Hole Creek in the vicinity of the railroad tracks near Sturgeon Street. They were particularly pervasive on RB4 in the vicinity of the exercise trail and railroad track stream crossings, and further upstream behind the fire station, as well is on RB3 downstream of Sturgeon Street and Escolar Road. In these areas, almost all other forms of riparian vegetation were shaded out.

Rearing Habitat Attributes

Rearing habitat was measured in sample reaches using a habitat classification system defined by McCain et al (1990). This system involves visually identifying up to twenty-two different stream habitat types at the finest level of resolution. However, all habitat types are not present in most stream systems and the number of habitat types observed is usually a subset of these. The twenty-two habitat types can be stratified into coarser strata such as pools and riffles. Given that this system involves a degree of subjectivity in naming the individual habitat units, the Timber-Fish-Wildlife (TFW) Monitoring Program pool criteria was adopted to provide some consistency in the identification of pool habitats (Pleus et al., 1999).

The survey of every third (sampled) reach began at the downstream reach boundary and proceeded in the upstream direction. Each identified habitat unit was sequentially numbered, identified as main channel or side-channel habitat unit, and measured for length, width, and average depth. Length was measured using a stadia rod for shorter habitat units and a hip chain for longer habitat units. The wetted width and depth were measured using the stadia rod. If the habitat unit met the criteria for a pool, the channel element causing pool formation was identified. In addition, maximum depth and downstream riffle crest depth was recorded for pools

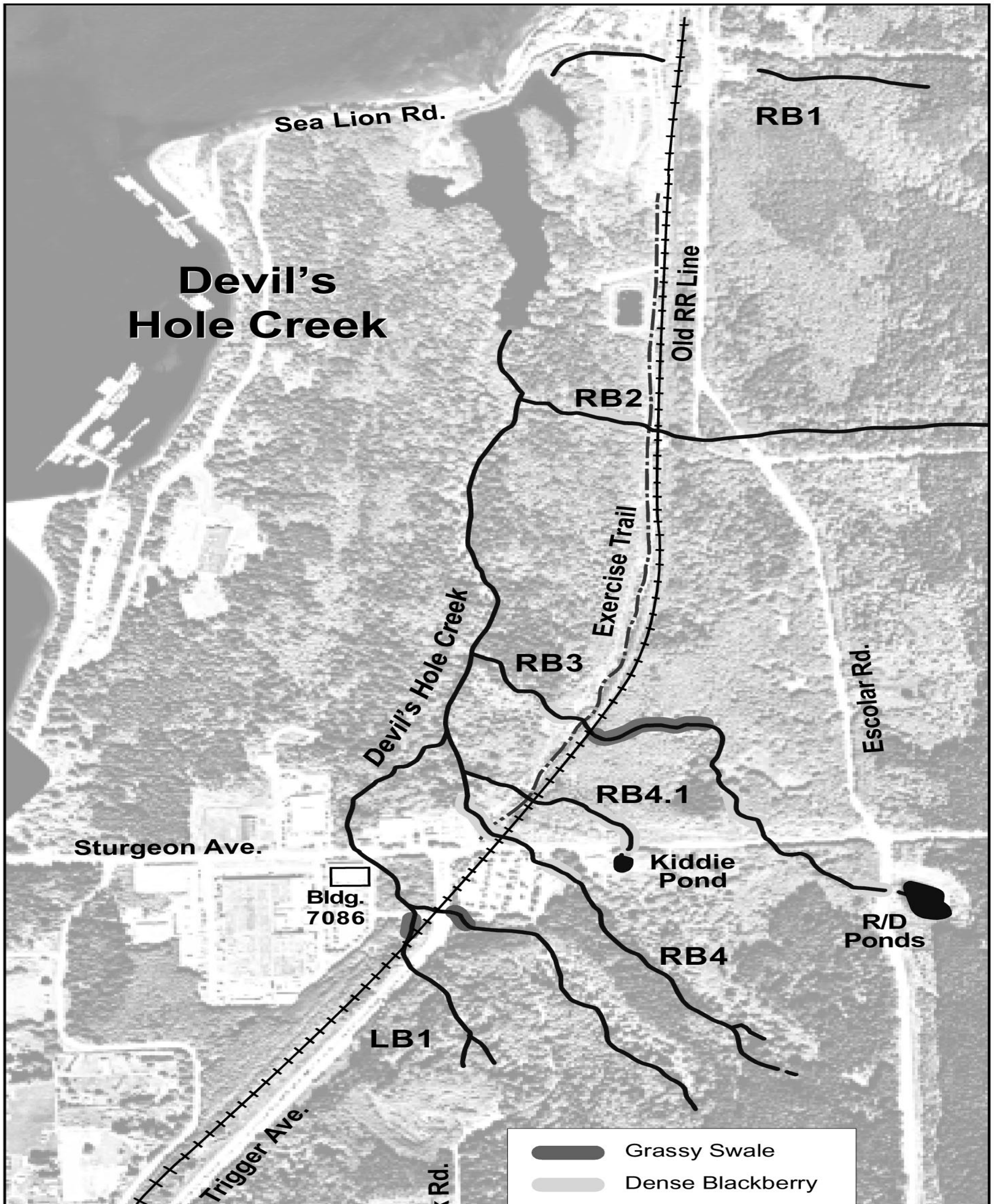

Figure 12. Problem Riparian Areas found in the Devil's Hole Watershed, 1999 and 2000.

to enable calculation of residual pool depth (i.e., depth of the pool if stream flow ceases). Finally, the percent pool cover is estimated and the complexity of cover is categorically rated. Cover was defined as areas that fish could hide under such as low over-water or in-water logs and vegetation, undercut banks, surface turbulence, and water of sufficient depth to obscure the bottom features. Cover complexity was rated from 1 to 5 based on the variety of cover types and the amount of surface area of cover present. A rating of 1 indicated very simple cover, 5 indicating very complex cover, and the other representing intermediate values.

Results

Over the 1999 and 2000 field seasons, a total of 1,814-meters of stream channel was surveyed in 19 reaches and 13 segments. Pool habitat accounted for 249-meters or 16.4% of the habitat by area (Table 5). Nearly all of the pool habitats were formed by woody debris. Eighty percent of the pools were classified as either wood-formed lateral scour pools, plunge pools, or dammed pools. On occasion, large cobble or small boulders contributed to the formation of pools, but these features were rare in the watershed. Of the pool habitat, 10.6%, or 1.3% of the total habitat area surveyed, was classified as step-run habitat. This habitat type was found in the higher gradient fish-bearing portions of the watershed and is not actually a pool habitat since their velocities are higher than is typically found in pools. It was classified as pool habitat for the purposes of this analysis since it functions as pool habitat in these higher gradient channels.

Table 5. Length, surface area, and proportion of the 1999 and 2000 surveyed portions of the Devil's Hole watershed in each observed habitat type.

Habitat Type/Sub-Type	Length (m)	Area (m^2)	Volume (m^3)	% Total Area	% Total Volume
Pools	**249.3**	**531.43**	**152.41**	**16.44%**	**19.15%**
Lateral Scour Pool - Log Formed	101.3	268.63	84.20	8.31%	10.58%
Lateral Scour Pool - Rock Formed	13.3	16.58	11.07	0.51%	1.39%
Lateral Scour Pool - Boulder Formed	2.3	3.11	0.54	0.10%	0.07%
Plunge Pool	71.8	133.21	38.71	4.12%	4.86%
Dammed Pool	26.8	57.57	9.71	1.78%	1.22%
Step-Run	26.4	40.82	5.57	1.26%	0.70%
Mid-Channel Pool	3.1	6.82	2.05	0.21%	0.26%
Corner Pool	4.3	4.69	0.56	0.15%	0.07%
Riffles	**1,564.6**	**2,701.19**	**643.6**	**83.56%**	**80.85%**
Low Gradient Riffle	1,380.0	2,250.46	565.88	69.62%	71.09%
High Gradient Riffle	7.5	12.75	1.79	0.39%	0.22%
Cascade	6.3	15.92	1.59	0.49%	0.20%
Glide	170.8	422.06	74.34	13.06%	9.34%
Total	**1,813.9**	**3,232.62**	**796.01**	**100.00%**	**100.00%**

The most prominent habitat feature found in the watershed are low-gradient riffles, which comprised 70% of the habitats identified by area. This is not surprising since a large proportion of the reaches surveyed were classified as plane-bed channels which are typically almost solely comprised of riffle habitats or by forced pool-riffle channels that exhibit a low degree of forcing.

Spawning Habitat

Methods

Salmonid spawning gravel composition was surveyed in the lower 435-meters of Devil's Hole Creek, above Bangor Lake, and in the lower 100-meters of RB4 in 1999. This section of Devil's Hole Creek was chosen because it represented the first spawnable habitat available to anadromous salmonids as they migrate upstream of the lake. RB4 was chosen because substrates appeared less affected by fine sediments here than in other surveyed portions of the Devil's Hole watershed. Together, these sites represented the first sites available to the fish and the best sites found in the watershed in 1999. No additional sampling was done in 2000. Other sites in the watershed were found with as good as, or better, spawning habitat than was sampled in RB4. However, the high composition of sand and fine sediment in the stream banks and beds throughout the watershed affected all reaches accessible to anadromous salmonids.

The survey was accomplished using modified TFW methods (Schuett-Hames et al., 1999). In each section of stream, the location and number of possible spawnable gravel patches measuring at least one square meter and dominated by gravels between 8-mm and 100-mm were determined. A subsample of six spawning patches was systematically chosen from the twenty-nine gravel patches found in Devil's Hole Creek. Three spawning patches were randomly selected from eight gravel patches found in RB4. In addition, three riffle crests from Big Beef Creek, located approximately 7-miles south of Devil's Hole Creek, were sampled to compare the Devil's Hole samples with samples from a relatively productive salmon stream in the area. These methods differ from the TFW method solely in the number of samples taken. The TFW method is designed for monitoring change and requires a higher level of precision, hence more samples, than was needed for this study where we were most interested in a general assessment of the condition of the spawning gravel.

The collection and processing of the samples followed the TFW method (Schuett-Hames et al., 1999). Each chosen gravel patch or riffle crest was sampled with a McNeil core sampler to collect a gravel sample for composition analysis. Samples were collected into a bucket with a sample label for identification during processing. Back at the lab, sediments in each sample were sorted by size using a set of Tyler sieves. The volume of material remaining on each sieve was measure by water displacement. Material that passed through the smallest sieve was left to settle with the wash water in a graduated cylinder for one hour, then the volume of the settled residue was read. These volumes were divided by the total volume of the sample to determine the percent composition of the material left on each sieve.

In addition to spawning gravel sampling, the bed substrate composition was visually assessed for most reaches surveyed. The percent composition of bedrock, boulder, cobble, gravel, sand, and silt/clay was recorded for each reach.

Results

Eleven of the twelve gravel samples taken were processed. We were unable to process one sample from Devil's Hole Creek. The sample contained a large amount of clay-mud that clogged the sieves and caused water and part of the sample to fall out of the sieve stack, ruining the results.

Sample analysis showed that samples taken from Devil's Hole Creek and RB4 had a much larger fraction of smaller size sediments than did Big Beef Creek (Figure 13). Excess fine sediments, grain sizes of less than 0.85-mm diameter, are considered deleterious to incubating salmon eggs. They fill the interstitial spaces between the larger gravels, preventing the flow of water and oxygen to the eggs, causing the eggs to suffocate (Spence et al., 1996). Sand and fine sediment can also act as a physical barrier to fry emergence and inhibit the removal of metabolic waste from the egg pocket (Koski 1975). Fine sediments in the five processed Devil's Hole samples averaged 39% and ranged from 30% to 55% (Table 6). Fine sediment from the three samples taken from RB4 averaged 27%. By comparison, those taken from Big Beef Creek averaged 15%.

Examination of surficial sediments for each reach indicated a high level of sand throughout the Devil's Hole watershed. Sand was estimated to comprise 20 to 90% of the bed substrate found in each reach. The best substrates found for spawning occurred in RB2, between 100 and 200-meters upstream from its confluence with Devil's Hole Creek; and RB4, over the first 200-meters upstream from the Sturgeon Street/Snook Road culvert. Both these areas combined a relatively low level of sand (<30%) with a high level of cobble or gravel and channel gradients of around 2%. There were other sites with relatively good spawning gravel, but channel gradients at those sites were over 3%, which is steeper than preferred by most salmonids.

While the high level of sand and fine sediments found in the Devil's Hole watershed samples undoubtedly have a negative impact on egg-to-fry survival, researchers have had a difficult time agreeing on the level of impact that results from these conditions. Egg-to-fry survival is highly variable relative to substrate size distribution. For example, Koski (1975) found a negative relationship between the percentage of sand and fine sediments in spawning habitat and egg-to-fry survival for chum salmon in Big Beef Creek. His regression equation predicts an average chum egg-to-fry survival of 12%, 32%, and 44% for Devil's Hole Creek, RB4, and Big Beef Creek, respectively using our substrate data. These survival rates may be somewhat optimistic for the Devil's Hole watershed. McHenry et al., (1994) measured egg-to-fry survival of coho and steelhead in Strait of Juan de Fuca streams and found less than 12% survival when fine sediments

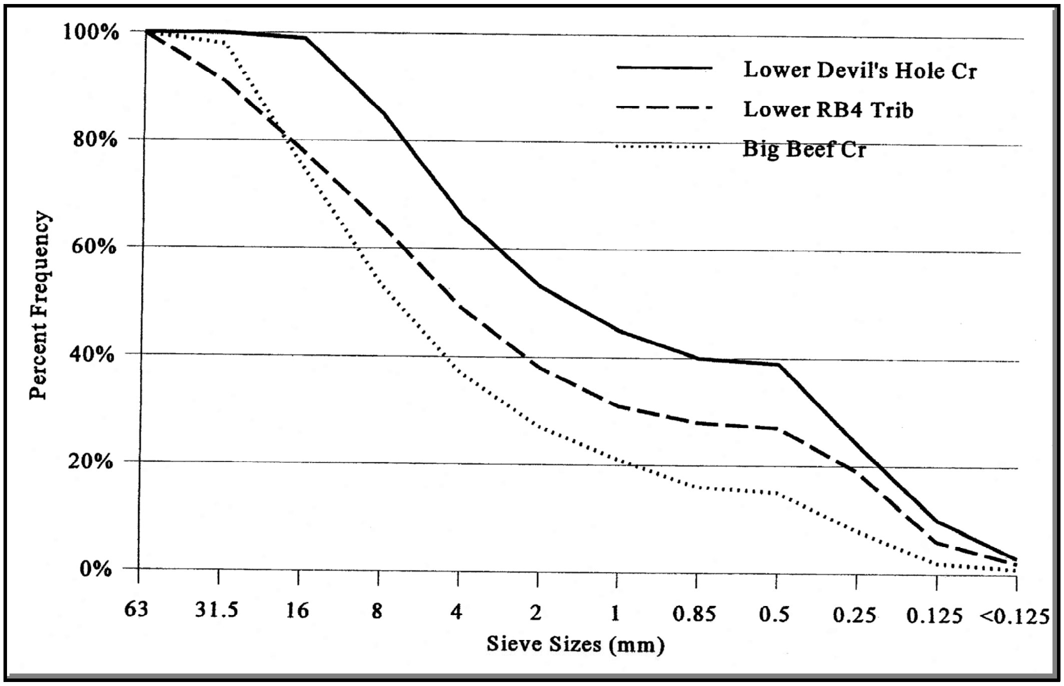

Figure 13. Average cumulative frequency distribution of sediment size categories found in samples form Devil's Hole Creek, RB4 tributary of Devil's Hole Creek, and Big Beef Creek, 1999.

Table 6. Percent composition of the various substrate size classes analyzed from the Devil's Hole watershed and a nearby salmon producing control stream, Big Creek, 1999.

	Sample	Sieve Sizes (mm)												% Fines
Stream Name	**#**	**63**	**31.5**	**16**	**8**	**4**	**2**	**1**	**0.85**	**0.5**	**0.25**	**0.125**	**<0.125**	**(<0.85-mm)**
Devil's Hole Creek	4	0%	0%	13%	21%	14%	9%	4%	0%	7%	21%	6%	4%	38%
	9	0%	1%	17%	25%	14%	8%	5%	0%	6%	17%	4%	2%	30%
	14	0%	0%	13%	14%	8%	5%	4%	1%	37%	0%	15%	3%	55%
	24	0%	0%	14%	19%	15%	9%	5%	1%	10%	20%	5%	2%	38%
	29	0%	2%	16%	16%	14%	10%	6%	0%	17%	14%	3%	2%	35%
													Average	39%
RB4	1	10%	17%	15%	12%	9%	6%	3%	1%	4%	14%	7%	4%	28%
	2	0%	10%	18%	21%	14%	8%	3%	0%	7%	15%	3%	1%	26%
	5	17%	12%	11%	13%	9%	6%	4%	1%	14%	11%	3%	1%	28%
													Average	27%
Big Beef Creek	1	0%	24%	30%	17%	8%	4%	2%	0%	6%	7%	1%	1%	15%
	2	0%	23%	20%	16%	11%	8%	7%	1%	8%	5%	1%	1%	14%
	3	6%	20%	16%	15%	11%	8%	6%	1%	7%	7%	1%	2%	17%
													Average	15%

exceeded 12% of the substrate composition. However, their sample size was low for sites with a high percentage of fine sediments. Shirazi and Seim (1979) correlated egg-to-fry survival with the geometric mean particle size. Applying the results of their research to our samples estimates an average egg-to-fry survival of 3%, 18%, and 33% for Devil's Hole Creek, RB4, and Big Beef Creek, respectively. Cederholm et al. (1981) evaluated the impact of fine sediments (<0.85-mm) on survival to emergence for coho salmon in a tributary of the Clearwater River on the Washington coast. Interpreting their results to the data we collected results in predicted survivals to emergence of 15% and 29% for RB4 and Big Beef Creek, respectively. A survival estimate for Devil's Hole Creek was not given since the level of fines were beyond those found in the Clearwater basin. Work done by Tagart (1976) in the Clearwater River also resulted in a negative relationship between egg survival to emergence and the percentage fines (<0.85mm). Applying his findings to RB4 and Big Beef Creek results in predicted survivals that were similar to Cederholm et al.

Egg-to-fry survival is not always well correlated with substrate characteristics. Research has shown that the amount of oxygen carried into the nest pocket may be a better predictor of egg-to-fry survival in some streams. In a study using rainbow trout, Sowden and Power (1985) found that dissolved oxygen levels correlated much better than the substrate size distribution in a groundwater-fed stream.

The Washington State Wild Salmonid Policy (WDFW 1997) and suggested habitat target conditions developed for the Washington State Timber-Fish-Wildlife Agreement (TFW) (Peterson et al., 1992) sets the maximum level of fine sediments (<0.85-mm) for spawning gravel at 11%. Fine sediment levels that meet or exceed these criteria are considered adequate for stream health. However, Peterson et al. also recognized that basin lithology and soil characteristics can greatly influence the level of fine sediments found in both pristine and degraded systems. The high sand content found in the streambanks as well as the deep soils present in the Devil's Hole watershed suggests that sand and fine sediment levels are probably naturally high in this system. Therefore, meeting the 11% fines criteria is most likely an un-realistic goal. However, because the level of sand and fine sediments found in the spawning gravels has a substantial effect on the productivity of the Devil's Hole watershed for salmonids, controlling future erosion and re-habilitation of the channel substrates are key elements for restoration of anadromous salmonid runs in the basin.

Migration Access

Road-fill used to create Sea Lion Road forms an earthen dam that, along with the fishway and concrete overflow chamber, creates the Bangor Lake reservoir. This dam, along with the numerous road culverts within the Devil's Hole watershed, are potential blockages to migrating salmon attempting to access and rear in the basin. The fishway and all culverts found in those portions of the watershed surveyed by WDFW were assessed to determine passability as per WDFW criteria.

Fishway

Methods

The fishway was evaluated on September 18, 2000 using WDFW passage criteria (WDFW 2000). The fishway is located at the outlet of Bangor Lake and carries water into the intertidal zone of Hood Canal. The evaluation was done during an ebbing tide at a tidal elevation of +6.3-ft mean lower low water (mllw).

Information collected included the fishway type, the number of pools/steps within the fishway structure, the hydraulic drop at each step, the location and type of grade control structure, and the dimensions of the weir pools.

In addition to the fishway, the overflow chamber was also evaluated as a downstream migration route for juvenile salmonids. Upstream migration through the overflow chamber is not feasable. The dimensions of the chamber, hydraulic drop, pool depth, and exit characteristics were measured or described.

Results

Downstream of the culvert under Sea Lion Road is a two-step weir-pool fishway. The bottom step had a 2.1 foot drop to the elevation of Hood Canal (+6.3-ft mllw) at the time of the survey. WDFW criteria calls for a maximum drop of 1.0-ft for coho salmon and steelhead and a 0.8-ft drop for chum salmon and cutthroat trout (Table 7). Therefore, the lower fishway only complies with WDFW criteria when the tidal elevation is above +7.6-ft mllw. The upper step had a drop of 1.0-ft.

Table 7. Washington Department of Fish and Wildlife fish-passage design criteria for culverts.

Criterion	Adult Trout >6-in. (150-mm)	Adult Pink and Chum Salmon	Adult Chinook, Coho, Sockeye, and Steelhead
Maximum Velocity (fps)	Velocity (fps)		
10-60 ft long culverts	4.0	5.0	6.0
60-100 ft long culverts	4.0	4.0	5.0
100-200 ft long culverts	3.0	3.0	4.0
>200 ft long culverts	2.0	2.0	3.0
Minimum Water Depth in Culvert	Depth (ft)		
	0.8	0.8	1.0
Maximum Hydraulic Drop at Culvert Outlet	Depth (ft)		
	0.8	0.8	1.0

Upstream of the lower fishway, migrating adult salmonids pass through a 60-ft long, 4-ft diameter reinforced concrete pipe culvert. The culvert begins to fill with seawater when the tidal elevation is above +9.4-ft mllw.

Upstream of the culvert, an 8-step weir-pool type fishway extends to the reservoir. The outlet of each pool drops 0.9-ft to the next pool. The reservoir level is controlled by a wooden stop-log control structure. The smallest pool measured 4-ft wide by 6-ft long by 3.3-ft deep.

The drops between pools (0.9-ft), meet WDFW criteria for coho salmon and steelhead, but fail to meet criteria for chum salmon and cutthroat. Outmigrant trapping in 1999 and 2000 indicated very low levels of coho, cutthroat, and steelhead are present in the basin. No chum salmon have been found over this two-year period. We believe this fishway is a blockage for chum salmon access, including the threatened Hood Canal summer chum stock (Figure 14).

Substantial debris was found at the inlet to the fishway which blocked salmon migration into the lake at the time of the assessment. It appeared that the debris blockage was constructed by beaver. After notification of the blockage to the base wildlife biologist, it was noted about one week later that most of the debris was removed. Debris blockages can seriously impede access to the Devil's Hole basin for anadromous salmonids.

The overflow chamber also controls the lake elevation using a stop-log control structure. Water leaving the reservoir vertically drops approximately 8-ft to the surface of a pool with a maintained depth of 2.5 ft. The water then flows into a culvert where it is carried under Sea Lion Road to Hood Canal. Upon exiting the culvert, the water drops approximately 1-ft onto a concrete apron which carries it to tidewater.

When the tidal elevation is below approximately +9-ft mllw, juvenile salmonids exiting the overflow chamber and culvert drop onto the concrete apron before being swept into the estuary. This likely results in some level of trauma and de-scaling which makes the smolts more susceptible to predation and disease.

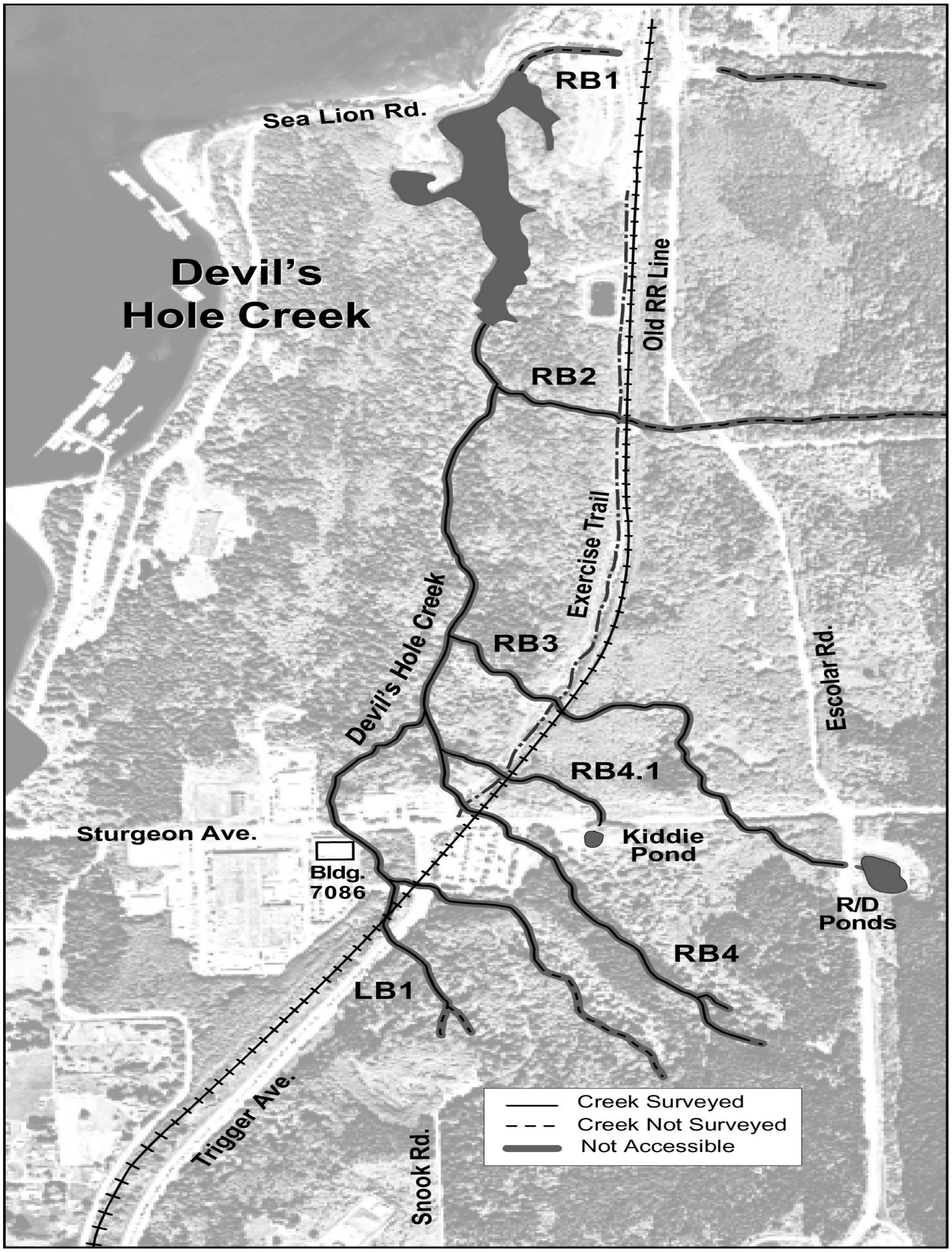

Figure 14. Access to the Devil's Hole Creek Watershed by Chum Salmon.

Culverts

Methods

Stream crossings identified during habitat surveys were given a unique identifier. Bridge crossings were assumed to be passable. Culvert crossings were assessed in September 2000 using the WDFW culvert evaluation methodology (WDFW 2000). Information recorded for each culvert included the following:

- A description of the culverts location,
- Latitude/Longitude (where GPS coverage was available),
- Shape and material used to construct the culvert,
- Culvert length, diameter, outfall drop, and slope,
- Water depth within the culvert,
- Whether the culvert contains streambed material,
- A description of the plunge pool downstream of the culvert,
- A description of the stream channel adjacent to the culvert,
- An assessment of the percent passability of the culvert and whether or not it is a barrier, and
- Comments as to why it is a barrier.

Latitude and longitude measurements were taken to position each culvert using a Trimble differential GPS. Culvert slope, length, outfall drop, and plunge pool depth was measured using a Lazer Tech Impulse Lazer Rangefinder and a reflector (+/- 0.06% accuracy). The rangefinder was mounted on a staff to enable repetition of instrument height for elevation measurements. Other measurements were made using a stadia rod or tape measure.

Results

A total of fifteen culverts were evaluated during the assessment. Two bridges were found where the Exercise Trail crossed RB3 and RB4 that were assumed passable. Two identified culverts were not assessed. One was located below the fishway at the mouth of Devil's Hole Creek. This culvert is typically flooded by sea water at high tide and was considered 100% passable. The second culvert was located on RB1 and travels under Buildings 7203 and 7053 as well as Escoloar Road, Guitarro Road, and parking lots. RB1 was carried over 100-meters through this culvert at a considerable slope. It was assumed to be a total blockage to upstream salmon migration.

Culverts in the Devil's Hole watershed were found to substantially effect the amount of habitat available for anadromous salmonids. Culvert passibility was described in four categories: 100% passable, 67% passable, 33% passable, and 0% passable (total blockage) and was assessed for coho, steelhead, rainbow trout, and cutthroat trout passibility. Devil's Hole Creek and most of its tributaries were found to be totally blocked to coho, steelhead, and anadromous cutthroat trout use upstream of the old railroad line or Trigger Avenue (Figure 15). Only one tributary, RB4.1

(the right-bank tributary to RB4), was passable above this point. On this stream, anadromous fish had access at least as far upstream as the Kiddie Pond; however, the stream became very small downstream of this point and it is doubtful that many coho would penetrate more than one to two hundred meters upstream of the old railroad crossing culvert. Table 8 describes each of the culverts and the results of the assessment on them.

Point Source Assessment

Point source discharges such as pipes and ditches convey storm runoff and, perhaps, other effluents to the stream. In addition, pipes crossing the stream may become damaged during high flow events resulting in the accidental discharge of toxics and other stream contaminants. An assessment of discharge points and piped stream crossings was made of those sections of the Devil's Hole Creek watershed that was surveyed in 1999 and 2000 to locate and document impacts associated with these features.

Methods

During the reach-scale assessment, where discharge points or piped stream crossings were observed the following information was collected:

- The stream and location where found,
- The size and material of the pipe,
- The location of the discharge point, if there is one, in relation to the banks,
- The amount of drop, if it is a discharge point,
- A description of the resulting bed and bank scour, and
- Other observations.

Results

Twenty outfalls or pipe crossings were identified during the survey (Table 9). The majority of the outfalls resulted in very minor to no impact to the bank or stream bed. More substantial impacts were noted at four locations (Figure 16).

The greatest impact was found from an outfall located on Devil's Hole Creek, 215-meters downstream from the Sturgeon Street culvert. Effluent from an 18-inch corregated steel pipe on the left bank has scoured a 2.2-meter channel to the creek. The pipe is perched above the stream and has scoured a 5-meter square hole below the discharge point.

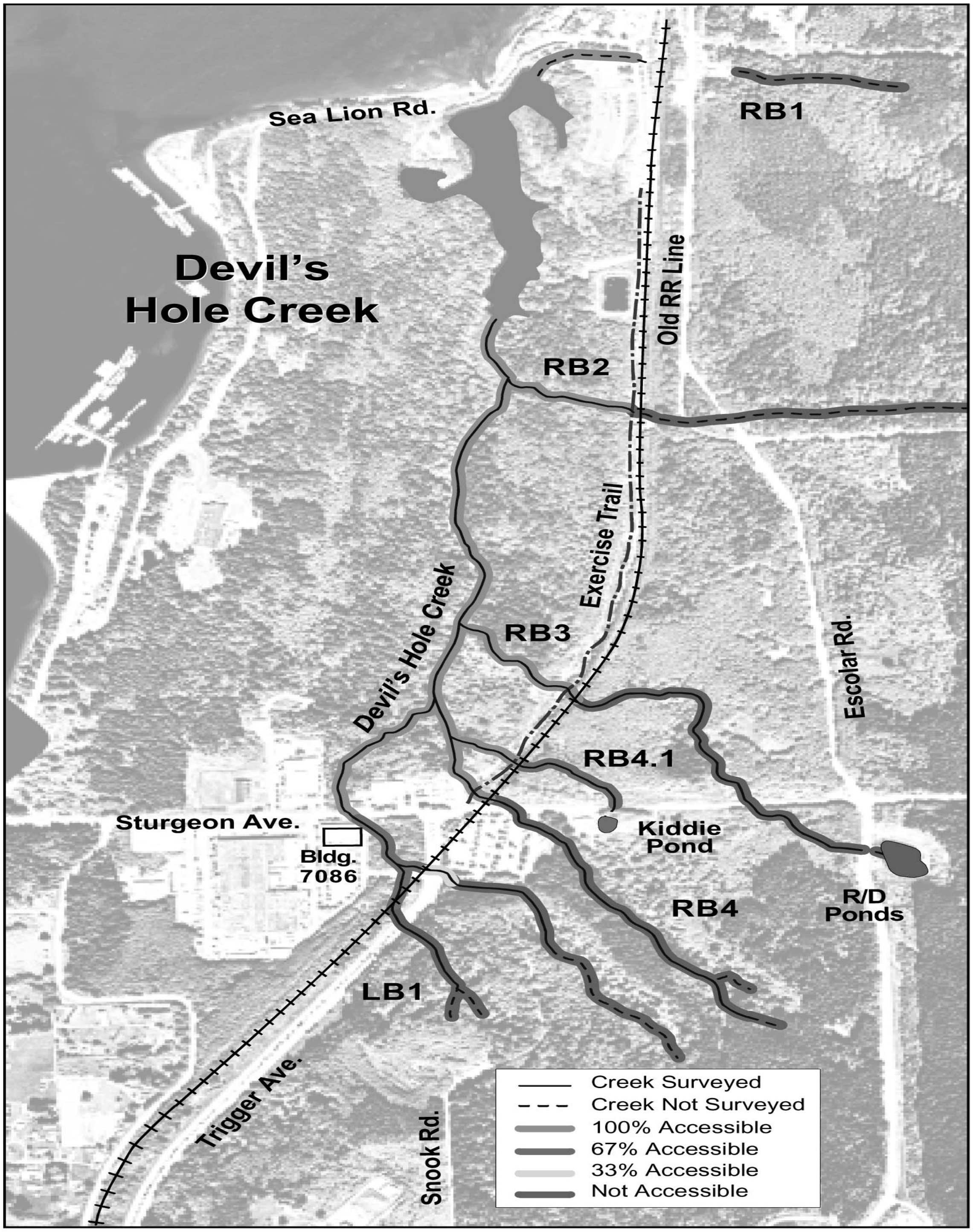

Figure 15. Access to the Devil's Hole Creek Watershed by Coho Salmon, Cutthroat, and Steelhead.

Table 8. Inventory and passability of stream crossing found in the Devil's Hole watershed, 1999 and 2000.

Crossing #	Stream	Type	Length (m)	Diam (m)	Material	Location	Slope	Outfall Drop (m)	Barrier	% Passable	Problems
DH-0	Devil's Hole Creek	Culvert	17.37	1.37	Concrete	Sea Lion Road	<=0.88%	<=0.15	No	100%	Dimensions, slope, and drop are from as-built drawings. Saltwater influence at high tide
DH-1	Devil's Hole Creek	Culvert	73.25	1.06	Corregated steel	Sturgeon Street	0.69%	0	Yes	67%	Undersized and too long (possible slope break)
DH-2	Devil's Hole Creek	Culvert	18.4	0.92	Corregated steel	Railroad Line	1.40%	0.14	Yes	33%	Steep Slope, Undersized
DH-3	Devil's Hole Creek	Culvert	36.88	0.48	Corregated steel	Trigger Ave.	2.70%	0	Yes	0%	Steep Slope, Undersized
DH-4	Devil's Hole Creek	Culvert	18.69	0.48	Corregated steel	Parking Lot	1.71%	0	Yes	0%	Steep Slope, Undersized
DH-5	Devil's Hole Creek	Culvert	18.97	0.46	Corregated steel	Snook Ave	3.58%	0.09	Yes	0%	Steep Slope, Undersized
LB1-1	LB1 Trib	Culvert	36.44	0.92	Corregated steel	Bldg 7086 access road	0.41%	0	No	100%	
LB1-2	LB1 Trib	Culvert	21.97	0.9	Concrete	Railroad Line	0.55%	0	Yes	67%	Slope break on upper 2/3rds pipe
LB1-3	LB1 Trib	Culvert	36.47	0.74	Corregated steel	Trigger Ave.	3.72%	0	Yes	0%	Steep Slope, Undersized
RB4-1	RB4 Trib	Bridge				Exercise Trail			No	100%	
RB4-2	RB4 Trib	Culvert	17.27	0.9	Concrete	Railroad Line	4.00%	0.21	Yes	0%	Steep Slope, Undersized (velocity)
RB4-3	RB4 Trib	Culvert	79.26	0.56	Corregated steel and concrete	Sturgeon Street	1.37%	0	Yes	0%	Steep slope, undersized, and length
RB4.1-1	RB4.1 Trib	Culvert	9.12	0.45	Corregated steel	Exercise Trail	0.29%	0.15	Yes	67%	Undersized, Velocity
RB4.1-2	RB4.1 Trib	Culvert	17.2	1.18	Corregated steel	Railroad line	0.26%	0	No	100%	None from a fish standpoint, bottom of culvert is rusted through
RB4.1-3	RB4.1 Trib	Culvert	14.39	0.4	Corregated steel	Sturgeon Street	0.83%	0	No	100%	
RB3-1	RB3 Trib	Bridge				Exercise Trail			No	100%	
RB3-2	RB3 Trib	Culvert	22.43	1.23	Corregated steel	Railroad Line	3.38%	0.61	Yes	0%	Outfall Drop, steep slope, undersized
RB3-3	RB3 Trib	Culvert	12.12	0.56	Corregated Aluminum	Sturgeon Street	1.82%	0.52	Yes	0%	Outfall Drop, steep slope, undersized

Table 9. Location and impacts from outfalls and pipe crossings found in the Devil's Hole watershed, 1999 and 2000.

Outfall #	Stream	Bank	Size (in)	Material	Discharge Point	Drop (m)	Bank Scour	Bed Scour	Year Observed	Description
DH-1	Devil's Hole	Left Bank	18	Corregated Steel	Outside channel	0.6	Severe	$5m^2$ hole	1999	215-meters downstream of the Sturgeon Street Culvert, extended channel 2.2-meters to outfall
DH-2	Devil's Hole	Left Bank	4	Concrete	in channel	0.05	none	none	1999	34.7-meters downstream of the Sturgeon Street Culvert
DH-3	Devil's Hole	Left Bank	8	Concrete	in channel	0	none	$0.5m^2$ hole	1999	29-meters downstream of the Sturgeon Street Culvert
LB1-1	LB1 Trib	Left Bank	12	Corregated Aluminum	in channel	0.34	Potential	none	1999	2-meters upstream of Trigger Avenue culvert. Drops onto concrete apron. Most road runoff gullies down bank and not in the pipe.
RB4-1	RB4 Trib	Left Bank		Ditch	n/a	0	High	High	1999	14.7-meters downstream of the Exercise Trail bridge. Covered in blackberries. Erosion of bed in ditch contributes fines. Bank erosion at high flows possible.
RB4-2	RB4 Trib	Left Bank	1.5	Iron pipe	none	n/a	none	none	1999	Very corroded. Appears 1940's circa. Carries no fluid. 9-meters downstream of the Exercise Trail
RB4-3	RB4 Trib	Left Bank	1	Iron pipe	none	n/a	none	none	1999	Very corroded. Appears 1940's circa. Carries no fluid. 9-meters downstream of the Exercise Trail
RB4-4	RB4 Trib	Right Bank	8	Concrete	Outside channel	0.75	minor	none	2000	16-meters upstream of the Snook Rd/Sturgeon St. culvert. Doesn't appear to be used.
RB4-5	RB4 Trib	Right Bank	0.75	PVC	in channel	0.05	none	none	2000	25-meters upstream of the Snook Rd/Sturgeon St. culvert. Doesn't appear to be used.
RB4-6	RB4 Trib	Right Bank	6	PVC	channel margin	0	minor	none	2000	25-meters upstream of the Snook Rd/Sturgeon St. culvert. Doesn't appear to be used.
RB5-7	RB4 Trib	Right Bank	4	PVC	Outside channel	1	none	none	2000	25-meters upstream of the Snook Rd/Sturgeon St. culvert. Doesn't appear to be used.
RB4-8	RB4 Trib	Right Bank	4	PVC	in channel	0	none	none	2000	25-meters upstream of the Snook Rd/Sturgeon St. culvert. Doesn't appear to be used.
RB4-9	RB4 Trib	Right Bank	2	PVC	channel margin	0	minor	none	2000	25-meters upstream of the Snook Rd/Sturgeon St. culvert. Doesn't appear to be used. Crosses stream and angles downstream on left bank
RB4-10	RB4 Trib	Right Bank	2	PVC	none	0	none	none	2000	25-meters upstream of the Snook Rd/Sturgeon St. culvert. Solid pipe, no discharge point observed
RB4-11	RB4 Trib	Right Bank	2	PVC	none	0	none	none	2000	25-meters upstream of the Snook Rd/Sturgeon St. culvert. Solid pipe, no discharge point observed
RB4-12	RB4 Trib	Right Bank	4	corregated plastic hose	in channel	0	none	none	2000	61-meters upstream of the Snook Rd/Sturgeon St. culvert. Extends 0.8-m into channel, then bends downstream 1.2-m. Doesn't appear used.

Table 9. Continued

Outfall #	Stream	Bank	Size (in)	Material	Discharge Point	Drop (m)	Bank Scour	Bed Scour	Year Observed	Description
RB4-13	RB4 Trib	Right Bank	3	Plastic Hose	in channel	0	Substantial	Substantial	2000	105-meters upstream of the Snook Rd/Sturgeon St. culvert. Appears un-used. Scour due to debris buildup on the hose.
RB4-14	RB4 Trib	Right Bank	4	corregated plastic drain field hose	channel margin	0	none	none	2000	105-meters upstream of the Snook Rd/Sturgeon St. culvert. Appears un-used.
RB4-15	RB4 Trib	Right Bank	4	corregated plastic drain field hose	channel margin	0.4	none	none	2000	105-meters upstream of the Snook Rd/Sturgeon St. culvert. Appears un-used.
RB3-1	RB3 Trib	Right Bank	12	Cast or forged steel	in channel	0	none	none	2000	15.6-meters upstream of the railroad culvert. Carries little or no fluid.

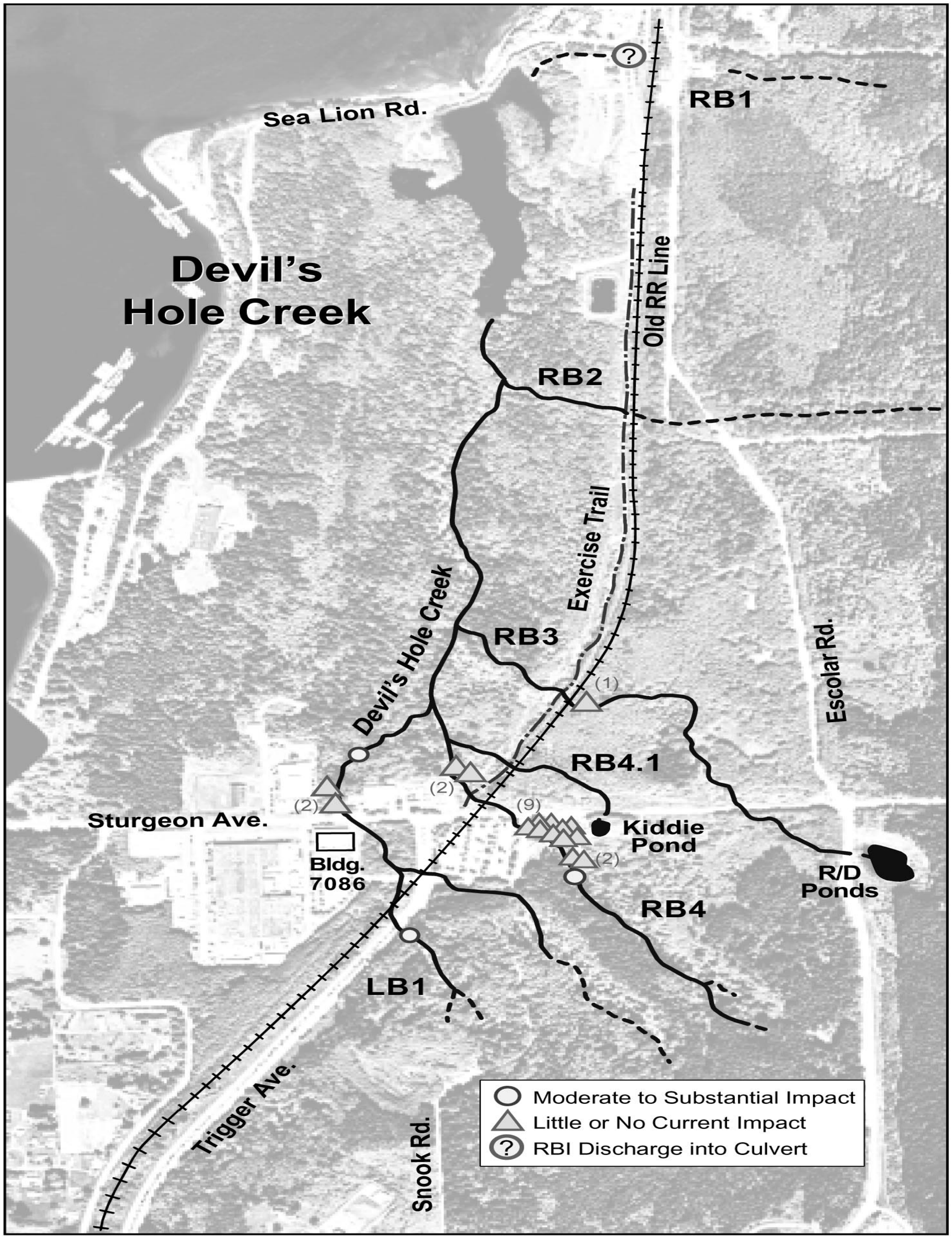

Figure 16. Location and Current Impact Level of Outfall or Pipe Crossings within the Devil's Hole Watershed, 2000.

A ditch on RB4 located 14-meters downstream of the Exercise Trail bridge also contributes sediment. The scouring of the bed and banks in the ditch results in transportation of sand and fine sediments to RB4. Blackberries growing over the ditch limits light penetration and the establishment of native plants which might better stabilize the bank.

A 3-inch plastic hose located on RB4 approximately 105-meters upstream of the Sturgeon Street/Snook Road culvert has resulted in bed and bank scour. The scour is not associated with the discharge from the hose, but from hydraulic conditions resulting from the placement of the hose itself. The hose spans the channel and accumulates debris. As the stream passes over or under the hose and debris, flow is routed toward the banks and bed.

Finally, roadside runoff has the potential to scour the bank at LB1 on the upstream side of the Trigger Avenue crossing. Road runoff is supposed to collect in a 12-inch corregated aluminum pipe. However, most of the flow is gullying down the left bank outside of the pipe.

Although not evaluated in the point source discharge assessment, a discharge to RB1 was previously noted and discussed in the Summer Low Flow section of the report. The actual discharge point was probably somewhere within the culvert that carries RB1 under Escolar Road, Guitarro Road, and Buildings 7203 and 7053.

Macroinvertebrate Indicators

Methods

The aquatic macroinvertebrate assemblage (e.g., aquatic insects, crustaceans, worms) can be a useful indicator for assessing stream habitat health. The technique for using this indicator involves comparing the numbers and species present in the stream of concern with the numbers and species present in a nearby healthy stream or reference site. The balance of predatory, herbivorous, and decomposer taxa, long-lived and short-lived taxa, pollution tolerant and intolerant taxa, and the numbers and abundance of different taxa present in the test stream compared to the control stream are used to diagnose habitat problems and to indicate the extent of degradation.

The 5-point kick-net composite method for sampling erosional habitats (Anderson and Wisseman 1996) was used to sample the macroinvertebrate assemblage in lower Devil's Hole Creek. This technique was also used to sample macroinvertebrates from the South Fork Stavis Creek, a local stream with relatively high habitat value (Neuhauser pers. comm.). The Stavis Creek drainage is located approximately 10-miles south of Devil's Hole Creek.

Five replicate samples were taken within Segment 4 of Devil's Hole Creek on September 20, 1999. The samples were composited to develop a single sample from the site. This process was repeated at SF Stavis Creek, approximately 0.5-miles upstream from the mouth of the creek, on September 21, 1999. The samples were fixed and preserved in ethanol. The two macroinvertebrate samples were shipped to Aquatic Biology Associates, Inc. for processing and analysis.

Results

The density and diversity of organisms in Devil's Hole Creek are substantially smaller than were found in South Fork Stavis Creek (Appendix A). A total of 44 taxa were identified from the Devil's Hole Creek samples compared to 55 taxa from S.F. Stavis. Invertebrate density was estimated at 550 invertebrates per square meter compared to nearly 1,700 invertebrates per square meter in S.F. Stavis Creek. The macroinvertebrate assemblages from both streams are truncated compared to other minimally impacted western streams with a high degree of habitat complexity; indicating that both streams are affected by periodic disturbance.

Analysis of the macroinvertebrate assemblage present in Devil's Hole Creek indicates that high water temperatures, nutrient enrichment, and lower dissolved oxygen levels are probably not affecting the health of Devil's Hole Creek. No or few species tolerant of these conditions were found in the basin. A very high proportion of "weed" species (those that re-colonize disturbed habitats quickly) were found in the Devil's Hole samples suggesting that substrate disturbance or toxic events occur regularly in the basin. The lack of organisms that are tolerant of toxic events suggests that substrate disturbance (i.e., scour, erosion, deposition, substrate sorting) is the most probable form of disturbance present in the watershed. Taxa that are sensitive to excessive scour or those requiring stable crevice space were absent from the Devil's Hole samples whereas they were found in low-moderate abundance in the S.F. Stavis samples.

Conclusions from this analysis suggest that biotic integrity in Devil's Hole Creek is low, mainly as a result of frequent substrate disturbance. Less disturbance and, therefore, higher biotic integrity is found in S.F. Stavis Creek. However, S.F. Stavis is not a good control or reference stream to compare the Devil's Hole results to. The sandy bank and soil conditions found in Devil's Hole Creek are not present in the S.F. Stavis Creek. We believe that Devil's Hole Creek historically experienced more substrate disturbance and naturally has lower biotic integrity.

Direct effects of scour and deposition on salmonid rearing includes exposing or burying egg pockets. Indirect effects include reducing the macroinvertebrate food supply for rearing salmonids, the filling of pool habitats, and the loss of interstitial spaces within the substrate that is used for refugia by some species.

Limiting Factors

Salmonid freshwater production from the Devil's Hole watershed occurs at very low levels relative to other streams in the area (Figure 17). Production from other nearby streams trapped in 1999 and 2000 averaged 0.01 to 0.33 coho smolts produced per square meter of wetted habitat. Production from the Devil's Hole watershed was 0.002 coho smolts per square meter; or about 1/5th the production from the next poorest producing stream. This section describes the conditions in Devil's Hole Creek that we believe contribute to this very low production level.

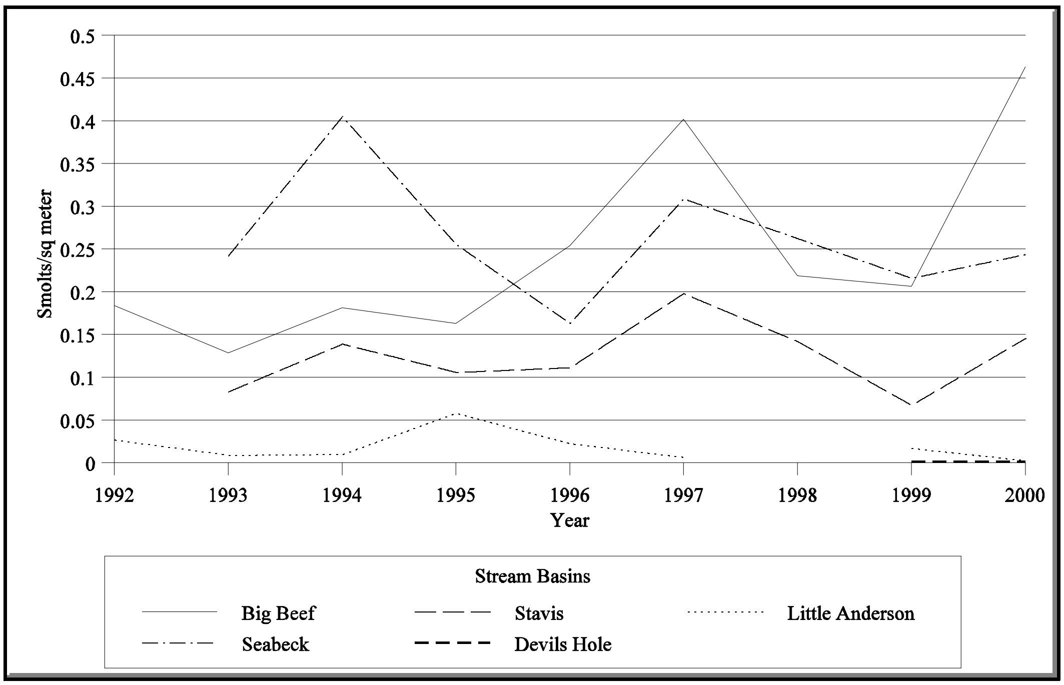

Figure 17. Comparison of the annual coho production rate between Hood Canal streams.

Factors or conditions that affect the population abundance of anadromous salmonids include the quality of the physical habitat, changing environmental parameters such as temperature and flow, the amount and quality of food available, and the level of fishing, predation, and pathogens. These conditions influence population size in the freshwater, estuarine, and marine environments, and at various life history stages. However, many of these factors are outside the direct influence of the Department of the Navy. This section will focus the discussion of those elements that can be corrected by the Navy through direct action, or set on the pathway to recovery by proper land management. These elements can be grouped into two categories; those factors affecting access of adult salmonids to the spawning grounds, and those affecting freshwater survival of juvenile salmonids.

Factors affecting salmonid populations may be species specific. We will focus our discussion on four species: coho salmon, chum salmon, steelhead, and cutthroat trout. Remnant populations of coho, steelhead, and anadromous cutthroat are currently found in the basin. Chum salmon are not currently found, but were likely present prior to the creation of Bangor Lake.

Factors Affecting Adult Migration

Adult salmonids migrating into the Devil's Hole watershed must first ascend the fishway into Bangor Lake and then migrate through Devil's Hole Creek and its tributaries to the spawning grounds. A number of culverts evaluated in this study preclude access to spawning grounds upstream of the railroad line or Trigger Avenue; which contain better spawning habitats than are found further downstream in the mainstem. The position and condition of the fishway also effects adult migration.

Fishway

The fishway, as designed and currently operated, precludes or severely restricts upstream access for all anadromous salmonid species. It does not meet WDFW passage criteria for chum salmon or cutthroat trout (Table 7). No chum salmon have been found after two years of out-migrant trapping. Although it is unknown if steelhead were ever abundant in the Devil's Hole watershed, so few steelhead have been found that they can also largely be considered extirpated from the system. In addition, the lack of maintenance to the fishway has resulted in it being clogged with branches and other small woody debris for much of the year. WDFW personnel working on this project have specifically requested that debris be removed each fall during the coho spawning migration period in order to improve access for coho salmon.

Were the fishway adequately maintained, it would likely provide for the passage of coho salmon and steelhead. However, beyond the physical design of the fishway, its location is problematic for all species, and especially chum salmon. The fishway is located at the mouth of Devil's Hole Creek where it empties into Hood Canal. This is a very unattractive placement for salmon since they have to immediately expend a lot of energy to ascend the fishway and enter the watershed. If the fishway was located further upstream, chum salmon would likely spawn below the fishway while coho and steelhead would probably spawn downstream and upstream of it. In its current position and if it met the passage criteria and was properly maintained, it is highly unlikely that many salmonids, especially chum salmon, would stray into the Devil's Hole watershed. Assuming we are correct, this would preclude natural re-colonization of the system if it were adequately restored. Even if a run of chum salmon were re-established through artificial propagation, their use of the fishway is doubtful. A few miles south at Big Beef Creek, we observe that chum salmon are reluctant to enter a weir trap located just upstream of the estuary even though this trap has only one small step.

Culverts

Based on criteria found in WDFW (2000), culverts on Devil's Hole Creek, LB1, RB4, and RB3 currently prevent access to 1,450-meters of habitat surveyed above these culverts plus probably 200 to 500-meters of additional habitat not surveyed on Devil's Hole Creek and RB4. Although blocking culverts also are found on RB1 and RB2, these were not considered in this analysis. The channel above the blocking culvert on RB2 provides little if any fish habitat due to its size and gradient. Fish habitat on RB1 was not assessed because the channel runs through at least 100-meters of culvert at a fairly steep gradient as it passes under Escolar Road, Guitarro Road, parking lots, and Buildings 7203 and 7053. While an undetermined amount of fish habitat exists above this culvert, we believed that the cost to restore access to this section of stream would greatly outweigh the benefits of providing access to it.

The amount of habitat surveyed above the blocking culverts represents about 1/3rd of the total habitat surveyed. This is a substantial amount of potentially fish-bearing habitat that is currently blocked to anadromous salmonid use. In addition, culverts downstream of the blocking culverts on Devil's Hole Creek and LB1, although not total blockages, limit upstream access by adults and probably prevent upstream access by juvenile salmonids. It should also be noted that the blocked habitat on RB3 and RB4 contain some of the better quality spawning gravel observed in the Devil's Hole watershed.

Factors Affecting Freshwater Survival of Juvenile Salmonids

There are three areas of concern that have surfaced during our evaluation of the Devil's Hole watershed pertaining to the freshwater phase of anadromous salmonid production. These include the generally low quality of spawning habitats available for incubating salmonid eggs, the low level of quality pool habitats available for rearing, and mortality associated with downstream migration through Bangor Lake and fishway/overflow chamber.

Spawning/Incubation

Visual observation confirmed that surficial substrates throughout the Devil's Hole watershed contain high levels of sand. Substrate samples taken with a modified McNeil core sampler had high levels of fine sediments as well. Fine sediments (<0.85-mm) in the interstitial spaces between gravel prevents the flow of oxygenated water from reaching eggs and carrying off metabolic waste products. Both sand and fine sediment may physically prevent alevins from emerging out of the egg pocket.

Excess sand and fine sediments are a problem in many streams in Puget Sound; however, they are particularly pervasive in Devil's Hole Creek due to the high sand content and thick soils found in the banks. These conditions indicate that the Devil's Hole watershed has historically been sensitive to high levels of sand and fine sediment. We surmise that, historically, high mortality during incubation has been the major limiting factor to salmonid production in the Devil's Hole watershed. Current conditions are such that egg to fry survival for the Devil's Hole Creek may be half to a third or less the survival seen in Big Beef Creek, a few miles to the south.

Macroinvertebrate analysis indicates bed disturbance is frequent within the Devil's Hole watershed. Scour and deposition can uncover or bury egg pockets resulting in a further reduction in egg-to-fry survival.

Development and other land-use activities in the watershed exacerbates these problems. Stormwater runoff from impervious surfaces can artificially increase streamflows and result in increased bank and bed erosion. Montgomery et al. (1996) suggests that even small increases in scour over historic levels can result in a substantial increase in egg-to-fry mortality. Stormwater runoff from impervious surfaces can also carry fine sediments into the stream channel from upland sources. In addition, stream banks can become destabilized where riparian vegetation is sparse or of poor quality.

Rearing Habitat

Much of the Devil's Hole watershed streams contain low pool densities. Pools are favored rearing habitats for coho salmon and cutthroat trout (Pauley et al., 1989). The lack of pools is attributed to a combination of high sediment transport and deposition, and low levels of LWD. LWD plays an important role in pool formation by providing roughness to the channel. Without wood, flow in the channel is mainly unidirectional and can be laminar (glides) or slightly turbulent (riffles). With LWD, water is forced to flow over, around, and under the LWD which causes changes in flow direction, velocity, scour, and erosion. This, in turn, results in the scouring of pools, creation of deposition areas, and increases the complexity of habitats in the channel. In addition, LWD is important for providing cover or refugia for juvenile salmonids to help them avoid predation.

The beneficial effects of LWD can be partially, if not wholly, over-ridden by excessive sediment loading. Excessive sediments can fill pools and bury LWD to make it largely ineffective. Portions of Devil's Hole Creek and LB1 suffer from excessive sediments which have filled pools and caused channel braiding in some reaches.

LWD is reasonably abundant in the mainstem Devil's Hole Creek below the Sturgeon Street culvert and in RB3 downstream of the exercise trail. Both of these areas have good quality riparian zones comprised of a mixed forest of mature conifers and hardwoods. However, LWD is sparse in the mainstem upstream of the Sturgeon Street culvert as well as in the tributaries. Riparian zones in these areas are generally hardwood dominated, or are dominated by blackberries.

Although habitat differentiation is complex, juvenile steelhead generally prefer well oxygenated riffle habitats for rearing compared to the pool habitats preferred by cutthroat and coho (Pauley et al., 1986). While streams in the Devil's Hole watershed have an abundance of riffle habitats, most have a high proportion of sand and fine sediments in them. Steelhead prefer more gravel/cobble dominated substrates than are found in Devil's Hole.

Chum salmon migrate to saltwater soon after emerging from the spawning gravel; therefore, rearing habitat is not as much of a concern as it is for coho, steelhead, and cutthroat which spend at least one or more years in freshwater.

Downstream Migration

After emerging from the spawning gravel, all anadromous salmonids migrate to saltwater after some period of freshwater rearing. Chum migrate almost immediately. Most coho salmon migrate after one year of freshwater rearing. Steelhead and cutthroat migrate after one to three years of freshwater rearing. All migrants pass through Bangor Lake and either the fishway or overflow chamber to reach Hood Canal. We believe there is a potential for increased mortality from both the lake and the engineered channels.

Bangor Lake

Bangor Lake provides both benefits and hazards to migrating salmonids. For coho, cutthroat, and steelhead, the lake provides a fertile rearing environment that allows the fish to grow to large size prior to emigration. However, these large salmonids, particularly the cutthroat, likely prey on salmonid fry and fingerlings entering the lake following emergence from the gravel or prior to over-wintering (Pauley et al. 1989, Wydoski and Whitney 1979, Moyle 1976). We believe chum salmon fry would be particularly vulnerable to predation since they are actively trying to pass through the lake to Hood Canal. The other species may be somewhat less affected since they can seek out refuge habitats within the lake to avoid predation.

As migrants leave the freshwater environment, they spend a period of time adjusting to saltwater. This time is spent in the estuary where the tides and stream flow create a gradation of salinity levels. The shape of the Bangor Lake basin suggests that lower Devil's Hole Creek probably flowed through a saltwater lagoon or wetland before entering Hood Canal. Now this one-time estuary is freshwater lake habitat and no longer provides this transition area which is especially important to chum salmon. Juvenile migrants traveling downstream of Bangor Lake now enter Hood Canal with little opportunity to swim back upstream once they leave the lake. The estuary habitat is much reduced from historical levels.

Fishway and Overflow Chamber

Migrants leaving the watershed must pass through either the fishway or the overflow chamber to reach Hood Canal. We are unsure which route is used most; however, most of the flow passes through the overflow chamber. As previously noted, the location of the dam provides for a much reduced estuary for the physiological transition to seawater. While it is doubtful that this abrupt transition will result in direct mortality, it could lead to reduced fitness during a critical period of their life history.

Fish leaving via the overflow chamber face additional risks. At tidal elevations of less than about 9-feet mllw, migrants exiting the culvert on the downstream side of the overflow chamber are deposited onto a concrete apron before being swept into Hood Canal. Velocities in the overflow chamber are high at even low to moderate flows and migrants likely leave the system somewhat disorientated and more susceptable to predation. In addition, the passage of fish over the concrete apron likely results in some de-scaling which further reduces fitness during this transition period.

Prioritization of Limiting Factors

Limiting factors are prioritized below by their order of impact on anadromous salmonids. This enables corrective actions to be focused first on those factors having the largest impact on anadromous salmonid production in the basin.

1. **Blockage to Upstream Migration at the Fishway**

   As currently designed and operated, the fishway is a total blockage to chum salmon. Without regular and routine maintenance, it is at least a partial blockage to coho salmon, steelhead, and cutthroat trout as a result of debris accumulations that the intake to the fishway.

2. **Fine Sediments and Sand in Spawning Habitats**

   High levels of sand and fine sediments are ubiquitous throughout the Devil's Hole watershed. Devil's Hole Creek and LB1 are particularly affected. Sand and fine sediment levels have a substantial impact on incubation success.

3. **Blockage to Upstream Migration at Culverts**

   Culvert blockages on most of the tributaries precludes access to at least 33% of the linear stream habitat in the Devil's Hole watershed that is capable of supporting anadromous salmonids. These blockages affect coho salmon, steelhead, and cutthroat trout access.

4. **Bed Scour and Deposition Impacts on Egg Pockets**

   Although scour and depositional depths were not measured, macroinvertebrate analysis indicates that frequent substrate disturbance is occurring in the basin. Impervious surfaces in the basin likely increase storm flows and subsequent bed disturbance in portions of the watershed. Evidence of bed scour was found during the habitat survey. Bed scour and deposition could have a substantial impact on egg-to-fry survival.

5. **Downstream Migrant Impacts through the Fishery and Overflow Chamber**

   It is likely that many smolts exiting the watershed by way of the overflow chamber are becoming de-scaled as they travel across the concrete apron downstream of the Sea Lion Road culvert. This impact results in reduced fitness and resistence to disease, but probably not acute mortality. Migrants exiting the fishway or overflow chamber at lower tidal elevations are deposited onto the beach which they are exposed to avion predation. The design of these sturctures prevents re-accessing safer habitats further upstream.

6. **Poor Estuarine Habitat**

   The lack of estuary habitat and loss of the refugia, food, and gradation of salinities that it provides likely results in reduced fitness and some additional mortality to emigrating salmonids.

7. **Poor Freshwater Rearing Habitat**

   Reduced pool habitat for coho salmon and cutthroat trout, and the poor quality riffle habitats available for steelhead, may limit production of these species. Their level of impact to freshwater production is currently unknown. Incubation success effects the level that these habitats are seeded with salmonid fry. The poor condition of the spawning gravel results in poor fry production and the potential for under-utilization of the available rearing habitat.

8. **Predation in Bangor Lake**

   Salmonid fry entering Bangor Lake are likely preyed upon by the large cutthroat trout found there. The level of impact to salmonid production from predation in the lake is unknown.

Recommendations to Improve Anadromous Salmonid Production

Recommendations given in this section represent those we believe will provide the greatest benefit to restoring anadromous salmonid production in the Devil's Hole watershed. They are designed to not only benefit those anadromous species currently present, including coho salmon, steelhead, and cutthroat trout, but also to remove impediments to the re-establishment of chum salmon in Devil's Hole Creek, including the threatened Hood Canal summer chum.

The following recommendations are prioritized to address those limiting factors having the largest impact on salmonid production first. The title for each recommendation will be in the form of a goal statement. With each recommendation is a description of one or more actions necessary to meet the goal. Included with each is a discussion of why we believe these goals and actions to be the best solution to the limiting factor(s).

Recommendation #1 - Restore the Lower Devil's Hole Creek Estuary

The single largest impact on salmonid use and production in the Devil's Hole watershed is the dam at the mouth of the creek. We recommend re-establishing a brackish water marsh in place of Bangor Lake. This would best be done by removing the fishway, overflow chamber, and culverts under Sea Lion Road as well as the road fill between the culverts and replacing these with a bridge. In the process, Bangor Lake would be drained. A basin and slough channels would be dredged to re-establish the grade between the current confluences of Devil's Hole Creek and RB1 with the lake, and the upper intertidal zone (Figure 18). The basin and slough habitats would be re-vegetated with a combination of native vegetation appropriate to the final design.

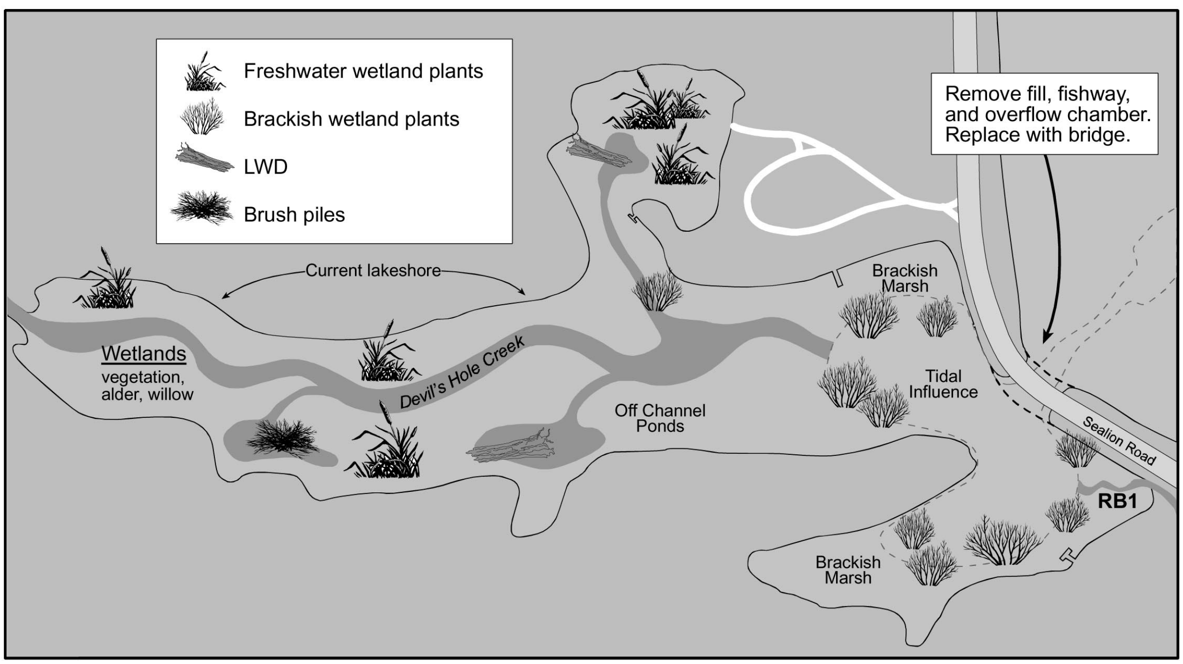

Figure 18. Conceptual drawing of the proposed brackish water basin and slough complex.

This recommendation addresses Limiting Factors #1, 5, 6, and 8. We believe that removal of the dam/fishway and re-establishment of a marsh complex has the best chance of restoring threatened summer chum to the Devil's Hole watershed. Removing the fishway and re-establishing stream grades between the streams and the intertidal zone will provide for better access into Devil's Hole Creek for chum salmon as well as the species currently found in the watershed. The overflow chamber, culverts, and concrete apron would also be removed which would halt the de-scaling of smolts that we believe currently occurs. Development of a brackish water marsh complex provides the smolts with much better habitat for the transition between the freshwater and saltwater environments. Once matured, it will also provide refuge and food for both smolts and juveniles rearing in the marsh. A marsh complex would provide unrestricted access to Hood Canal and would reduce residualization of large piscivorous cutthroat trout as currently occurs in the lake.

Recommendation #2 - Manage Stormwater to Reduce Bank/Bed Erosion

Develop a stormwater management plan for the basin that includes the design, installation, and maintenance of a stormwater system to ensure that streamflows resulting from storm events mimic those which occurred prior to development in the basin.

This recommendation addresses Limiting Factors #2, 4, and 7. The Devil's Hole watershed is very sensitive to high stream flows. Design, installation, and maintenance of a stormwater system and management plan that restores the natural hydrograph for the basin would reduce bank and bed erosion. If stormwater management is successful in restoring the storm hydrograph, we expect that over time, sand and fine sediment levels would improve and approach those observed prior to development in the basin. We would also expect egg pocket scour and burial to approach historic rates.

Land-use activities have a greater ability to effect stream flows associated with moderate to large storms than they have on very large storms (Lautz pers. comm.). During very large storms, such as a 25-year storm event, soils over the entire watershed become saturated and all additional precipitation ends up in the stream. In this case, moderate intensity land-use has little effect on the storm flow. However, during intermediate to large storms, such as the 1 to 10-year storm events, land-use has the ability to exacerbate storm flows. The magnitude of the exacerbation depends on the intensity of land-use. Flows associated with the one to two year storm normally have little impact on incubating eggs (Montgomery et al., 1996). However, if storms of this size result in a 5-year storm-level stream flow due to land-use, the impact on incubating salmon eggs would be substantial, and would be expected to repeat or be exceeded on a one to two-year basis. It is this effect we need to prevent through stormwater management.

The best spawning habitat in the basin is found in RB2, RB3, and RB4. The focus on these three streams should be to maintain substrate quality and prevent the potential for egg pocket scour. May (1997) presents some ideas for stormwater management that should help to protect spawning habitat in these streams. First of all, he suggests modifying an existing stormwater control and treatment facility on RB2 (SWFPAC tributary) to detain and possibly infiltrate stormwater from the SWFPAC area of the base. May also advocates installing rock downstream of the retention/detention (R/D) facility on RB3 (he mistakenly calls it the Sturgeon branch of RB4 or the "Firehouse tributary") to dissipate energy and prevent bed and bank erosion.

Downstream of Sturgeon Street on RB3 is a very low-gradient area that is currently filled with blackberry. We would suggest developing an in-channel sediment trap adjacent to Sturgeon Street, just downstream of the culvert, where sand and fine sediment could collect. The trap would need to be maintained through periodic removal of the collected sediments.

Devil's Hole Creek and LB1 have a higher proportion of sand in the bed sediments than do the other tributaries. May (1997) suggests creating a riparian wetland and new R/D pond in the vicinity of the confluence of LB1 with Devil's Hole Creek. This is a good location, in our opinion, for creation of a wetland/sediment trap. The wetland should be designed to settle out sand and fine sediments for periodic removal so as to limit the downstream transport of these sediments. Another R/D pond should be installed on the left bank of Devil's Hole Creek, downstream of Sturgeon Street to meter the stormwater flows currently entering the stream from outfall DH#1 (Table 9). Finally, the Kiddie Pond or wetland area just downstream of the Sturgeon Street culvert on RB4.1 is another site that could be used for a settling pond and for R/D.

Recommendation #3 - Re-establish Access to Spawning and Rearing Areas

Replace blocking culverts first on RB4 and RB3, and then on Devil's Hole Creek and LB1, to restore access to spawning areas in the watershed. Culverts under the abandoned railroad line should be removed along with sufficient fill material to pull-back and stabilize streambanks. All culvert replacements should conform with Bates et al. (1999).

This recommendation addresses Limiting Factor #3. Adult migration access is precluded for portions of the Devil's Hole watershed for coho salmon, steelhead, and cutthroat by a series of culverts that exist in the basin. On RB3, migration is blocked at the railroad culvert and the Sturgeon Street culvert (Figure 13). We recommend removing the railroad culvert to re-establish an open channel. Railroad fill will need to be removed to enable the streambanks to be pulled-back for stability. Stabilized slopes should also be revegetated with conifer seedlings and native riparian vegetation appropriate for the soil conditions present at the site. The culvert at Sturgeon Street should also be replaced with a culvert sized to accommodate the bankfull channel (1.3-meters) and placed so as to carry the bed at its natural slope or, otherwise, meet velocity criteria for migrants.

On RB4, culverts at the abandoned railroad crossing and the Sturgeon Street/Snook Road crossing are also total blockages to upstream migration. The railroad culvert should be removed and the streambanks pulled back and revegetated as previously described. At the Sturgeon Street and Snook Road crossing, the culvert measured nearly 80-meters in length. Given the slope of the culvert, it would be extremely difficult or impossible to engineer a culvert of this length that will meet the water velocity criteria necessary to pass cutthroat trout or even the more powerful swimming salmonids. We suggest passing RB4 under Sturgeon Street using a bridge. The crossing under Snook Road should be either done with another bridge or by re-routing Snook Road through the parking lot to meet Sturgeon Street west side of (instead of over) RB4. This later option would allow RB4 to flow through an open channel before reaching the Sturgeon Street crossing. If Snook Road were re-routed as described, sufficient clearance between the road and RB4 should be provided for a small buffer of riparian vegetation to be planted.

Devil's Hole Creek passes through six culverts as it flows to Hood Canal. Of these, three of the five are total blockages; two others are partial blockages. All of the blocking culverts are at or upstream of Sturgeon Street. Restoring access to upper Devil's Hole Creek and LB1 requires either replacing or removing these culverts.

The culvert at the Sturgeon Street crossing is 73-meters in length. Because the culvert gradient is not excessive, we believe this culvert is at least passable at some flows. However, because of its length and since it also carries flow from LB1, we recommend that a bridge be built to cross the stream at this point. The next culvert upstream is at the abandoned railroad line crossing. We recommend this culvert be removed and the banks pulled back to form a stable open channel. The remaining culverts have relatively steep gradients and are under-sized for the flows they must contain. We recommend replacing these with structures that are appropriately sized and set at a gradient so as to maintain the stream bed through the culvert or designed to meet the swimming performance criteria of cutthroat trout.

Two culverts exist on LB1. The first culvert on the abandoned railroad line is a partial blockage to migration. We recommend removing this culvert and pulling back and re-vegetating the stream banks. The second crossing at Trigger Avenue is a total blockage. The culvert here needs to be replaced with a larger culvert that is engineered to meet the swimming capabilities of cutthroat trout as described in Bates et al. (1999).

Recommendation #4 - Increase Riparian Functioning

Improve riparian functioning by re-establishing native vegetation and/or a conifer component in areas that have been degraded through stream encroachment, introduction of non-native vegetation, or land management. Maintain the riparian corridor between Bangor Lake and Sturgeon Avenue.

This recommendation partially addresses Limiting Factors #2 and 7. Riparian areas are degraded over substantial portions of Devil's Hole Creek, particularly where road and facility development has occurred (Figure 12). Riparian impacts have generally taken three forms:

1. Replacement of native riparian vegetation by Himalayan blackberry leading to excessive shade and poor bank stability,

2. Loss of the conifer component in riparian stands where soils exist that can support conifer growth, and

3. Encroachment of the channel by roads and parking lots resulting in development of a grassy-swale type stream habitat.

Habitat and water quality requirements include the need for a well developed riparian zone that provides the following functions:

- A balance of shade for temperature control and sunlight for food production,
- Structural components (LWD) for development of habitat diversity,
- Nutrients in the form of leaf litter and other organic debris,
- Microclimate control through the vegetative mass that isolates the stream-side climate from that of the surrounding uplands, and
- Bank and surface soil stability through the soil binding cohesiveness provided by the roots of the riparian vegetation.

Protection of aquatic species requires the restoration and maintenance of the riparian functions appropriate for each channel area carrying water over the course of the year. In the Devil's Hole watershed, stream temperatures are naturally cool from what we believe is a high rate of groundwater contribution to the channels. Nutrients from leaf litter are adequate due to the extensive riparian areas found in the watershed. The riparian functions that are not well provided for in parts of the watershed are LWD recruitment and bank and surface soil stability.

The growth of Himalayan blackberry in parts of the Devil's Hole watershed has resulted in excessive shading of the stream channel and loss of bank stability. As blackberry canes grow, they climb over the stream and older canes. Native riparian vegetation and canes that were growing closest to the stream are shaded out resulting in little plant density or root strength at the margins of the stream bank. This condition generally has occurred where the stream has been daylighted through construction of a road or railroad grade.

In the Devil's Hole watershed, blackberry patches that effect riparian function are located downstream of the Exercise Trail on RB2, downstream of the railroad crossing, Sturgeon Street, and Escolar Road on RB3, downstream of Sturgeon Street, the railroad crossing, and the Exercise Trail on RB4 as well as upstream of Sturgeon Street behind the fire-station, and downstream of Sturgeon Street on RB4.1 (Figure 12).

To restore these areas, blackberries should be removed. Banks should be pulled-back where they have downcut to increase stability and should be planted with appropriate native vegetation such as willow, red ozier dogwood, and douglas fir. Maintenance of theses areas should occur on an annual basis to ensure that blackberries don't return and overtake the native vegetation. Where this level of restoration is occurring on RB3 and RB4, appropriately sized LWD should be placed in the stream channel to collect and sort the higher quality spawning gravel held therein, protect exposed banks, and scour and sort gravel and other sediment.

Conifer trees are rare on RB3 over the first 100 meters upstream of the railroad crossing and on LB1 near its confluence with Devil's Hole Creek. Soils in this area should support conifer growth; therefore it is assumed that past logging removed conifers from these areas. The stands are currently in alder. We recommend planting conifers that are appropriate to the soil type in these areas, particularly within 50-ft of the stream. It may be necessary to create daylight for conifer growth by removing some of the hardwood trees. In addition, both stream have severely downcut into their beds at places along the channels. Work in these areas may include pulling back and stabilizing the streambanks in these sections. Once banks are stabilized, appropriately-sized LWD can also be added to the stream channel to collect and sort the higher quality spawning gravel held therein, protect exposed banks, and scour and sort gravel and other sediment; however, bank pull-back should only be done if it is necessary to bring heavy equipment in for the riparian work.

Another area of concern is located upstream of the Trigger Avenue culvert on Devil's Hole Creek. The stream channel is constrained at this point by a parking lot and parking lot access road. It flows through a grassy swale that provides little benefit to salmonids. We recommend that the access road and part of the parking lot be removed to provide space for the re-establishment of a riparian zone around this section of Devil's Hole Creek. Removal of the access road would also enable removal of a culvert from the creek channel. Access to the remaining sections of the parking lot can be accessed from Sturgeon Street. Appropriately-sized LWD should be added to the stream channel in this section to create pool habitat and protect bank slopes.

Finally, good riparian habitats exist adjacent to the mainstem Devil's Hole Creek between Bangor Lake and Sturgeon Street, as well as on portions of RB2, RB3, and RB4 where they flow into the valley of the mainstem. The riparian zone in this area should be left intact to provide for future LWD recruitment as well as other riparian functions. We recommend that no logging occur in this area.

Recommendation #5 - Restore Hood Canal Chum Runs

Re-establish first fall, and if successful, then summer chum into the Devil's Hole watershed. Use remote site incubators (RSIs) to re-introduce chum into RB2.

The quickest route to recovery of chum salmon would be through jump-starting the run using artificial propagation rather than to wait for straying or another natural mechanism to re-populate the basin. RSIs would be used to plant fall chum salmon into RB2, Segment 1, where suitable spawning habitat exists. We believe this would be a good stream for chum salmon since it is low in the system and has good spawning habitat available. Re-colonization of chum salmon would have the best chance of succeeding after the Devil's Hole estuary were restored (Recommendation #1).

We do not believe that artificial propagation is necessary for the other anadromous species found in the Devil's Hole watershed. Coho salmon will recover as a result of the straying of Port Gamble net pen fish into the watershed. Strays from this stock are observed every year migrating into Big Beef Creek and other nearby streams. Steelhead production in Devil's Hole Creek was likely low historically because the stream is a low energy system that favors coho and chum salmon. Cutthroat trout are found throughout the watershed. This species may have residualized as a result of the formation of Bangor Lake at the lower end of the system. Removal of the lake may help to restore the anadromous run by providing easier access to and from Hood Canal and by providing less favorable freshwater habitat.

Recommendation #6 - Evaluation and Re-alignment of Outfalls and Pipe Crossings

Evaluate the continued use/need for outfall pipes and pipe crossings identified during the survey. Remove pipes and outfalls no longer needed. Re-route necessary outfalls in accordance with the Stormwater Management Plan (Recommendation #2). Re-align necessary pipe crossings at road crossings or through bore holes.

This recommendation addresses Limiting Factor #2. During the habitat survey, one ditch, two stormwater outfalls, and one outfall hose appeared to cause moderate to substantial erosion or sedimentation within Devil's Hole Creek or its tributaries. Numerous outfalls and pipe crossings were found which appeared to be used either very little or not at all.

We recommend the following steps be taken to reduce current or potential future impacts that may result from the confusion of outfalls and pipes that are indiscriminately placed within the watershed:

1. An assessment should be done to evaluate all outfalls and pipe crossings for current/future need,

2. All outfalls or stream crossings that are not needed should be removed,

3. Outfalls that are needed for stormwater should be made part of the Stormwater Management Plan (Recommendation #2) and incorporated into a design which avoids impacts to the stream system, and

4. Pipe crossings that are needed should be either attached to bridge crossings or placed in holes bored under the stream bed to avoid impacts resulting from high flows such as scour, erosion, and breakage/discharge.

Monitoring

Monitoring is necessary for any restoration plan to provide feed-back on the adequacy of restoration activities and to determine if they are cost-effective. We believe that at a minimum, two types of monitoring should be performed during the recovery of the Devil's Hole watershed: population monitoring and restoration effectiveness monitoring. Of these, population monitoring is most important as this provides the best feedback as to whether restoration for anadromous salmonids is succeeding.

Population Monitoring

The ultimate goal for restoration is to increase production of anadromous salmonids in the basin. The best indicator for evaluating this goal is to monitor the production of salmonids from the watershed. Annual smolt trapping would enable the tracking of trends in smolt production from the basin. A less costly alternative may be to periodically monitor smolt production (e.g., 1 year in 5) and to compare the results to those attained in 1999 and 2000, and to those from other streams in the area that are trapped annually to determine the relative strength of the measured smolt production from each data point.

If Recommendation #5 is carried out, the monitoring of chum escapement over at least a couple of brood cycles is necessary to determine if the population is successfully replacing itself. This would best be accomplished by performing spawner surveys in the basin.

Restoration Effectiveness Monitoring

Habitat-based restoration actions recover salmon populations indirectly. This type of restoration restores habitat which increases the suitability of the stream for salmonid production. Effectiveness monitoring is performed to determine if the restoration activities are having the desired effect on the habitat. To be cost-effective, this type of monitoring should focus most on activities that are at risk of failing. For Recommendation #3, monitoring may simply evaluate whether the passage structures meet current WDFW criteria (WDFW 2000). For the other recommendations, monitoring should focus on answering a number of key questions or hypotheses. Key questions might include the following:

Recommendation #1

Key Question #1. Is channel depth in lower Devil's Hole Creek maintained in a manner that is conducive to upstream migrations of adult salmonids?

Key Question #2. Does riparian vegetation above the bankfull channel and extreme high water (tidal) cover at least 70% of the substrate?

Recommendation #2

Key Question #3. Is the rate of bank erosion increasing/decreasing as a result of implementing the stormwater management plan?

Key Question #4. Is the rate of bed erosion increasing/decreasing as a result of implementing the stormwater management plan?

Recommendation #3

Key Question #5. Do repaired stream crossings meet WDFW criteria (WDFW 2000)?

Recommendation #4

Key Question #6. Are blackberries and other non-native vegetation maintained at less than 10% of the stream cover in stream sections where vegetation management has occurred?

Key Question #7. Is survival of conifer seedlings at least 30% in areas where planted over the first 5-years following planting?

The key questions presented here represent an example of the range of questions that might be asked for projects developed out of the restoration recommendations made. The key questions that are actually used for monitoring in the Devil's Hole watershed would be developed around the restoration activities that are actually taken and would need to represent a balance between doing sufficient monitoring to ensure that limiting factors are adequately corrected and the cost of monitoring.

Citations

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Appendix A